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ADVANCED AUCTIONS IN DYNAMIC MARKETPLACES: CLASSIFICATION, TECHNOLOGIES, APPLICATIONS AND BEHAVIORAL STUDY

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Dedicated to my beloved family

…
And the colors of the sea blind your eyes with trembling mermaids,
And you touch the distant beaches with tales of brave Ulysses
…
And her footprints make you follow where the sky loves the sea
…

Tales of Brave Ulysses, Cream

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Περίληψη

Για πολλούς αιώνες οι δημοπρασίες αποτελούν έναν μηχανισμό διαμόρφωσης τιμών όταν η αξία του αντικειμένου συναλλαγής δεν είναι γνωστή ή μεταβάλλεται. Οι τεχνολογικές εξελίξεις του Internet και των ασύρματων επικοινωνιών απάλειψαν τους περιορισμούς θέσης και χρόνου και ενίσχυσαν την ευρεία διάδοση των δημοπρασιών σε αγορές παγκόσμιου εύρους. Ακόμα, οι σύγχρονες εφαρμογές λογισμικού μπορούν όχι μόνο να υποστηρίξουν αλλά και να ενισχύσουν περισσότερο σύνθετους μηχανισμούς δημοπρασιών με εξελιγμένες ιδιότητες όπως τη διαπραγμάτευση ποιοτικών χαρακτηριστικών ή συνδυασμών αντικειμένων. Η παρούσα διατριβή πραγματεύεται την εφαρμογή δημοπρασιών ως μηχανισμούς συναλλαγής σε δυναμικές αγορές. Ειδικότερα, εστιάζει στην εφαρμογή εξελιγμένων τύπων δημοπρασιών σε δυναμικές αγορές στις οποίες μία ή και περισσότερες διαστάσεις μεταβάλλονται δυναμικά. Τέτοιες διαστάσεις, είναι η γεωγραφική θέση του αντικειμένου συναλλαγής ή των συναλλασσόμενων, η τιμή, η διαθέσιμη δυναμικότητα, ο αριθμός των συμμετεχόντων.

Έπειτα από εκτεταμένη βιβλιογραφική έρευνα η οποία εστιάστηκε στην τελευταία δεκαετία, εντοπίστηκαν και μελετήθηκαν περισσότερες από 450 ερευνητικές εργασίες που πραγματεύονται θέματα μηχανισμών και θεωρίας δημοπρασιών, και περισσότερες από 300 ερευνητικές εργασίες οι οποίες πραγματεύονται θέματα υλοποίησης δημοπρασιών σε ηλεκτρονικές και κινητές αγορές. Ο αριθμός αυτός αποτελεί μία σημαντική απόδειξη του υψηλού ερευνητικού ενδιαφέροντος στην περιοχή των δημοπρασιών. Με την ολοκλήρωση της βιβλιογραφικής έρευνας, διαπιστώθηκε ένα σημαντικό κενό στη συστηματική οργάνωση των δημοπρασιών ως προς τα χαρακτηριστικά των μηχανισμών, τις παραμέτρους και τα στοιχεία υλοποίησης. Στην παρούσα διατριβή επιχειρείται η κάλυψη του κενού αυτού, προτείνοντας ένα πρωτότυπο μοντέλο ταξινόμησης δημοπρασιών βασιζόμενο στα συμπεράσματα της βιβλιογραφικής έρευνας το οποίο ορίζεται ως *"Auction Classification Ecosystem – ACE"*και στοχεύει στο να αποτελέσει πρότυπο σχεδιασμού και διαχείρισης μηχανισμών δημοπρασιών.

Το μοντέλο ACE αποτελείται από τρία διακριτά αλλά απολύτως συσχετισμένα επίπεδα: (α) Το Επίπεδο 1 υποστηρίζει το σχεδιασμό των βασικών μηχανισμών δημοπρασιών, παράλληλα όμως υποστηρίζει και το σχεδιασμό σύνθετων μηχανισμών πολλαπλών διαστάσεων μέσω κατάλληλα σχεδιασμένων plug-ins, (β) το Επίπεδο 2 το οποίο εμπλουτίζει τον βασικό μηχανισμό με πρόσθετες παραμέτρους που προσδίδουν χαρακτηριστικά τα οποία ενισχύουν τον μηχανισμό ως προς την ανθεκτικότητα, την δίκαιη εφαρμογή, τον ανταγωνισμό, κ.α. και, (γ) το Επίπεδο 3 το οποίο στοχεύει στην αποτελεσματική υλοποίηση της δημοπρασίας. υποστηρίζοντας πολλαπλούς τύπους ληπτών αποφάσεων (π.χ., δημοπράτης, πάροχος τεχνολογικών υποδομών, κ.α.) κατά τη φάση της οργάνωσης της δημοπρασίας αποδίδοντας προτεραιότητες ανάλογα με την υποδομή υλοποίησης. Τα τρία επίπεδα χρησιμοποιούνται είτε ανεξάρτητα, είτε σειριακά. Εν κατακλείδι, το ACE έχει πρακτική εφαρμογή, είναι εύκολα κατανοητό, επεκτάσιμο και υποστηρίζει (α) την εκτενή και δομημένη οργάνωση μηχανισμών αγορών βασιζόμενων σε δημοπρασίες, (β) ολοκληρωμένη λήψη αποφάσεων και (γ) επεκτασιμότητα και διασύνδεση με άλλες περιοχές ερευνητικού ενδιαφέροντος.

Στη συνέχεια η διατριβή καινοτομεί προτείνοντας για πρώτη φορά την έννοια των "χωρικά ευαίσθητων δημοπρασιών" *(location-aware auctions / "l-auctions")* ως έναν προηγμένο τύπο κινητών δημοπρασιών. Οι δημοπρασίες αυτές υλοποιούνται σε δίκτυα κινητών επικοινωνιών συνδυάζοντας τις ιδιότητες των τεχνολογιών γεωγραφικού εντοπισμού

(π.χ., κινητή τηλεφωνία, GPS) με τις δημοπρασίες για τη διαμόρφωση δυναμικών αγορών στις οποίες τα χαρακτηριστικά του αντικειμένου συναλλαγής ή/και των συναλλασσόμενων έχουν γεωγραφική ευαισθησία. Οι δημοπρασίες αυτές καινοτομούν στο ότι είναι γεωγραφικά εστιασμένες και έχουν υψηλή χρησιμότητα σε δυναμικές αγορές όπου οι συναλλασσόμενοι ή το αντικείμενο συναλλαγής είναι εν κινήσει. Η παρούσα έρευνα επικεντρώνεται σε δύο εμπορικές εφαρμογές οι οποίες χαρακτηρίζονται από υψηλή κινητικότητα, τις υπηρεσίες τουρισμού και τις υπηρεσίες εμπορευματικών μεταφορών και προτείνει την αρχιτεκτονική υλοποίησης των αγορών αυτών, τη ροή των πληροφοριών και τις ειδικές τεχνολογικές απαιτήσεις. Η χωρική ευαισθησία που επιτυγχάνεται, προσφέρει σημαντικές λειτουργίες όπως, το φιλτράρισμα των συμμετεχόντων με βάση τα χαρακτηριστικά θέσης τους, την εκτίμηση των επόμενων γεωγραφικών θέσεων, την αυτόματη εκτίμηση της αξίας με βάση χαρακτηριστικά θέσης και χρόνου, κ.α.

Ένα ακόμα ιδιαίτερα ενδιαφέρον συμπέρασμα το οποίο ανέδειξε η έρευνα, είναι το ιδιαίτερα υψηλό ενδιαφέρον στην περιοχή του revenue management αλλά και ειδικότερα η εφαρμογή μηχανισμών δημοπρασιών σε τεχνικές revenue management. Με αφετηρία τη διαπίστωση αυτή, η διατριβή επεκτάθηκε στη διερεύνηση των δυνατοτήτων συμπληρωματικής εφαρμογής των δημοπρασιών σε τεχνικές revenue management, εξετάζοντας την σκοπιμότητα και τους τρόπους με τους οποίους ένας μηχανισμός δημοπρασίας μπορεί να ενισχύσει μία τακτική revenue management.

Η διατριβή ολοκληρώνεται με τη μελέτη του ανθρώπινου παράγοντα στις δημοπρασίες, ερευνώντας τους τρόπους με τους οποίους η εμπειρία, η γνώση και η τεχνολογία επηρεάζουν τη συμπεριφορά των συμμετεχόντων σε μία δημοπρασία. Σχεδόν όλες οι θεωρητικές εργασίες στην περιοχή των δημοπρασιών βασίζονται στη θεωρία δημοπρασιών με την παραδοχή ότι οι συμμετέχοντες είναι απόλυτα λογικοί. Στην πραγματικότητα η παραδοχή δεν είναι ρεαλιστική αφού η συμπεριφορά των συμμετεχόντων εξαρτάται από πλήθος εξωγενών ή ενδογενών παραγόντων. Αξιοποιώντας τα ευρήματα που παρουσιάστηκαν στα προηγούμενα μέρη της διατριβής, αναπτύσσεται ένα ερευνητικό πλαίσιο το οποίο προτείνει μία μεθοδολογία εκπαίδευσης και βελτίωσης της συμπεριφοράς των συμμετεχόντων μέσω της γνώσης και της εμπειρίας που αποκτάται μέσω της συμμετοχής τους σε δημοπρασίες. Προκειμένου να εξετασθούν και να επικυρωθούν οι υποθέσεις του ερευνητικού πλαισίου σχεδιάζεται και εκτελείται μία σειρά από πειράματα στα οποία αυξάνεται βαθμιαία η πολυπλοκότητα των μηχανισμών των δημοπρασιών, καλύπτοντας στο τελικό στάδιο δημοπρασίες με ιδιότητες χωρικής ευαισθησίας. Σε κάθε ένα από τα πειράματα συλλέγονται ποιοτικά (αναφορές συμμετεχόντων) και ποσοτικά ευρήματα προκειμένου να διαπιστωθεί η συμβολή τη γνώσης και της εμπειρίας στη βελτίωση της συμπεριφοράς. Η αξιολόγηση των αποτελεσμάτων δεν περιορίζεται μόνο σε συνήθεις δείκτες (π.χ., τελική τιμή) αλλά εισάγεται για πρώτη φορά η έννοια της *«Πρόθεσης Συναλλαγής» (Willingness to Trade)*, η οποία διαπιστώνεται σε ένα εύρος τιμών λήξης της δημοπρασίας στο οποίο όλοι οι συμμετέχοντες (αγοραστές και πωλητές) προτίθενται να εκτελέσουν τη συναλλαγή θεωρώντας ότι η συναλλαγή είναι δίκαιη.

Η προστιθέμενη αξία της διατριβής συνοψίζεται στα εξής: (α) στην πρόταση του πρωτότυπου μοντέλου ACE, (β) στην εισαγωγή της έννοιας των *χωρικά ευαίσθητων* δημοπρασιών, (γ) στον προσδιορισμό των προϋποθέσεων συμπληρωματικής εφαρμογής δημοπρασιών και τεχνικών revenue management και, (δ) στην πρόταση της μεθοδολογίας μελέτης και βελτίωσης της συμπεριφοράς των συμμετεχόντων σε προηγμένες δημοπρασίες. Οι προτάσεις αυτές δημιουργούν σημαντικές ερευνητικές ευκαιρίες για το μέλλον, αλλά ταυτόχρονα μπορούν να αποτελέσουν τη βάση για την ανάπτυξη καινοτόμων επιχειρησιακών εφαρμογών.

Extended Abstract

This thesis considers auctions as trading mechanisms in dynamic marketplaces. In the recent past, the evolution of Internet and wireless communications leveraged the wide and global expansion of auctions by abolishing time and location restrictions. These developments enabled the initiation of trade and participation for almost any type of entity like consumers, business, government etc. Moreover, the technological infrastructure facilitated and enhanced the implementation of more complex auction mechanisms introducing advanced properties like negotiation attributes, bundles of items, etc. The thesis focuses on the application of advanced forms of auctions in dynamic marketplaces where one or more of its dimensions are characterized by high variability. These dimensions can be, for example, the location of the trading item or market participants, the price, the available capacity, the number of participants, etc.

An extended literature review mainly from the last decade yielded more than 450 research works dealing with auction mechanisms and corresponding auction theory, and more than 300 research works dealing with the implementation of auctions in electronic and mobile marketplaces. This number reflects the intensive research interest in the area of auctions. The extensive study of these resources demonstrated a serious gap on the systematic organization of auctions regarding the mechanism attributes, their parameters, and implementation instance. This thesis comes to bridge this gap by introducing a conceptual auction classification prototype that resulted from the intensive study of the research literature and the systematic unification of the findings. This model is conceptually defined as "*Auction Classification Ecosystem – ACE*" and it intends to be used in the future as the state-of-the-art model for auctions engineering.

The ACE model consists of three discrete, yet strongly integrated Levels: (i) Level-1 supports the design of the basic auction mechanism, yet, it also supports the design of more complex multi-dimensional auction formats including special decision-making plug-ins, (ii) Level-2 deals with the enrichment of the core auction mechanism with additional parameters which entails enhancing characteristics related to, for example, robustness, fairness, competitiveness, etc., (iii) Level-3 aims on the efficient implementation of the auction supporting several types of decision-makers (e.g., auctioneer, technology provider, etc.) to organize the implementation of the auction and prioritize their actions depending on the implementation context. These layers can be used either independently of each other or in a sequential form. Overall, ACE is highly comprehensive and expandable and usuable, able to serve for: (i) the extensive and structured organization of auction-based dynamic marketplaces, (ii) the analysis of auction formats, (iii) the classification of literature and research findings (iv) the completeness in decision-making, (v) the expandability and integration with other research disciplines, and, (vi) the development of software applications.

Next, the thesis introduces the innovative concept of *location-aware auctions* (l-auctions) as an advanced form of auctions conducted over mobile networks. L-auctions combine the properties of Information and Communication Technologies and auctions to formulate dynamic marketplaces characterized by spatial sensitivity of trading item, participants or both of them. The groundbraking characteristic of this type of auctions is that they are geographically focused. They can prove particularly attractive in dynamic marketplaces where the participating entities or the trading item are on-the-move. The thesis identifies two major commercial applications (and several collateral use cases) with high mobility, namely, tourism services and freight transportation services and presents in detail the business models and the associated benefits from location-awareness, for example, the

geographical filtering of participants, the estimation of future location, and the automatic estimate of valuation based on temporal and spatial attributes etc.

A focused review of the literature identified a growing interest on revenue management in general and the application of auctions in the revenue management context, in particular.The research of application of auctions complementary to revenue management techniques came as a necessity. The thesis examines this complementarity in freight transportation applications and identifies when and how auctions can apply.

The thesis culminates with the pioneering study of the human factor examining how experience, knowledge and technology affect the behavior of participants in one auction. Almost all theoretical works on auctions are based in auction theory assuming that participants are rational. In most real cases this assumption can hardly be realized; participants' rationality is affected by several factors related to exogenous or intrinsic characteristics. Findings and concepts from previous parts of the thesis are used to develop a research framework which estblishes a methodology to induce participants, and improve their rationality through knowledge and experience. A series of experiments are organized and conducted aiming to examine and validate this research framework through the experimentation on a sequence of auctions with progressive increase of mechanism complexity (simple auctions, multi-round auctions and, location-sensitive auctions) and different parameters. The impact of knowledge and experience on participants' behavior is evaluated using both qualitative data (participants' statements) and quantitative data (e.g., final price). The most important derivation of this experimental is the discovery of a price range, conceptually defined as "Willingness to Trade" within which all participants perceive trade fairness and they are minded to trade.

The special value of the thesis is summarized in the following: (i) the introduction of the ACE prototype, (ii) the use of advanced communication technologies to enhance auctions with location awareness, (iii) the amalgamation of auctions and revenue management, and, (iv) the methodology for the improvement of rationality and behavior of participants in advanced auctions. Finally, the thesis proposes several business and practical implications and potential openings for further research.

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Chapter 1

Introduction

The thesis investigates three self-contained, yet strongly interrelated domains: (i) the development of a formalistic and evolutionary framework (referred to as “Ecosystem”) for the classification of auctions, (ii) the influence and integration of IT-related advances in the construction of sophisticated auction mechanisms that serve dynamic marketplaces (e.g., logistics, tourism, etc.), and, (iii) the experimental evaluation of market participants’ behavior in environments where advanced auction schemes complement revenue management practices.

This chapter is structured as follows: Section 1.1 describes the motivating factors for the present research while Section 1.2 presents a short analysis of the thesis title. Section 1.3 poses the research problems and the objectives through a series of research questions and associates them to the generated contributions. Finally, Section 1.4 illustrates the structure of the thesis and justifies why this best serves the imposed research targets.

1.1 Research Motivation

Auctions have proven to be an excellent trading mechanism to allocate goods, services, resources, etc., (from now on "items") to individuals and firms. A great variety of items are commonly traded via auctions including art, antiques, tickets, public goods, air seats, stamps, flowers, freight capacity, stocks, radio spectrum licenses, livestock, industrial supplies, construction contracts, oil drilling rights, manufacturing capacity, etc. Although the items described above are heterogeneous, they have a common characteristic: the valuation of each item is not standard so they cannot be traded using a direct pricing mechanism.

The systematic research in the area of auctions has advanced considerably since William Vickrey's seminal work on 1961. Although earlier research on auctions has been based mainly on Microeconomics and Game Theory, recent advances extended relevant research in Operational Research, Information Technology and Behavioral Analysis. From a research point of view, Klemperer (1999) reviewed more than 210 research papers on auction-theoretical aspects while in our recent research we identified more than 450 research papers published since 2000 until 2009, excluding papers related to electronically conducted auctions (e-auctions) which exceed 300. A significant part of the literature deals with complex auctions of multiple items with different degrees of value complementarity and multiple negotiable attributes beyond price, defined as *multi-dimensional* auctions.

The rapid diffusion of Internet and related Information and Communication Technologies (ICT) in the last decade established the conditions for a "big bang" of auctions conducted electronically (e-auctions) making them accessible to almost any interested market participant either corporate or individual. Besides accessibility, the Internet enabled the realization of advanced auction formats for certain applications allowing selling or procurement of single or multiple trading items and competition on multiple (mostly qualitative) evaluation criteria beyond price; in several cases, auctions made use of additional parameters in an attempt to control key characteristics in a market, such as, efficiency, competition, security, information diffusion, fairness, etc. These formats, however, increased the complexity of the auction setting and raised specific problems to both the auction designer and the market participants.

The advances in mobile communications technology and the penetration of mobile devices[1] further boosted the shift from traditional, physical auctions and incented the evolution of innovative mobile auction (m-auction) applications that expanded the goods of e-auctions by offering on-the-move trading capabilities. Recently developed Location-Based Services (LBS) enriched the technological arsenal of m-commerce with the ability to obtain location information and to use it in targeted business transactions while on-the-move. In the area of m-auctions particularly, LBS can prove extremely useful since they can differentiate the value of the auction participant subject to spatial attributes; this set the foundations for the so-called l-auctions (where, l- stands for location-sensitive)[2]. Such auctions have special (mostly technology-related) requirements concerning the transmission bandwidth, range of coverage, security, fairness, topology changes, mobile device specifications, etc.

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[1] Results from many market surveys provide evidence for the potential and the future; a recent study published by the Commission of the European Communities (CEC 2009) states a 7,2% annual increase in mobile subscribers penetration rate in EU which in 2008 reaches 119%. Furthermore, penetration rate is more than 100% in 23 Member States while in Greece it was reached 122% in 2008.

[2] In 2009, Morgan Stanley Research published a Global Mobile Internet Report where amongst other claimed that "*Mobile Internet will be the next major computing cycle*", "*GPS and related location-based services proliferation are big deals*", "*mobile internet unlocks power of data on physical location*". From a technical-requirements viewpoint, they claim that "*push notification technology enables effortless monitoring of auction process*" in m-commerce.

Auctions and revenue management constitute two widely used methods for the dynamic formation of prices for goods and services. Revenue Management, in particular, aims to enhance the demand by adjusting the price. Electronic and mobile infrastructure enhanced the ability of interested parties to collect information about demand in order to modify appropriately the offered prices in real-time, enabling the interested buyer to monitor the price evolution and react accordingly. Considering these concepts, it is very interesting to identify where and how they complement each other and which particular benefits arise from this; the present thesis attempts to contribute towards this direction.

Several applications today may be carried out effectively with the use of auctions in e-, m- or l- settings. In the freight industry, for example, a carrier may offer his fleet's unused capacity through an auction in order to increase the revenue for a scheduled trip. A shipper can respectively obtain low freight prices through a procurement auction. In the tourism sector, on the other hand, the service provider may offer non-booked capacity (e.g., tickets, hotel rooms, etc.) through an auction in order to increase revenue by increasing capacity utilization. In these examples the use of e-, m- and l- infrastructure offers the opportunity to all stakeholders to participate in real-time markets even while on-the-move. Today, several web sites offer the trade of such services through electronic auctions[3]. In general procurement applications, auctions may be a formidable tool in the hands of a procurement manager since they are advantageous in establishing a dynamic environment which increases the competition between potential suppliers especially between those who wish to sell unused resources. In their more technologically advanced formats, auctions can magnify the potential suppliers' base, giving access to broader, even global, marketplaces. Based in these observations, a set of four major motivating factors fueled our research and are described in the sequel.

The observation of the rapidly appearing applications and technological advances stimulated our interest to further expand upon the existing knowledge in the domain of auctions. Following a preliminary literature review, we first realized that a systematic framework to classify auctions, which, at the same time, would be flexible enough and be able to respond in an evolutionary manner in the design process, was lacking. We thus decided to proceed to an extensive literature review on research works of the last decade and to extract results from a mechanism-engineering viewpoint, covering both the foundational auction mechanism issues along with the technological aspects of implementation. This research resulted in the development of the *Auction Classification Ecosystem (ACE)*. ACE consists of three layers; the first two model the auction types and parameters in a structured, expandable, configurable and applicable form. The third level deals with the implementation aspects of an auction incorporating also technical and market-organizational issues.

The creation of the ACE was followed by the tests of its usability on the design and description of advanced auction settings (p, e, m, and l). We capitalized on the developed approach to dig deeper in two popular applications (tourism and freight). We, furthermore, examined the properties and the applicability of specific functionalities of modern auctions in those typical dynamic marketplaces going beyond usual on-the-move participation. We proposed several use cases analyzing how they benefit from the automatic location-awareness of auctions when geographic attributes, such as closeness, affect the value of the trading item, We identified and examined several indicative cases, for example, the automatic filtering of potential participants set, the automatic identification and valuation of spatial attributes, and the development of bidders' collaborative schemes. Our findings can be easily expanded in other real-life trading institutions with dynamic market characteristics with spatial awareness.

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[3] Several web-based auction-based marketplaces are operating currently for the trade of both B2B freight transportation services (e.g., www.bidfreight.com, www.cargoauctions.com, www.freighttender.com) and B2C tourism services (e.g., www.allcruiseauction.com, www.priceline.com, http://www.bid2travel.com/) showing a real application potential.

As already hinted, auctions are not, and should not be considered irrelevant to RM. Thus, we investigated this relationship and proposed that auctions can effectively be used complementarily to RM techniques, especially in service markets. In this phase, we were motivated from the fact that an appropriately designed auction mechanism can prolong the market effective duration. More specifically, a quick auction mechanism implemented over m- or l- infrastructure may complement the RM effective period of the service offering even during the execution of the service.

Once this research stage progressed in a mature state, we directed our actions on the investigation of whether the behavior of participants changes with knowledge, maturity, experience and acquaintance with the auction mechanism and the application at hand. It had become evident from our extensive study of the scientific literature in the field of auctions, that the majority of auction-theoretic approaches focuses on issues like mechanism design and formulation of bidding strategy mostly from an econometric or game-theoretic approach, assuming that all participant are rational; this assumption, however, although proves facilitating for research purposes, is overly simplistic and often quite distant from reality. Motivated from the lack of research on behavioral issues of bidders, we proceeded to the experimental study of the behavior of auction participants. Based on our previous findings, we designed and conducted a series of experiments to examine and evaluate how knowledge and experience of the dynamic market characteristics and auction mechanism attributes affect the outcome of an auction-based market considering the freight transportation paradigm as basis. This experimental study led to a set of important findings regarding the behavior of participants, the attributes of the auction mechanism and the effectiveness of location-awareness expressed as behavioral trends, verbal statements, final market price and, what we conceptually defined as *Willingness to Trade (WTT)*.

Based on the aforementioned motivating factors, we developed our research path. First, we aimed on the development of a generic auction customizing tool considering a plethora of design characteristics, attributes, values and technological elements based on an extensive literature review. Then, we combined the location-awareness properties of modern communication technologies with auctions and we employed this bundle to complement Revenue Management (RM) strategies. We finally focused on participants' behavioral components and attitudes and studied how these evolve in a progressive learning context for a mobile auction. This thesis associates (i) auction engineering, (ii) location-awareness, (iii) Revenue Management, and, (iv) behavioral analysis and examines business implications in the trade of freight services and tourism services in dynamic marketplaces.

1.2 A Brief Note on the Title of the Thesis

This section provides a concise justification of the keywords delegated to form the title of this thesis. This effort associates the analytical meaning of the keywords to the research path followed (presented in the previous section) and the resulting contributions (presented in the next section). To save the reader from navigating to the cover page, we highlight below the thesis title:

"Advanced Auctions in Dynamic Marketplaces: Classification, Technologies, Applications and Behavioral Study"

The present thesis is focusing primarily on ***dynamic*** marketplaces. We characterize a marketplace as dynamic when it has at least one of the following characteristics:

- Changing location and spatial characteristics of market participants: It is assumed that market participants are not static; their spatial attributes (e.g., actual location, speed, direction etc.) are changing.
- Time-sensitivity of the trading item: The qualitative characteristics of the trading item change temporally. This is an intrinsic issue in services which are characterized by

high perishability. Typically the value of the non-used service capacity becomes zero at the time of the service offering. Similarly, the issue of perishability is also of particular interest for rapidly-deteriorating goods. Yet, the present thesis is focusing on marketplaces where the trading item is a service offering.

- Fluctuating number of participants: Modern technology-assisted marketplace (for example, Internet-based marketplaces) supports the simultaneous interaction between huge numbers of participants, any time of the day in a global basis. In addition to that, marketplaces based on mobile communication networks allow the interaction between participants even when they are on-the-move. In both cases, the number of participants is highly variable.
- Price variability: In several cases the price of a trading item does not depend solely on cost and exhibits variability. The present thesis focuses on the services domain where the price of the service offering is not fixed and depends on several factors. Each of these aforementioned characteristics may independently affect the price of a service offering; moreover, the price depends highly on market participants' perceived utility and it can be different for each of them. Finally, when the capacity is fixed, the provider may alter the price intentionally in order to increase demand and, consequently, utilization.

This thesis is primarily focusing on service ***marketplaces*** which entail the dynamic characteristics described above. As stated above, it identifies two major ***application*** areas, namely, (i) the freight transportation service which is a typical Business-to-Business case, and (ii) the tourism service which is a typical Business-to-Consumer case. The dynamic characteristics of the relevant marketplaces are described in brief in Table 1.1

Characteristics	**Freight**	**Tourism**
Location sensitivity	Location of carrier Speed, (projected) direction	Current location of tourist Projected location
Time sensitivity	Freight loading time	Bus departure time
Number of participants	Carriers moving away from a loading site	Tourists within an area of interest
Price variability	Location, time, capacity management (revenue management techniques), private valuations, number of participants, supperaditive valuations	

Table 1.1: *Dynamic Attributes of Freight and Tourism Marketplaces*

The present thesis not only assumes the convergence between the two major types of marketplaces (electronic and mobile), but also explores relevant ***technologies*** to identify the number of participants, filter-out participants based on eligibility checking indices and adapt the trading mechanism based on this information. Furthermore, it combines heterogeneous electronic and mobile networks to support location-dependent services, the value of which is highly sensitive to the actual (or projected) location of the market participant and (or) the trading item.

Without loss of realism, the value of both the freight service and the tourism service is highly subjective, not standard, and depends on interested participants' perceptions and current needs. Thus, these service marketplaces are ideal candidates for the application of an ***auction*** mechanism as a price-setting trading mechanism. The auction mechanisms considered in the present thesis are innovative; they are operating over heterogeneous electronic and mobile networks and they are sophisticated enough to use the spatial information in order to support the dynamic nature of the examined marketplaces; these auctions are considered as ***advanced***. The design attributes of the auction mechanisms perceived in this thesis and the relevant applicability issues have been based on an extended study of a vast amount of literature sources. The literature research revealed the emergence of auctions as well as the existence of a significant set of decision elements related to the design, strengthening and implementation of an auction mechanism. It also evidenced the lack of a systematic decision-making tool for the study of auctions. To remedy this, the thesis deals also with the design of a generic ***classification*** methodology serving not only classification but also parameterization and implementation plans purposes.

A critical issue on the operation of such innovative dynamic markets relates to the viability which is not restricted to the technical and economic issues which are examined separately in relevant chapters. Most importantly, the success of these marketplaces depends on how potential market participants behave in such marketplaces. Based on a set of research hypotheses we develop an experimental setting aiming to support the evolutionary design of auction marketplace. Through an extended ***behavioral study*** we show the contribution of the methodology on the enhancement participants' experience, providing evidence on the overall acceptance, fairness and efficiency of the proposed advanced auction dynamic marketplace.

1.3 Research Problems, Questions and Contributions

This thesis deals with the design and execution of contemporary dynamic auction-based markets for location-sensitive logistics and tourism services under the prism of modern ICT infrastructure. Since auctions apply in either forward (selling) or reverse (procuring) form, the auction designer can be either the seller or the buyer respectively. From a time-specific point of view, auctions may also complement RM strategies in order to allocate last-minute service offerings. The integrated research problem can be broken down to the following components:

.1 How to construct a generic, descriptive, and evolvable auction design scheme

A vast amount of research literature deals with the design of auction mechanisms and the formulation of bidding strategies. Yet, research results cannot easily put to work because of lack of understanding from practitioners and due to low relevancy to particular applications. The decision-making problem is much more intense for multi-dimensional auctions; on the one hand the bidder has to formulate complex bids and on the other hand the auctioneer has to solve problems of high complexity in order to determine the winner(s) and the corresponding payments. The core problem here relates to the consolidation of these decision-making elements into the generic design scheme.

.2 Why and how to design applicable contemporary location-sensitive auctions

E-auctions have been widely used for the trading of freight transportation and tourism services. A particular characteristic of such services is that their value depends on location relativity between the intended buyer and the service offering. Recent ICT advances not only allow the wireless execution of commercial transactions - such as auctions - between moving entities, but also enable the identification, monitoring, communication and interaction between them while on-the-move. Based on these properties, it is of special interest to examine if it makes sense to use these technologies in certain business cases, and to how to benefit from this auction-technology integration in an RM context.

.3 How to effectively design and deploy location-aware auctions in dynamic service marketplaces

Conceptual design of contemporary market infrastructures is of high interest amongst researchers. Yet, the applicability of the concepts is equally important in terms of viability, market acceptance and practicality. So, it is important to set a strategy in order to "train" potential users through a progressive and evolutionary methodology and evaluate the corresponding results in order to fine-tune the proposed process.

These problems synthesize the research objectives as follows:

To identify and classify contemporary auction design types and parameters, and use them systematically for the development of a generic and complete auction design model. To investigate how location may affect the auction-based price definition and how may ICT developments support this in a RM context. To examine how we can approach the design of *an evolutionary learning methodology that supports the gradual familiarization of market participants within the context of advanced auction formats.*

The research objectives are accomplished gradually by defining the subsequent, clearly-sequenced, crisp research questions:

1.3.1 Research Question 1

Can we develop a generic and unified auction classification scheme containing features and mechanism parameters for the design of application-dependent auctions?

The main part of the thesis begins in Chapter 2 with an extended literature review on auction-theoretical issues which provides a sense of the width of the auction mechanism design problem. We use the results as building elements for the development of a comprehensive and practical 2-Level taxonomical frame presented in Chapter 3.

1.3.2 Research Question 2

How can we associate participants' decision elements for multi-dimensional auctions in order to further enhance the auction design and support participants' decisions?

The study of emerging auction formats (applied in modern market settings) proceeds in Chapter 2 through the analysis of some critical auction parameters that affect directly the decision-making process and the problems that the auction participants face before, during and after an auction. Chapter 3 culminates with the graphical presentation of the decision framework for the majority of approaches presented in the contemporary literature, in order to highlight the association between decision elements and auction design. The proposed decision framework is tied to specific sockets of the 2-Level model.

1.3.3 Research Question 3

What are the specific properties of ICT-enabled auctions (e- and m-) and how do they differ from physical auctions?

Physical and ICT-enabled auctions share the same core mechanism characteristics. Yet, ICT-enabled auctions allow the facilitation of special operational characteristics; for example, they support more efficiently complex multi-dimensional auction mechanisms. They also allow the use of intelligent agents to automate bid formation and submission – sometimes unattended. Important issues related to magnification of market and new forms of vulnerabilities are also discussed in Chapter 2. The specific properties presented in Chapter 3.

1.3.4 Research Question 4

How can m-auctions successfully evolve to l-auctions?

M-auctions are auctions organized and executed over wireless networks, in general. Since the associated operational cost is comparably higher than that of e-auctions, the first issue examined along with technical and information requirements, is the economic viability. We also examine how location-sensing technologies are used as drivers to design and execute location-aware auctions. Therefore, Chapter 4 establishes technical and transaction-flow architecture for e-auctions which is progressively evolving to support m- and l-auctions.

1.3.5 Research Question 5

In which ways may l-auctions enhance the trade of location-aware services?

Chapter 6 considers two representative business cases where mobility and location-awareness plays significant role, namely, tourism services (a typical B2C application) and freight transportation (a typical B2B application). We first analyze how l-auctions allow filtering of participants based on their current and projected location. Then, we provide evidence on how l-auctions may automate the bid evaluation process in complex auction formats. We finally describe how l-auctions complement a typical RM strategy to support last-minute trading.

1.3.6 Research Question 6

Can we determine auction parameters by observing participants' behavior in a way to simultaneously train them?

We focus on the freight transportation case and conduct a series of experiments to evaluate the outcomes of an experimental setting based on market participants' behavior (Chapter 7). Experimental results are focusing mainly on the behavior of market participants (carriers) identifying how it is affected from knowledge and experience gained through the progression of experiments based on gradual and controlled revelation of market information. Prior to this, in Chapter 5 we set the methodology to design the auction mechanism and discuss the impact of relevant auction parameters using the design model developed in previous chapters. The experimental setting is developed in a simulation research tool (z-Tree). The programs developed in z-Tree are presented separately in the appendix of the thesis.

It is necessary to clarify herein that the present thesis does not deal with the evaluation of the efficiency of the models that researchers have presented through the years neither assesses the computability, convergence to the equilibrium or other mechanism characteristics. On the contrary, this thesis focuses on the systemic and conceptual design in the areas of auctions, dynamic pricing and logistics. The obtained results set the basis for further and more systematic research from such viewpoints.

The thesis advances the research on contemporary auctions design and their applications in several ways outlined below.

.1 Auction Classification Ecosystem

The work by Wurman et al., (2001) ("*A parameterization of the auction design space*") is a systematic approach to describe the basic and fundamental parameters of and auction, while the work by Fasli and Michalakopoulos (2005) ("*Simulated electronic markets: Design and implementation*") takes a more practical turn into electronic market. The developed Auction Classification Ecosystem, encompasses, unifies, and expands previous efforts and enriches the classification mentality with the necessary perspective for specific and focused parameters. In particular, the first level illustrates the contributions of each of these works, fine-tunes the terminology and categories of characteristics for classification and indicates the branching of criteria that when combined lead to the fundamental auction types.

The results and benefits of this integration that occurs in the first level are the following: (i) the expansion of the classification of auctions to a second level comes as a necessity; (ii) the researcher is assisted in selecting the auction type most appropriate for his application and in determining instantly the necessary values of the auction characteristics, and, (iii) the researcher and the practitioner have the ability to contrast and compare a desired auction type with other potential ones that result by altering the value of one or more auction characteristics. The second level in essence digs into detail the auction parameters and further crisps the taxonomy effort. Thus, the second level is valuable for the expert auction designer who wishes to shape the auction by determining mechanism parameters not evident in the first level. As a result, the benefits of the classification exposed in the second level are that: (i) it constitutes a natural extension and deepening into the study of auction design and handling, and (ii) it serves as a tool to design efficient, fair, and structured (thus safer) auction schemes.

.2 Decision-making support for multi-dimensional auctions

The research on contemporary auctions culminates with the presentation of three decision models that help the auctioneer and bidder in shaping their strategy for any multi-dimensional auction. The indicative graphical representation serves as a template to map the core decision areas an auction designer faces, namely, the allowed bids and related parameters, the bid submission procedure, and the method for winner determination and price paid. In this illustrative representation, the auctioneer needs to define parameters on the format of the accepted bids (where bids consist of a price and attribute value vectors) and allowable combinations of attributes in each bid.

The proposed mapping may also serve as a tool for the coherent communication of the auction parameters to interested bidders and a means for fair treatment since the full auction representation is clear; moreover, bidders may use this representation for the selection of decision tools and methods to support their bidding strategy. Finally, the proposed representation is useful for researchers wishing to standardize research on auction formats, their parameters and interdependencies.The employed notation is generic and although it resembles to, yet it does not fall into any standard modelling method or a notation format for the development of software architectures; nevertheless, it intends to contain the core information for the further design of applications independent of modelling tool or language. The models are thus useful for the representation of the evolution of literature, related findings, tools and methods.

.3 Synergy between auctions and revenue management techniques

We demonstrate when and how auctions operate as complementary dynamic price-setting mechanisms to RM in Logistics-related services, by enhancing the price-setting process, aligning RM and auctions with the recent ICT advances, and describing how the use of Location Based Services (LBS) may improve the market efficiency.

.4 Progressive behavioral auction design

We provide a systematic methodology for the design of auctions based on bidders' behaviors. The methodology collects and analyzes bids and discovers bidders' strategy attitudes based on linguistic statements. Results are evaluated in each stage to strengthen the mechanism with auction design parameters. At the same time bidders' experience and familiarity with the auction process is gradually strengthened. This constitutes the basis for an innovative experience-based design and learning progressive design methodology.

.5 Potential applications

We identify several cases where trading of logistics services may benefit from the coupling between m-commerce and LBS and the adoption of l-auctions through: (i) efficient pre-screening of potential bidding carriers based on their current and projected spatial characteristics in order to execute more efficient auctions, (ii) opportunities for collaboration between small carriers aiming to win large-volume shipments and to offer adjacent long-haul services, (iii) automatic collection and evaluation of carriers' spatial and temporal but non-price related attributes (here estimated loading time), to reduce bid evaluation complexity, and, (iv) application of positive discrimination strategies of submitted bids based on carriers' location at the time of bidding allowing carriers to formulate more efficient and profitable bidding strategies, and shippers to better manage their logistics resources (e.g., inventory, loading bays etc.). We extend our findings in the tourism services area; we propose a mobile auction-based dynamic marketplace that allows a hospitality service provider to offer unused capacity through an innovative low-cost channel for geographically-focused and subscription-based customer target group. The model may complement RM strategies and can easily apply to a large variety of tourism and hospitality services especially for last-minute offerings.

1.4 Thesis Organization

The thesis is organized in eight interrelated chapters as illustrated in Figure 1.1. Chapter 2 provides a theoretical approach on auctions, mechanisms, parameters and relevant theory from simple to multi-dimensional auction formats. It also reviews e- and m- auctions and the relevant ICT infrastructure requirements. The analysis is based on an extensive literature review mainly from the last decade. The outcomes are then systematically organized to develop the auction customizing model (conceptually defined as *Auction Classification*

Ecosystem - *"ACE"*) presented in Chapter 3 which is further expanded to sub-levels supporting the organization of multi-dimensional auctions.

Chapter 4 expands the research on m-auctions by adding location sensitivity properties of Location-Based Services (LBS), coins the concept of *l-auctions* and presents a fundamental ICT architecture and the associated information workflow. Chapter 5 consolidates results from previous chapters and justifies the need and the applicability of previous results for both the auctioneer (design of auction mechanism) and the bidder (shaping of appropriate bidding behavior). Results are used to develop experimental auction model with the use of *z-Tree*, a widely-accepted software for the design and execution of economic experiments, developed by the University of Zurich, Institute for Empirical Research in Economics.

Chapter 6 provides the "big picture" of applications of l-auctions and their prerequisites. Based on systematic analysis and models developed in Chapters 3 and 4, it presents a detailed analysis on how l-auctions may apply in the logistics and tourism domain and under which circumstances they complement RM strategies. The outcomes of the previous findings are tested in Chapter 7 through a series of experiments based on models and methods developed in Chapters 5 and 6. Findings related to the market efficiency, auction design and participants' behavior are extracted and commented. Chapter 8, finally, is dedicated on the summarization of main findings and concludes with business implications and opportunities for further research. The source code developed for the implementation of experiments, along with indicative snapshots for the experiment is presented in the Appendix of the thesis.

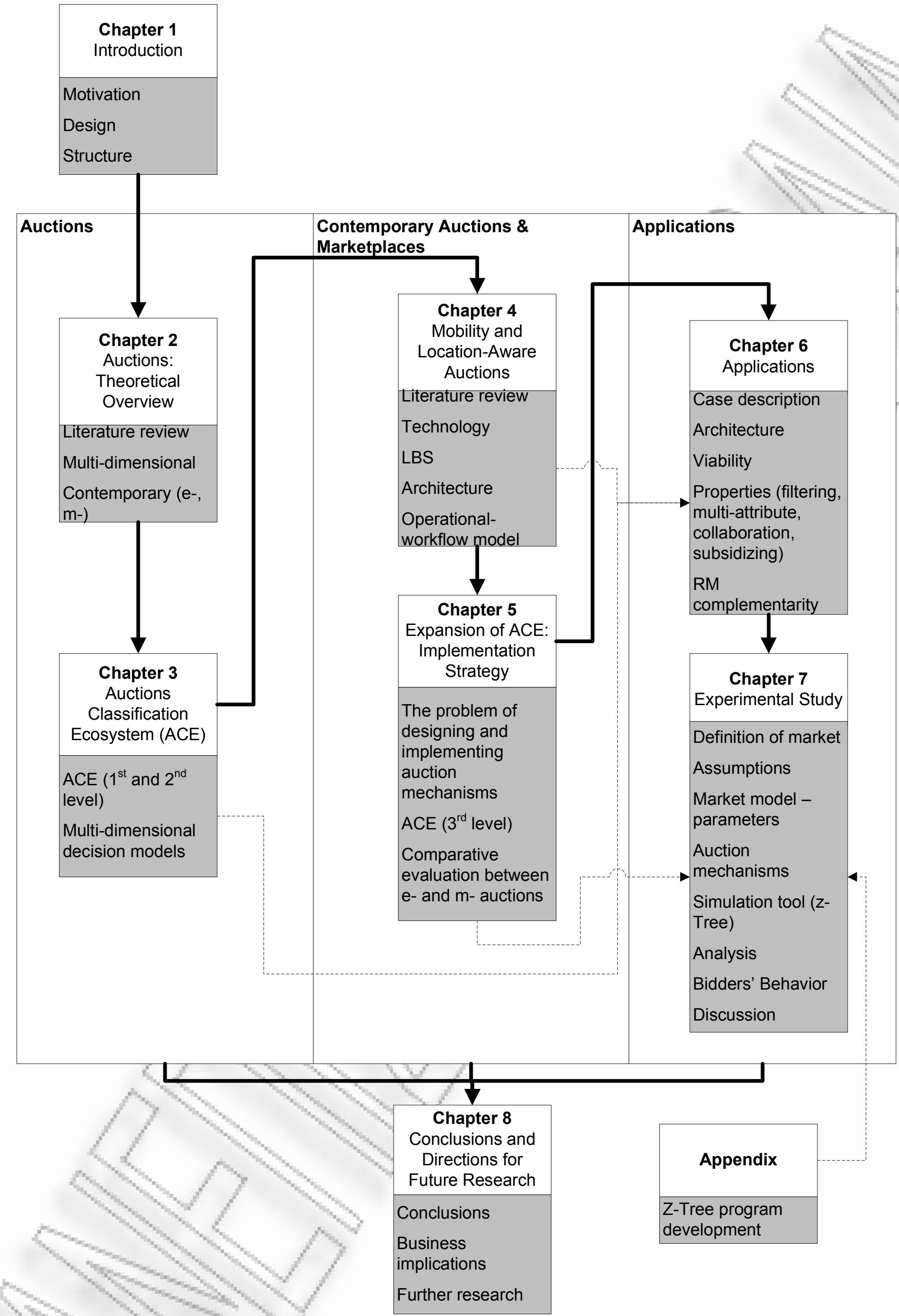

Figure 1.1: *Thesis Outline*

In the schematic representation of Figure 1.1, the white area of each box includes the Chapter number and the topic addressed, while the grey box shows the main outcomes included in the respective chapter. Solid lines show the interrelationship between Chapters and dashed lines presents the previous Chapters' results used in each Chapter. Chapters have been allocated in three logical parts which namely are *Auctions*, *Contemporary Auctions* and *Applications* (big frames).

At the time of completion of this thesis, the publications in Table 1.2 (along with their order of appearance) have been derived.

Author	**Year**	**Title**	**Journal/Conference/Book**	**Appeared in text as:**
Emiris, D., Marentakis C.	2011	Enhancement of Revenue Management Techniques through Location-Aware m-auctions for Logistics Services	*International Journal of Revenue Management*, (To Appear)	Emiris and Marentakis (2011)
Marentakis, C.	2011	Telematics for efficient transportation and distribution of agrifood products	In Bourlakis, M., Vlachos, I., Zeimpekis, V. (Eds.) *Intelligent Agrifood Chains & Networks*, Blackwell Publishing, Oxford, UK (*forthcoming)*	Marentakis (2010)
Marentakis, C., Emiris, D.	2010	Location Aware Auctions for Tourism Services	*Journal of Hospitality and Tourism Technology*, 1(2)	Marentakis and Emiris (2010a)
Marentakis, C., Emiris, D.	2010	Decision-Making Elements for the Design of Emerging Multi-Dimensional Auctions	*International Journal of Operations Research and Information Systems*, 1(4)	Marentakis and Emiris (2010b)
Marentakis, C., Emiris, D.	2010	Comparative Evaluation of the Unique Elements of e- and m- Auctions	24th European Conference on Operational Research (EURO XXIV), Lisbon, Portugal, July 11-14, 2010	Marentakis and Emiris (2010c)
Emiris, D., Marentakis C.	2010	A Unified Classification Ecosystem for Auctions	*International Journal of Operations Research and Information Systems*, 1(3),	Emiris and Marentakis (2010a)
Emiris, D., Marentakis, C.,	2010	An Expanded Template for the Hosting of Contemporary Auctions for Freight Services	24th European Conference on Operational Research (EURO XXIV), Lisbon, Portugal, July 11-14, 2010	Emiris and Marentakis (2010b)
Petridis. I., Emiris, D., Marentakis, C.	2010	Progressive Design of Auctions for Freight Transportation Services	24th European Conference on Operational Research (EURO XXIV), Lisbon, Portugal, July 11-14, 2010.	Petridis et al., (2010)
Marentakis, C., Emiris, D.,	2009	Simplification of Multi-Attribute Auctions in the Freight Procurement Domain through the Incorporation of LBS technology	4th International Workshop on Freight Transportation and Logistics (Odysseus 2009), Cesme, Izmir, Turkey, May 26-29, 2009	Marentakis and Emiris (2009)
Emiris, D., Marentakis, C,	2009	A Novel Template for the Hosting of Auctions Conducted in the Freight Services Marketplace	4th International Workshop on Freight Transportation and Logistics (Odysseus 2009), Cesme, Izmir, Turkey, May 26-29, 2009	Emiris and Marentakis (2009)
Anagnostou, T., Marentakis, C., Emiris, D.	2009	Procurement of Transportation Services Using Electronic Auctions and the Process of Choosing the Optimal Offers	4th International Workshop on Freight Transportation and Logistics (Odysseus 2009), Cesme, Izmir, Turkey, May 26-29, 2009	Anagnostou et al., (2009)
Marentakis, C., Emiris, D.	2008	Διαμόρφωση Πακέτων Συμπληρωματικών Πόρων Τουριστικών Υπηρεσιών και Τιμολόγηση Μέσω Ηλεκτρονικών Συνδυαστικών Δημοπρασιών σε Περιβάλλον B2C	20ο Εθνικό Συνέδριο Ελληνικής Εταιρίας Επιχειρησιακών Ερευνών, Σπέτσες, 19-21 Ιουνίου 2008	Marentakis and Emiris (2008)
Emiris, D., Marentakis C.	2008	The Expansion of E-Marketplace to M-Marketplace by Integrating Mobility and Auctions in a Location-Sensitive Environment: Application in Procurement of Logistics Services	In Kotsopoulos, S., Ioannou, K. (Eds.) *Handbook of Research on Heterogeneous Next Generation Networking: Innovations and Platform*, Information Science Reference Publishing, ISBN: 978-1-60566-108-7	Emiris and Marentakis (2008)

Emiris, D.M. Marentakis, C.A., Laimos, P.P.,	2007	Towards an Integrated LBS-Enabled Mobile Auctions Marketplace for Logistics Services	18th IEEE Annual International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC 2007), Athens, September 3-7, 2007	Emiris et al., (2007a)
Emiris, D., Marentakis, C., Karasideri, K.	2007	Εφαρμογή Ηλεκτρονικών Δημοπρασιών σε Υπηρεσίες Logistics: Σχεδιασμός ενός Μοντέλου Προμήθειας Μεταφορικών Υπηρεσιών	3ο Εθνικό Συνέδριο Ελληνικής Εταιρίας Συστημικών Μελετών, Πειραιάς, 26-28 Μαΐου 2007.	Emiris et al., (2007b)
Marentakis, C., Emiris, D., Koulouriotis, D.	2007	Επισκόπηση Ειδικών Μηχανισμών Δημοπρασιών για Διαμόρφωση Τιμών σε Συναλλαγές στη Νέα Αγορά	3ο Εθνικό Συνέδριο Ελληνικής Εταιρίας Συστημικών Μελετών, Πειραιάς, 26-28 Μαΐου 2007.	Marentakis et al., (2007)

Table 1.2: *Appearance of Publications in the Thesis*

Chapter 2

Auctions: Theoretical Overview

This chapter contains an extended analysis of auctions and the corresponding theory, through a broad literature review with emphasis in the last decade and underlines the most significant research findings in each area. Auction types, mechanisms and parameters are analyzed and special focus is given in the more complex *multi-dimensional* auction formats. The review is expanded to include ICT-supported e-, and m- auctions. A considerable portion of this chapter is based on material from our published work[4].

This chapter is structured as follows. In Section 2.1, an introduction to auctions is presented. The different basic auction types and basic taxonomical approaches are presented in Section 2.2. Section 2.3 presents an overview of auction theory focusing mainly on mechanism design and bidding strategy along with an overview of relevant literature review. Section 2.4 presents and reviews literature on contemporary auction formats including multi-dimensional, reverse and double mechanisms. Section 2.5 provides a brief overview of the parameters used in auction mechanisms while Section 2.6 presents the most important threats for auction mechanisms. Section 2.7 enumerates literature on the applications of auctions from the last decade. Section 2.8 deals with electronically conducted auctions focusing mainly on their unique properties and requirements. Finally, Section 2.9 concludes.

[4] Marentakis and Emiris (2010b), Emiris and Marentakis (2010a), Marentakis et al., (2007)

2.1 An Introduction to Auctions

The term "auction" comes from the Latin word "auctus" the exact meaning of which is "increase". In this case, auctions are used when a seller (monopolist) wishes to sell an item aiming to increase the price of the item. Auctions may also be used for procurement aiming to decrease the price of the item. In such cases there is a single buyer (monopsonist) who wants to purchase an item from one group of interested suppliers. According to economic theory, monopsony is essentially the same as monopoly but with reverse signs of some variables A modern and most coherent definition of an auction is provided in McAfee and McMillan (1987a), where an auction is defined as "*a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants*". Market participants are buyers, sellers and auctioneers. In most cases, sellers do not organize or conduct the auction; typically, this is a responsibility for an intermediary auctioneer. Auctioneers are independent agents, experienced in conducting and securing the auction process, possibly receiving commission from the other participants. Figure 2. depicts a typical auction process which constitutes of bid submission, bid evaluation, price computation, closing, and the (optional) feedback to bidders.

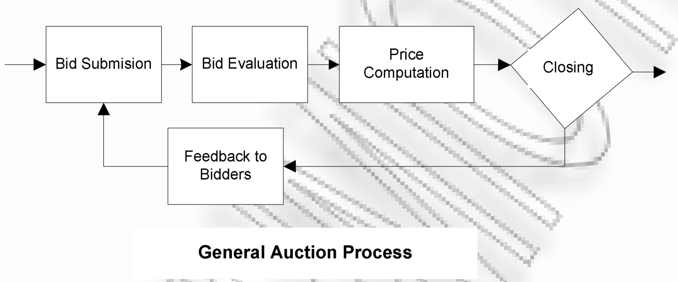

Figure 2.1: *Simplified Auction Process (Bichler et al., 2002b)*

An alternative definition of an auction has been proposed by Wolfstetter (1996). It is "*a bidding mechanism, described by a set of auction rules that specify how the winner is determined and how much he has to pay. In addition, auction rules may restrict participation and feasible bids and impose certain rules of behavior*". These definitions are generic and cover the purchasing case too, also known as *reverse* auction, where a buyer uses an auction for procurement. In reverse auctions –in contrary to forward auctions- the winner is the one who submits the lowest bid (offer).

The aim of all trading mechanisms (e.g., auctions, negotiations, bargaining, posted pricing, etc.) is to reach a final price which is acceptable to the involved parties (that is, sellers and buyers) and which serves, at the same time as the dominant evaluation criterion for a bid. A final price in this context is assumed to be "acceptable" when these parties have the feeling or impression that it is fair, attractive and profitable for them. The common denominator in all trading mechanisms is therefore, the formation of this final price. The value of the final price is highly likely to differ depending on the trading mechanism when all other factors (e.g., number of participants, type of market, information dispersion, etc.) remain unchanged. Overall, any price formation system needs to be efficient in communicating and dispersing information among interested market participants under specific limitations concerning information and society asymmetries and trading item qualities, so that the only decision-making variable for buyers and sellers is the final price.

In order to systematically study auctions results and participants behavior, economists developed *Auction Theory*, which provides the framework for explicit modeling (yet with certain restrictions) of price formation. Auction Theory has many research implications: it is applicable – much more than economic mathematics; it can constitute a testing platform for economic theory (games with partial information); it is an excellent price formation mechanism especially in oligopoly; and, it is a base for theoretical research in price formation and negotiations (McAfee and McMillan, 1987a; Klemperer 1999).

The wide application of auctions in a huge number of commercial and economic transactions increases considerably the research opportunities in auction theory. A typical case of pertinent research efforts concerns the study of auctions in the case of several items (either identical or different), or in the case of consideration and evaluation of additional criteria such as quality, time, etc. In the business domain, on the other hand, companies and individuals have successfully implemented classic auctions schemes in several application areas and adopted reverse auction strategies for procurement purposes. Recent trends and requirements in business transactions extended the classic auctions format and added new characteristics; however, the determination of the winner of these types of auctions becomes more complex and new Operational Research techniques and algorithms need to be incorporated in the auctions framework.

The intense interest over the last three decades on auctions and their applications has led to the production of a large number of scientific publications worldwide. Review papers have managed to gather the most critical of these publications and to form the basis for further study and research in the area; yet, new works are continuously being published.

2.2 Auction Types and Classification

The main participants in any auction, as mentioned above, are the buyer(s), the seller(s) and the auctioneer; the latter is typically an independent entity. Buyers and sellers, depending on the environment an auction is conducted, may either have the role of an *initiator* (the one who initiates the auction in order to buy or sell a good) or that of a *bidder* (the one who makes an offer). In the so-called *forward auctions*, the seller acts as the initiator while a buyer is the bidder; in *reverse auctions* in the contrary, a buyer acts as the initiator while a seller is the bidder (Figure 2.2).

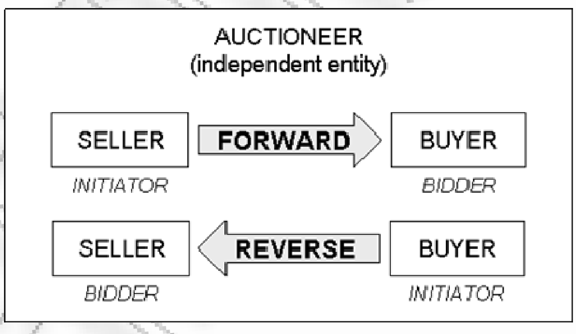

Figure 2.2: *Auction Participants and Roles*

2.2.1 A Taxonomy of Auctions

Auctions may be distinguished between single-good and combinatorial ones, depending on the nature of the object of trade. An auction is called *single-good* if the objects of the trade are of the same type. An auction is called *combinatorial* if the object of the trade concerns inter-related goods of different types, characteristics or functionalities. In both cases, the number of units for the good(s) under auction characterizes an auction as *single-unit* or *multi-unit*.

Auctions may further be distinguished between single-attribute and multi-attribute auctions, depending on the number of attributes (or criteria) used for the evaluation of a bid. In *single-attribute auctions*, a unique criterion is used to evaluate the bid; typically, this criterion is the price. In *multi-attribute auctions*, on the other hand, several criteria may be used for the evaluation of the bid, which are often combined to produce a *value* for the bid.

Auctions may also be characterized as single-side and double-side ones depending on the number of initiators and bidders. In *single-side auctions*, there exists only one initiator (either seller or buyer, depending on whether the auction is a forward or a reverse one, respectively) and many bidders (buyers or sellers for forward or reverse auctions, respectively); that is, the relationship between initiator and bidders is one-to-many. In *double-side auctions*, this relationship is many-to-many as there may exist many initiators and many bidders at the same time in the same auction.

In addition to the above, auctions may be distinguished between sealed-bid and outcry (or open-cry) auctions, depending on the visibility to information that bidders have on rivals' bids. In *sealed-bid auctions*, bidders normally submit their sealed offers in order to be evaluated and they have no information on the contents of the opponents' offers. In *outcry auctions*, as the name implies, the contents of each bid are open to all bidders, usually at the time when the auction takes place. Typically, outcry auctions generate multiple rounds of auction, while sealed-bid auctions may terminate in a single round. An extended comparison between outcry and sealed-bid auctions for various cases and parameters and some important results useful for making decisions about format selection can be found in Li and Riley (2007). Finally, depending on how the auction progresses and on the resulting awarding rule, auctions may be classified into English or Dutch in the outcry case and *k-th* price sealed-bid (where *k*=1, 2,…) in the sealed-bid case, where the most common values of *k* are 1 and 2.

2.2.2 Fundamental Auction Types

Based on the previous paragraph, three basic types of auctions are regarded as fundamental and are further elaborated below:

- *English auctions* are also encountered in the literature as "oral", "open", "ascending-bid", "ascending-price", or "ascending open-cry". In this type of auctions, the price offered is raised successively until only one bidder remains; this bidder is the winner and is awarded the object of the auction at the final price. Prices may be announced by buyers or sellers during the course of the auction. It is by far the most common type.
- *Dutch auctions* are also encountered in the literature as "descending-bid", "descending-price", or "descending-clock". In this type of auctions, the auctioneer announces the highest desirable price; then, the price decreases continuously or in discrete intervals until a bidder announces his willingness to pay the current price. This bidder is the winner and is awarded the object of the auction at the final price. Examining clock speed in Dutch auctions, Katok and Kwasnica (2008) compared between Dutch auctions for slow and fast clock speed (i.e, the speed by which the price decreases) and FPSB mechanisms (defined below) and they conclude that clock speed is an important design issue for Dutch auctions.
- In *k-th* price sealed bid auctions each bidder submits independently a single sealed bid. The bidder that submitted the highest bid is awarded the object of the auction at the price corresponding to the *k-th* ranked bid. The case where *k*=1, is most commonly referred as *first-price sealed-bid auction* (FPSB) and is widely used in business procurement. The case where *k*=2, is most commonly referred as *second-price sealed-bid auction* (SPSB) or *Vickrey auction*. Practical applications for this type are limited but are important for the theoretical study of auctions. Rothkopf et al., (1990) and Sandholm (2000b) examine these practical limitations while Lucking-Reiley (2000) presents past and current applications of Vickrey auctions. Empirical study shows limited applications of Vickrey auctions (Ausubel and Milgrom, 2006a).

2.2.3 General Classification of Auctions

A concise description of different possible features in an auction is presented in Table 2.1. This table has been developed based on the taxonomy schemes proposed by Wurman et al., (2001) and later by Fasli and Michalakopoulos (2005). These research attempts highlight core and common auction activities and result in the development of a customizing standard for several different auction types. The two schemes are depicted in Figure 2.3, where the contribution of each author is clearly indicated. The auction types appear to expand on the left side of the tree, for economy of space purposes; in fact, the branching of auction types is applicable from the topmost node of the tree. He et al. (2003) recognized and incorporated temporal attributes (such as the duration of an auction) in their own taxonomy scheme.

These additional attributes are (i) the ratio of buyers / sellers, (ii) the duration, (iii) the settlement price and, (iv) the closing rule.

Feature	Value	Description	Value	Description
Nature of Traded Goods	Single Good	Item(s) of same type	Combinatorial	Item(s) of different type
Item Units	Single	Bid for a single item	Multi	Bid for bundles of items (similar, complementary or different)
Dimensions (Attributes)	Single	Price is the only criterion for bid formation and evaluation	Multi	Multiple criteria for bid formation and evaluation
Sides	Single	Buyer or seller set bid	Double	Buyer and seller allowed to bid
Bid Type	Outcry	Each bidder has information on other bids	Sealed-Bid (SB)	Only auctioneer has access to all bids
Price	First	Winner pays his bid	k-th	Winner pays the price of the k-th ranked bid
Bid order	Ascending	Increasing bid order	Descending	Decreasing bid order

Table 2.1: *Format of Auction Features*

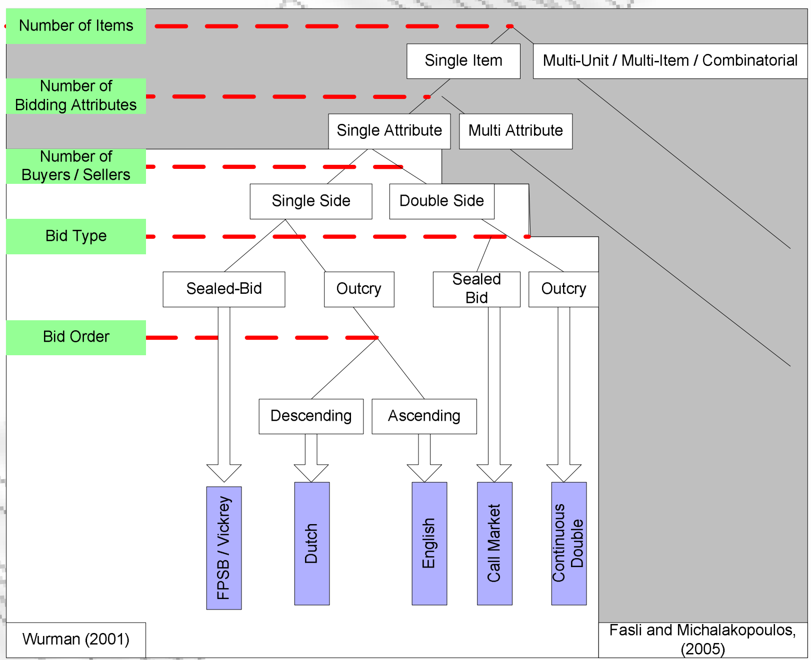

Figure 2.3: *Auctions Taxonomy (Wurman et al., 2001; Fasli and Michalakopoulos 2005)*

Since each basic auction type has specific properties, choosing the appropriate auction format often becomes an empirical matter in terms of efficiency, revenue maximization, privacy, implementation, asymmetries levelling, risk aversion and collusion avoidance (Cramton, 1998). A substantial and comprehensive review of managerial considerations in the design and execution of auctions has been provided by Rothkopf and Park (2001). Such considerations include, but are not limited to, the following: why use an auction, what to set for auction, who will bid, number of rounds, bid increment, winner determination (scoring), etc. They also refer to the disciplines an auction relates to: economics and game theory, operations research, management science, engineering, computer science and social sciences. Due to their extended diffusion and applicability, auctions should not be studied as isolated trading mechanisms. Haruvi et al. (2008) assert that auction settings face strong competition from other auction settings and study a number of competitive features namely, competition with complementarities and substitutes, competition between items, competition between sellers, competition between formats, mechanisms and institutions and competition between auction hosts. Their statements have strong implications on auctions executed electronically.

As a result of the different needs an auction has to address, it is not rare to combine properties of two or more auction types, and thus to develop hybrid auction types. In this context, Klemperer (2002) presented the "Anglo-Dutch" auction: the process starts with an ascending auction until just two bidders remain, who then participate in an ascending-price sealed-bid auction. During the first stage, the auctioneer receives the maximum valuation information while during the sealed-bid stage the weaknesses of a common value setting are minimized. The Anglo-Dutch auction type and its mechanism are further studied by Levin and Ye (2008). Perry et al., (2000) also present their version of a two-stage hybrid auction: during the first stage all bidders submit bids in a ***first-price*** *sealed-bid* auction context, while during the second stage only the two highest bidders participate in a ***second-price*** *sealed-bid* auction. Another interesting form of a two-stage auction has been introduced by Ye (2007) when the traded items are of high value; in the first stage, bidders submit non-binding bids, while during the second stage the auctioneer selects the eligible bidders who then submit binding sealed-bids. Manelli and Vincent (2004) examine the mechanics of hybrid formats that combine features of auctions and negotiations (take-it-or-leave-it offers) for the case of high-value items. Other popular hybrid auction types include (i) the *OpenBook* type where bidders initially set ascending bids and during the last hour they set sealed-bids (Klemperer (2002); and (ii) the *Elimination* (or *"survival"*) auction which consists of several rounds of sealed-bid auctions, where the auctioneer sets a revised threshold in each round and rejects bids under this threshold (Fujishima et al. (1999).

2.3 Overview of Auction Theory

Economists use Game Theory to study auctions, as a basis to analyse interactions between rational players, where each player's decision depends on his/her presumptions about the decisions of other players. This approach provides different models for each type of problem and cannot be generalized to cover the entire problems spectrum. To remedy this weakness, Auction Theory emerged as a generalized microeconomic approach to study the price formation problem and to examine the strategic behaviour of auction participants facing information asymmetries. William Vickrey (1961) in his nobel-prize awarded paper on auction theory was the first one to study questions concerning the bidding strategy and the auction outcomes for different types of auctions.

Extensive reviews and research on many aspects on auction theory have subsequently been provided by Stark and Rothkopf (1979), Engelbrecht-Wiggans (1980), Riley and Samuelson (1981), Cox et al., (1982), Milgrom and Weber (1982), McAfee and McMillan (1987a), Milgrom (1989), Feldman and Mehra (1993) and Wolfstetter (1996) while Rothkopf and Harstad (1994) first made a realistic approach to the fundamental problems of mechanism design and bidding strategy from a decision-making perspective. An extensive review of early and recent research literature on auction theory has been provided by Klemperer (1999), who also criticized the erroneous application of economic theory in auctions (Klemperer, 2003). Most recent reviews of the theoretical fundamentals of auctions have been published by Kalagnanam and Parkes (2005) and Maasland and Onderstal (2006). A simple and comprehensive review on auctions and implications for Marketing science has been provided by Chakravarti et al., (2002) The remainder of this section deals with works in the recent literature that address key aspects of auction theory, namely: (i) the uncertainty and information asymmetry; (ii) the existing valuation models; (iii) the comparison of auction types; (iv) the design of an auction mechanism and the development of optimal auctions; and (v) the bidding strategy and the management of information. Despite the fact that these topics are encountered in almost every work associated to auctions, in the context of the present thesis, the works of Vickrey (1961), Myerson (1981), McAfee and McMillan (1987a), Milgrom (1989), Feldman and Mehra (1993), Wolfstetter (1996), Klemperer (1999), are considered fundamental in the introduction, analysis and explanation of these terms.

2.3.1 Uncertainty and Information Asymmetry

Information asymmetry is a common and crucial attribute in auctions when the item of trade does not have a standard or known value (McAfee and McMillan, 1987a). It applies, for instance, when a seller does not have an exact opinion on the bidders' valuation for the price of an item, or when each participant has different information about the item value and does not know the information other participants may have. Information asymmetry is related to *uncertainty*, which may further be distinguished into *preference uncertainty* and *quality uncertainty* (Myerson, 1981). In the case of preference uncertainty, informing bidder A about the valuation of bidder B should not cause bidder A to revise his valuation (although he may do so). In the case of quality uncertainty, bidder A may tend to revise his valuation after being informed about bidder's B valuation.

2.3.2 Valuation Models

It is obvious that the valuation characteristics strongly affect auction outcomes. Two major different valuation models have been developed to systematically study auctions. These are:

(a) The Independent Private Values Model (IPVM)

The IPVM is usually employed when there exist no resale opportunities for the item or when each bidder knows exactly the cost of the item. The model assumes n participants (seller and bidders) where each participant i ($i = 1,2,\ldots,n$) has an exact valuation u_i for the item, does not know the other participants' valuations, but knows that all participants draw their valuations from a statistical distribution F_i, which is known to all and can be estimated from historical data (Milgrom, 1989). The IPVM has several properties (Milgrom and Weber, 1982), (Wolfstetter, 1996):

- Bidding strategies in Dutch and first-price sealed-bid auctions are equivalent. Bidding strategies in English and second-price sealed-bid auctions are equivalent.
- English and second-price sealed-bid auctions are efficient and Pareto-optimal; winners are the bidders with higher valuations. Dutch and first-price sealed-bid auctions are efficient when bidders are symmetric.
- Seller's revenue is almost equal in all four basic auction types.

(b) The Common Value Model (CVM)

The CVM applies when bidders plan to resell the item. The model assumes n participants i ($i = 1,2,\ldots,n$) with different information resources and different valuations u_i for the item. The participants have common valuation criteria and the same objectives. If V is the true value of the item, the bidders are assumed to draw their valuations u_i from a statistical distribution $H(u_i|V)$ known to all participants. The model is not always realistic because many bidders may have private information which should be incorporated in the model (Feldman and Mehra, 1993). Frequently, valuation uncertainty does not depend on bidders' native differences but on different sources of information. This situation is described by the *almost* *common values model (ACVM)*. In this model, the actual value is the same for all bidders, but they have different estimates about this value. When minor asymmetries arise, then bidders with higher estimates tend to bid more aggressively. Obviously, if a bidder with low valuation wins, then he cannot be sure about the actual profit. To avoid this, bidders with low valuations do not bid aggressively, bidding competition decreases and the winning bid is much lower. Even then, the winner may be uncertain about his true earnings (a phenomenon, commonly known as *the Winner's Curse*). Usually sellers provide bidders with additional information about the true value of the item in order to avoid this phenomenon (*information revelation strategy)*. Then bidders estimate more accurately the true value of the item, bids become more aggressive and price increases further. Pure IPV and CV models contain a number of hard assumptions; although they are useful for auction theory research, they can hardly apply in real situations; numerous research articles examine different variations or combinations of these extreme models. Milgrom and Weber (1982) have developed a correlation model which combines attributes from both models and state that "*affiliation*" occurs whenever positive correlation between bidders' valuations exists.

2.3.3 Comparison of Basic Auction Types

The auction model in which: (i) bidders are symmetric and risk neutral, (ii) the IPVM applies, and (iii) payment is a function of bids alone, is referred to as the *benchmark model*. Based on the above, a fundamental theorem has been developed for use in auction theory, namely, the *Revenue Equivalence Theorem* or *RET*. The RET states that for the benchmark model the four basic auction types, namely, English, Dutch, first-price sealed-bid and second-price sealed-bid, all yield the same price on the average. This situation hardly applies in real situations but it is the simplest model for studying auctions. The RET may also be not applicable when bidders show different *attitude against risk*. The equivalence between basic auction types under different valuation models and bidders' risk attitudes is summarized in Table 2.2 (as per Shoham and Leyton-Brown, 2008).

Valuation Model	**Bidders' risk attitude**	**Auction type and revenue comparison**						
IPVM	Risk-Neutral	English	=	2nd price	=	1st Price	=	Dutch
	Risk-Averse		=		<		=	
	Risk-Seeking		=		>		=	
CVM	Risk-Neutral		>		>		=	

Table 2.2: *Comparison of Basic Auction Types and Revenues for Different Risk Attitudes and Valuation Models (Adapted from Shoham and Leyton-Brown, 2008)*

When bidders draw their valuations from different statistical distributions then *bidders asymmetries* exist and the RET does not apply. A bidder, for example, who acts as a reseller and a bidder who acts as a collector are asymmetric. Another example refers to bidders from different countries because of different tax law, exchange rates and commissions, experience level, analytical ability, access to information, etc.

When distributions of bidders' valuations are similar except of their averages, then sellers may support bidders with lower average valuations to force bidders with higher valuations to further increase their bids; this is referred to as *price-discrimination.* Discrimination applies as a bonus or as a minimum variation between bidders from different classes and may have revenue-maximizing or strategic intentions (*positive discrimination)*; however, sometimes a seller may discriminate against a bidder (*negative discrimination).* Hubbard and Paarsch (2009) examine effects and outcomes of *bid preferences* (positive discrimination) a buyer shows over specific sellers in sealed-bid procurement auctions.

The term *asymmetry* also appears in the case where a seller's payment is a function of the winning bid *and* future information about the bidder's valuation (*asymmetry of payment*). Examples are the *Royalties* and *Incentive Contracts (in reverse auctions).*

2.3.4 Design of Optimal Auction Mechanisms

In order to execute an auction, an *auction mechanism* is required. An auction mechanism is defined as "*a process which accepts bids as inputs and determines winner(s) and winning prices*". As a part of auction theory, the design of auction mechanisms aims to develop market institutions and study the results in trading transactions. An *optimal auction* is considered to be the auction which yields best results for the seller, while from a bidder's point of view an optimal auction occurs when he perceives to obtain the most benefits for the bid he put.

A mechanism is *direct* if each bidder bids according to his/her valuation; this is the case, for example, in a second-price sealed-bid mechanism. A mechanism is *incentive-compatible* when it induces bidders to reveal their true valuation; this is the case, for example, in reverse second-price sealed-bid auctions. Kalagnanam and Parkes (2005) present an extended analysis for auction mechanism design, which includes six core components to formulate a design requirement framework. An adaptation of their approach is summarized in Table 2.3.

Design Component	Description
Resources	Trading items (single/multiple, standard/multi-attribute, etc.)
Market Structure	Forward / reverse / double (exchange)
Preference Structure	Agent's utility function for expected results (scoring rule, utility reduction as a function of item units, etc.)
Bid Structure	Bid formation flexibility as a function of price and other components as quantity, quality, alternative bids (etc.)
Matching Supply to Demand	Winner determination, single-sourcing, multiple-sourcing
Information Feedback	Direct mechanism (bidders have no feedback during process, e.g., sealed-bid) / Indirect mechanism (bidders have feedback during process, e.g., English)

Table 2.3: *Auction Mechanism Parameters (Adapted from Kalagnanam and Parkes, 2005)*

Auction theory uses the RET for the design of optimal auctions and incorporates the "*Revelation Principle*" according to which "*for any mechanism, there is a direct, incentive-compatible mechanism with the same outcome*" (McAfee and McMillan, 1987a), (Wolfstetter, 1996). In fact, it has been observed that in the search for optimal auctions one may restrict attention, without loss of generality, to direct, incentive-compatible auctions (Myerson, 1981); therefore, when a designer (e.g., a seller) has to select between different mechanisms, the use of the Revelation Principle downsizes the problem to the selection between direct, incentive-compatible mechanisms with information asymmetry.

2.3.5 Bidding Strategy

Besides auction mechanism, another critical factor that influences auctions outcomes is the strategy that each bidder follows during the auction process. Feldman and Mehra (1993) summarize bidders' strategy formation and expected payoffs for each of the four basic auction types, as summarized in Table 2.4.

Auction Type	Bidder's Strategy	Bidder's Expected Payoffs
English	Function of (i) personal valuation, (ii) prior assessment of rival valuations and, (iii) new information obtained during the bidding process	Bidder's valuation of auctioned item minus his/her highest bid
Dutch	Function of (i) personal valuation, (ii) prior assessment of rival valuations and, (iii) no new information obtained during the bidding process	Bidder's valuation of auctioned item minus his/her actual bid
FPSB or multi-object discriminatory	Same as for Dutch	Same as for Dutch
SPSB or multi-object uniform-price	Same as for Dutch	Bidder's valuation of auctioned item minus the second highest bid

Table 2.4: *Bidders' Strategy and Outcomes in Four Basic Auction Types (Adapted from Feldman and Mehra, 1993)*

2.3.6 Additional Resources

Apart of the fundamental works in auction theory as stated in the beginning of Section 2.3, there exist numerous other published works that investigate the basic aspects of auction theory that have been discussed herein. Table 2.5 contains a delegation (not an exhaustive presentation) of representative, last-decade works in these areas. Many of these works deal with extremely specific cases and are not examined further in the remainder of the chapter.

Discipline	Reference	Main Focus
Valuation Models	Guerre et al. (2000)	Use of nonparametric methods to test first-price IPV auction
	Athey and Haile (2002)	Use of nonparametric methods to test auction types models
	Einy et al. (2002)	Examination of common-value second-price auctions
	Li et al. (2002)	Affiliated Private Value (APV) model which allows dependence among private values through affiliation
	Hong and Shum (2004)	Convergence rates of prices is sequences of CV auctions
	Banerjee, (2005)	CV with independent bidders' signals having different precision levels
	Levin and Kagel (2005)	ACVM case where one bidder's ex-post valuation is slightly higher than rivals'
	Li (2005)	Variability of valuation on the expected rent in a reverse second-price auction
	Fang and Morris (2006)	Bidders with noisy information about rivals' valuations
	De Frutos and Pechlivanos (2006)	Asymmetric second-price common-value auctions; linkage between CVM and ACVM
	Lebrun (2006)	Uniqueness of the equilibrium of first-price auction in the asymmetric IPVM
	Martinez-Pardina (2006)	First-price private-value auction where the valuation of one of the bidders is common knowledge
	Monteiro and Moreira (2006)	Equilibrium in private-value first-price auctions without affiliation
	Chen et al. (2007)	IPVM with uncertain distribution of bidders' valuations (ambiguity)
	Virag (2007)	First-price common-value auction for the rent of a good for a period without revelation of previous periods bids
	Harstad et al. (2008)	Information aggregation in large CV auctions
	Kim (2008)	Asymmetric improvement of one bidder's information in first-price common value auctions with two bidders does not always improve his revenue.
	Malakhov and Vohra (2008)	Identification of an optimal auction under IPVM, where two bidders compete – one of them being budget constrained
	Palfrey and Pevnitskaya (2008)	Bidders' self-selection effect in PV auctions
	Quint (2008)	Upper and lower bounds of seller's expected revenue and optimal reserve price in symmetric affiliated private values
	Rose and Levin (2008)	Behavioral model of the two bidder with different level of rationality ACVM and adaptation to English-clock auction
	Araujo and de Castro (2009)	Equilibrium in asymmetrical double auctions with interdependent values
Auctions formats comparison – RET - Asymmetries	Che and Gale (1998)	Bidders with budget constraints due to marginal costs and option of bidders' finance
	Runeson and Skitmore (1999)	Review of Tendering Theory
	Grimm and Schmidt (2000)	Asymmetries due to taxation
	Gul and Stacchetti (2000)	Simultaneous multiple object English auction with not budget constrained bidders
	Bali and Jackson (2002)	RET in auctions with a large number of bidders
	Ettinger (2003)	Impact on efficiency when bidders with crossholdings exist
	Kirchkamp and Moldovanu (2004)	Bidders with asymmetric and interdependent valuations
	Maskin (2004)	Book review – support for theorem proofs
	Povel and Singh (2004)	Impact of bidders' asymmetry on seller's revenue
	Talluri and van Ryzin (2005)	Overview of auction theory

	Cheng (2006)	Benchmarking model for asymmetric auctions
	De Frutos and Jarque (2007)	Positive impact of first-price auction in weaker bidders participation under small asymmetries
	Lamy (2009)	Revenue comparison between 1st and 2nd price auctions when seller submits shill bids.
	Page (1998)	Unified approach in optimal auctions
	Ausubel (2000)	Efficient Generalized Vickrey Auction when bidders have interdependent values
	Ausubel and Cramton (1999)	Examination of optimality in auction with perfect resell and no seller's commitment for not selling
	Jehiel et al. (1999)	Mechanism which maximizes seller's expected utility (revenue and externality) design when bidder types are multi-dimensional in terms of externalities between them
	Parkes (2000)	Auctions where bidders cannot easily determine their valuations (or the determination is costly or with computational complexity); comparison of auction formats
	Byde (2003)	Mechanism evaluation methodology based on Evolutionary Game Theory
	Dufwenberg and Gneezy (2002)	Information revelation strategy in FPSB
	Fiat et al. (2002)	Design of cancelable and generalized auctions
	Roth (2002)	Role of computation and experimentation to bridge the gap between theory and design of mechanisms
	Vulcano et al. (2002)	Dynamic variants of first-price and second-price multiple-unit auction, when random groups of bidders arrive in different periods
	Dickhaut et al. (2003)	Information management
	Jackson (2003)	Review on mechanism design
	Mares and Hardstad (2003)	Common-value auctions where the seller reveals information to selected bidders
	Schmitz (2003)	Case of two capacity constrained sellers in second-price auctions
	Hajiaghayi et al. (2004)	Auctions with limited supply and dynamic arrival and departure of bidders
Mechanism design	Lochner and Wellman (2004)	Configurability of an auction with the use of a scripting language (AB3D) to describe auction mechanisms
	Mikoucheva and Sonin (2004)	Cases where information disclosure causes inefficiencies
	Nti (2004)	Equivalence between first-price all-pay auction with reserve price and contests where participants have different valuations
	Chillemi, (2005)	Examination of the effects of passive ownership links among bidders in auctions
	Jullien and Mariotti, (2006)	Mechanism design minimizing the "informed seller" problem
	Benoit and Dubra, (2006)	Buyers' and sellers' revelation behavior
	Bierbaum and Grimm (2006)	Comparison between fixed price mechanism and uniform price auction in selling shares of a divisible good to retail buyers
	Grigorieva et al., (2006)	Bidder's information revelation and communication requirements of efficient incentive-compatible auctions
	Janssen (2006)	Auction where the prize is the right to play a market game
	Monteiro (2006)	Equilibrium bidding functions in first-price auctions
	Shogren et al. (2006)	Use of second-price auction tournament with non-linear payoff schedule to bear sincere bidding
	Tan and Yilankaya (2006)	Equilibria in second-price sealed-bid auctions with bidder participation costs in IPVM for a. Symmetric and b. Asymmetric bidders
	Yoon (2006)	Affirmative bid preference and efficiency in government auctions
	Bergemann and Pesendorfer (2007)	Optimal information revelation strategies when seller is able to estimate bidders' information precision
	Vagstad (2007)	Revelation of (some – not necessarily the best possible) information prior to bidder's entry
	Moldovanu et al. (2008)	Comparison between uniform auction in one centralized market and two distinct auction markets when two sellers want simultaneously to auction a homogeneous good.

	Turocy (2008)	Relaxation of the equilibrium assumption in a class of auction environments with interdependent values within Milgrom and Weber's (1982) framework. (The last characterized the unique symmetric Bayes-Nash equilibrium in first- and second-price auctions of a single indivisible good with bidders with symmetric affiliated values)
	Zhan (2008)	Review of optimality and efficiency issues
	McAfee and McMillan (1987b)	Bidder's knowledge on number of opponents and risk-attitude
	Eso and Futo (1999)	Auctions with risk averse seller and risk neutral bidders
Risk	Bulow and Klemperer (2002)	Analysis of the "winner's curse" and its impact on price formation
	Hong and Nishimura (2003)	Comparison between English and second-price auction when item contains risk
	Eso (2005)	Auctions with risk averse bidders who have correlated valuations and risk neutral seller
	Cingottini and Menicucci (2006)	Effect of number of (risk-averse) bidders in all-pay auctions
	Menicucci (2006)	Auction with risk averse seller and correlated bidders' values
	Janssen and Karamychev (2009)	Operations and characteristics of aftermarket where participants are the winners of a preliminary license auction
	Avery (1998)	"Jump bidding" strategy and affiliated values
	Moresi (2000)	Bidders' research to better estimate item's value for both private and common values
Bidding Strategy	Fibich et al., (2002)	Study of behaviour of high-value bidders when they belong to the same high type group.
	Cramton (2004)	Bidding strategy in uniform-price auctions
	Kim and Che (2004),	Asymmetries in bidders knowledge about rivals
	Isaac et al. (2005)	Examination of "jump bidding" behavior in ascending auctions
	Dodonova and Khoroshilov (2006)	Ability of target firm to reject highest offer in order to prevent from jump bidding strategies in takeover auctions
	Ham and Kagel (2006)	Gender effects in a two-stage (indicative bidding) auction
	Andreoni et al., (2007)	Asymmetries in bidders knowledge about rivals; Experimental analysis
	Isaac et al. (2007)	"Jump bidding" strategy due to strategic concerns and impatience
	At and Morand (2008)	"Jump bidding" strategy in takeover auctions
	Drichoutis et al., (2008)	Effect of indicative (reference) price in bidding strategy
	Goncalves (2008)	Irrational bidding in common-value English auction
	Elbittar (2009)	Experimental analysis of bidding behavior in FPSB auction; amongst two bidders, the bidder with lower valuation bids more aggressively after the revelation of the rankings of valuations

Table 2.5: *A Delegation of Representative Last-Decade Works on Basic Aspects of Auction Theory*

2.4 Emerging Auction Formats

The evolution of auctions over the years has been greatly assisted by the progress of information technology and the internet. The ability to exchange information in real-time, over long distances and to develop virtual auction environments where evaluation criteria are incorporated and decisions are obtained automatically, are only some of the factors that have boosted the more systematic investigation and implementation of more complex auction schemes than the so-called "traditional" ones. The need to define herein a "traditional" auction scheme is essential in setting a benchmark for what will be called an "advanced" or "emerging" auction; yet, this definition is not a confining one and has a chronological flavor, since several of the schemes that have received attention recently have been first presented even in the very early works in auctions, at least as theoretical concepts. The bibliographical survey in the present chapter therefore, focuses on the advancements in the theory of auctions that have been recorded in several research articles over the past few years.

In this context, the term "traditional" or "classic" auction will be used to refer to single-unit, single-item, single-attribute (or single-criterion) that are conducted according to the English, Dutch, FPSB or Vickrey schemes. These auctions correspond to the lower left branches of the taxonomy tree in Figure 2.3 and can either be forward or reverse auctions. All other auction types that divert from this definition will be considered as advanced. The remainder of this section deals with multidimensional auctions and the different variations these exhibit, as well as with an overview of the recent research regarding reverse and double-side auctions.

2.4.1 Multi-dimensional Auctions

Multi-dimensional auctions constitute a broad category which emerged from the expansion and generalization of traditional auctions, as defined previously; in essence, a multi-dimensional auction is a three-dimensional one where the three dimensions correspond to the number of units, the number (or mix) of items and the number of the bid attributes. Different combinations of these three parameters result to 2^3=8 discrete auction formats, as illustrated in Figure 2.4 (Bichler et al., 2002a), where the degenerated case in the origin of the coordinate system (denoted with "1") corresponds to a traditional auction.

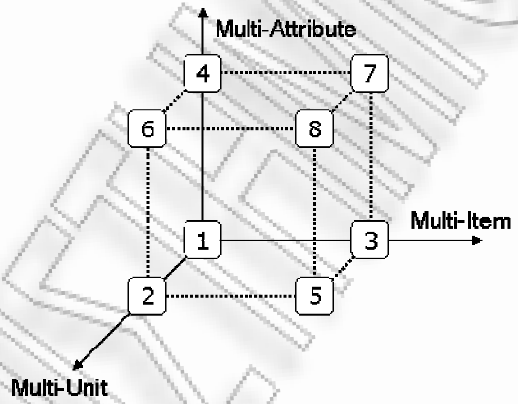

Figure 2.4: *The Three Dimensions of a Multi-Dimensional Auction (Bichler et al., 2002a)*

.1 Multi-attribute Auctions

Attributes are characteristics that pertain to either the item (endogenous) or to the bidder (exogenous), and which may serve as additional evaluation criteria to award an auction. Endogenous attributes refer to the different negotiable characteristics that an item (object or service) may have, while exogenous attributes refer to quantifiable criteria the value of which may depend on the subjective opinion of the seller (in a forward auction environment) or the buyer (in a reverse auction environment) for the bidder (such as the bidder's reliability or experience). These attributes and their relative importance (weight) must be open and known in advance to the participants in order to ensure the integrity of the auction. An auction type where the winner is decided based on more than one attributes is called a *multi-attribute* or *multi-criteria* auction. The evaluation of a complex bid with many attributes usually results from a *scoring rule* (or *scoring function*) that transforms attributes values to a total score and allocates the item(s) to the bidder that performs best. A common scoring rule is the weighted scoring function which for an auction with j bids evaluated based on n attributes x_i^j (i=1,…,n) takes the form:

$$S(x_j) = \sum_{i=1}^{n} w_i S_i(x_i^j) \quad \text{and} \quad \sum_{i=1}^{n} w_i = 1$$

where, w_i is the weight for the attribute x_i^j in bid j, $S_i(x_i^j)$ is the score for this criterion in bid j and $\mathbf{x}_j$ is the ix1 vector that contains the distinct attributes for bid j. It has been demonstrated through experimentation that the utility in multi-attribute auctions is significantly higher than the corresponding utility in a single-attribute auction for the same item (Bichler, 2000). He also showed that increasing the number of attributes results to complexity inflation equally for the auctioneer and the bidders and the usage of decision supporting tools is thus inevitable.

An extended analysis of multi-attribute mechanisms, their design and some laboratory experimental results has been presented by Bichler and Segev (2001), where the above weighted scoring function is referred to as the buyer's true utility function. David et al., (2006), however, state that a scoring function may differ from the utility function and discuss auction theory aspects like mechanism design, information revelation and bidding strategy for a number of reverse, multi-attribute auction protocols, namely the first-score sealed-bid, the second-score sealed-bid, and the English sequential with full information revelation. In a relatively earlier work on reverse simultaneous and sequential multi-attribute auctions, David et al., (2002a) examine the application of variations of two typical auction protocols, namely, FPSB and English, while later (David et al., 2003a, 2003b) examine bidder's strategies when a deadline exists. Examining reverse multi-attribute auctions, Strecker and Seifert (2004) compared the outcomes and efficiency between the English and Vickrey implementation and found that the English format yields higher buyer's surplus and allocative efficiency due to bidders' experiential learning. Asker and Cantillon (2008) examine the properties of multi-attribute procurement auctions where price enters linearly into the scoring rule.

Sometimes multi-attribute auctions permit bidding on different combinations (configurations) of attributes (configurable offers). This option allows bidders to propose multiple values for different combinations of attributes, thus reducing the complexity of bid evaluation. Bichler et al., (2002c) introduce a Decision Support System called "RECO" (Representation and Evaluation of Configurable Offers), which simplifies collection and evaluation of configurable offers. The special case of allocation to multiple bidders when configurable offers allowed has been studied by Bichler and Kalagnanam (2005).

Several other researchers studied and proposed complex multi-attribute auction mechanisms. Liu et al., (2000a) examine two variations of multi-parameter bidding systems, one lower-bid system and one average-bid system, respectively, and evaluated their properties. David et al., (2002b) suggest an English auction protocol for procurement multi-attribute auctions, called the full-information revelation auction. Beil and Wein (2003) use a multi-round reverse auction mechanism which gradually discloses bidder's costs; in each round the auctioneer is free to modify scoring rule. Strecker (2003) demonstrated that the revelation of the scoring rule during the auction process enforces auction efficiency and drew their results from a computer-based laboratory experiment; during the same period Parkes and Kalagnanam (2002, 2005) suggested how to implement incremental preference revelation using iterative mechanisms and proposed relevant models. Bellosta et al., (2004) introduced a notion of reserve price (reserve point) by using two reference points, where the first point defines target values of attributes while the second point defines the minimum values, and focused on its application in electronic multi-attribute auctions. Moreover, Suzuki and Yokoo (2006), and Chen and Hu (2006) propose multi-attribute reverse auction protocols that incorporate the benefits of Vickrey auctions and they are secure and strategy-proof, respectively. Finally, De Smet (2007) considered problems in multi-attribute auctions without full bid-comparability.

Parallel to the problem of auction mechanism design, one has to consider the complex problem of bid formation and to develop and apply a bidding strategy. In the work of Cagno et al., (2001) an Analytical Hierarchy Process (AHP) is presented which results in a bid formation model that evaluates the winning probability based on available information about the owner, the competitors and the profile of his own bid; this decision model is depicted in Figure 2.5. In order to reduce the complexity during the bidding and evaluation stages for both the buyer and the seller in multi-attribute auctions, especially when the number of attributes is significant, Burmeister et al., (2002) propose a "package-oriented" approach, that is, a rational reverse auction mechanism based on bundling of relevant combinations of attributes into packages. An extensive analysis of bidding strategies on multi-attribute auctions along with some models can be found in David et al., (2006).

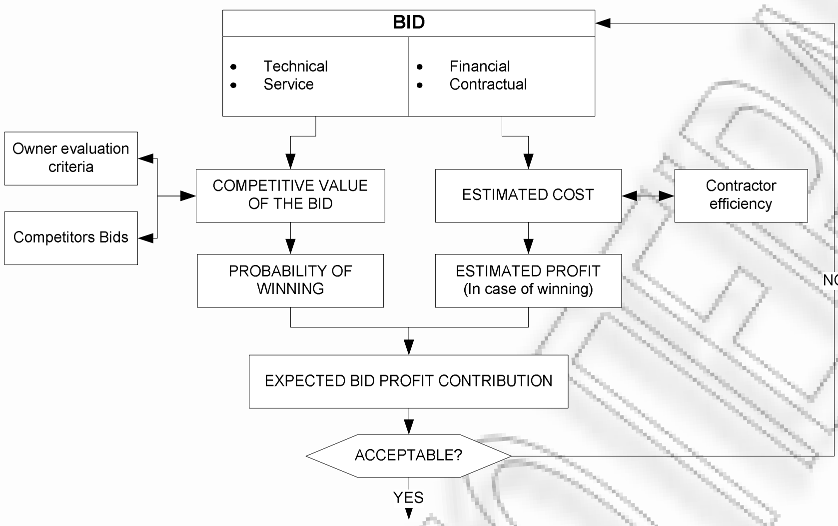

Figure 2.5: *A Decision Framework in the Bid Preparation Process (Adapted from Cagno et al., 2001)*

.2 Multi-unit Auctions

In a multi-unit auction the seller sets a fixed quantity of items and each bidder submits separate bids for different fractions of this quantity or for the whole. When units are identical then the auction is called *homogeneous* – otherwise the auction is called *heterogeneous*; obviously, a heterogeneous multi-unit auction is a multi-item one and is examined in the respective section. In single-attribute auctions, submitted bids consist of a bid price for the desired quantity; however, although this seems facilitating, past research has shown that it is hard to achieve efficient outcomes in multi-unit auctions. Vickrey (1961) first studied multi-unit auctions where each participant bids for one single unit, but when bidding for multiple-units the problem may get very complex. In the recent past, Ausubel (2004) proposed a dynamic ascending-bid mechanism which supports privacy and efficiency. The multi-unit auction proposed by Ausubel (2004) compared to Vickrey auctions yields less revenue in private-value settings and higher revenue in common-value settings (Manelli et al., 2006). Bennouri and Falconieri (2006) examine the optimal design and behavior of a mechanism for multi-unit auctions when information asymmetries between bidders exist and De Castro and Riascos (2009) engage differential methods to generalize bidding behavior findings in multi-unit auctions.

Cramton (1998) recommended two main procedures to conduct a multi-unit auction:

- *Demand schedule*: According to this procedure, bidders submit their demand schedules in each round. The auctioneer then sums the demands in order to construct a demand curve and to calculate the clearing price. To avoid phenomena of "*late bidding*", auctioneers use "*activity rules*" which obligate all bidders to submit bids in each round; moreover, activity rules ensure that interested bidders improve their bids in each round – otherwise they are rejected from the auction.
- *Ascending clock*: According to this procedure, the current price is displayed in a "clock" and bidders submit the quantity they want for this price; if the total demanded quantity exceeds the available quantity, then the price rises. The process continues until the required quantity becomes less than available quantity. An activity rule here ensures that bidders are not allowed to raise demand while price rises. This procedure prevents *signaling* and is easier to implement.

Several works have dealt with the determination of the winning price in a multi-unit auction. Feldman and Mehra (1993) dealt with special sealed-bid mechanisms and reported that: (i) in a *discriminatory auction (*or *multiple-price* or *multiple-yield* or *pay-your-bid auction)*, where multiple units are auctioned at the same time, sealed-bids are sorted in descending order and quantities are allocated to the corresponding bids; (ii) in a *uniform auction (*or *marginal-price* or *uniform price)* sealed-bids are sorted in descending order and quantities are allocated to bidders at the winning price (Figure 2.6).

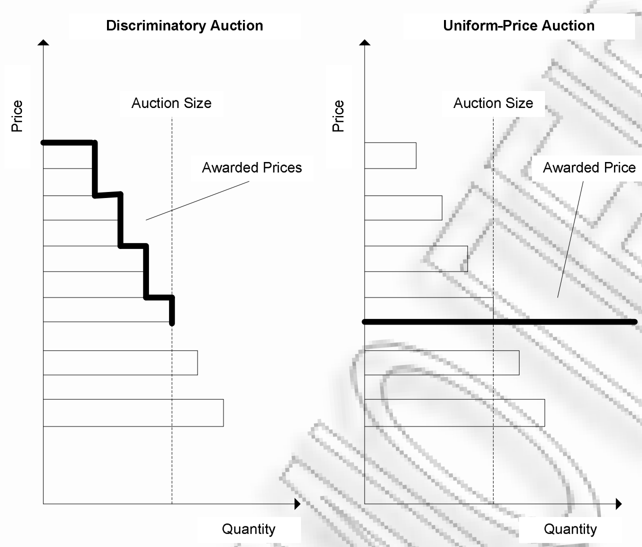

Figure 2.6: *Comparison Between Winning Price and Winners' Payments in Discriminatory and Uniform-Price Auctions (Adapted from Feldman and Mehra, 1993)*

A hybrid mechanism that combines both discriminatory and uniform-price formats is the mechanism used by the Spanish Treasury to sell government debt (Alvarez and Mazon, 2007). According to this mechanism, payments are based on the weighted average price of the winning bids; if the bid price is lower than the weighted average price, bidders pay their bid price- otherwise they pay the weighted average price. Bidding behavior and revenue outcomes of the Spanish auction have been experimentally tested by Abbink et al., (2006); they concluded that the Spanish auction yields greater revenue, as the uniform auction does. Jackson and Kremer (2007) provide an analysis of the price behavior and efficiency of discriminatory auctions.

In a uniform-price mechanism bidders may set bids lower than their actual valuations (*bid shading)* and *demand reduction* phenomenon may rise; the price per unit is lower but each bidder acquires less units. Bidding behavior for such cases has been studied by Engelbrecht-Wiggans et al., (2006), while Kagel and Levin (2005) in their extended research on multi-unit auctions show that bid shading weakens when synergies between bidders occur or when items are complementary (in multi-item auctions). List and Lucking-Reiley (2000 and 2002) also study experimentally the demand reduction problem comparing Vickrey and uniform price mechanisms.

Huh et al. (2004) introduced the minimum rejected bid (*uniform-price first-rejected, UPFR)* and the highest accepted bid (*uniform-price last-accepted, UPLA)* schemes to define the winning price. The authors propose a new rule called *quasi-uniform-price (QUP)* where a bidder receives for each of his accepted units the lower rejected bid submitted by another bidder; when the number of bidders or the quantity raise then so does the expected *stop-out price* (minimum winning bid). An interesting research on efficiency and item allocation in multi-unit auctions can be found in Cramton (1998).

A special case of multi-unit English auctions is the *Yankee auction* where the set of winning bids consists of the *N* highest bids, where *N* is the number of units of the item. A new bid has to be at least equal to the minimum bid or increased by a pre-specified increment. An extensive analysis of Yankee auctions is presented in Bapna et al., (2001b,), while a customisable simulation tool for this auction type is provided by Bapna et al., (2003). Teich et al., (1999b) present an algorithmic approach to multi-unit sealed-bid auctions, aiming at reducing the level of price discrimination, where each bidder may be informed about his bid status and the "activating" price required continuing to the next round. They also claim that the advantages of this auction mechanism over the traditional Yankee auction is that bidders will not see each other's bids, and bidders do not have to decide what amount to bid to make their bid active, simplifying the process; furthermore, they have the option to bid automatically at reduced quantities. Issues concerning truth revealing have also been discussed by Kothari et al., (2005), who also examine the winner-determination problem complexity and propose an algorithm using a knapsack problem approach.

Depending on whether the item units are set in auction in a sequential or a simultaneous manner, multi-unit auctions appear in two main variations, namely the *sequential (or repeated)* auctions and the *simultaneous* auctions, respectively. Many researchers stated that the RET applies in both variations when units are homogeneous and no buyer is interested in more than one unit (Klemperer, 1999).

One of the most commonly used simultaneous auction formats is the *Simultaneous Ascending Auction (SAA)* which was first used by the US government during 1994 to sell radio spectrum licenses (Milgrom, 2000). In SAA all items (or units) are set simultaneously in auction but the bidders submit binding sealed-bids in a sequence of rounds. At the end of each round the auctioneer announces information about the bidders, the "*standing high bid*" and the corresponding bidder. The next round begins with a price equal to the standing high bid (or slightly increased by an increment) of the previous round. At the end of each round, bidders may readjust their valuations for the next round aiming to obtain proper item portfolios. A minimum bid may be applied to retain a number of rounds. The auctioneer also has to define and announce an "*activity rule*" to potential bidders before the auction begins. This rule defines bidders' eligibility to bid in each round.

Simultaneous ascending auctions have been widely used in resource scheduling problems like individual time slots (Reeves et al., 2005) and they are efficient only when items are substitutes. An extended research on the theory of simultaneous ascending auctions and an analysis of the case where items are complementary is presented in Zheng (2005). Goeree et al. (2006) experimentally comparing the overall performance between SAA, simultaneous first-price, sequential first-price and simultaneous descending auctions, found that the SAA always achieves efficiency while the sequential first-price auction yields greater revenue when items are auctioned in descending quality order. Examining simultaneous multi-item auctions Sherstyuk (2007) compares between FPSB, hard-closing and soft-closing English types concluding that soft-closing English are most efficient, FPSB maximize revenue and hard-closing are inferior in terms of revenue and efficiency.

Sequential auctions are widely used as procurement mechanisms. Luton and McAfee (1986) examine some applications in government procurement and research project implementation and they study topics like seller's information, costs and efficiency when the first auction reveals cost-related information to the next auction participants. Usually the seller defines the order according to which units or items are set in auction; nevertheless, in some cases the winning bidder in each round has the right to select the item to be auctioned in the next round. This special case is defined as *right-to-choose (*or *"option"* or *"pooled")* auction (Gale and Hausch, 1994). Contrary to simple sequential auctions, right-to-choose auctions limit the information revealed in early stages and consequently participants bid more aggressively Burguet (2007). It has been shown that the aggressive bidding behavior leads to greater outcomes than the optimal theoretically estimated revenue as studied and supported experimentally for heterogeneous goods (hence, for multi-item auctions) by Eliaz et al., (2008). In the same context, Salmon and Iachini, (2007) demonstrated that a pooled auction generates higher revenue than the ascending auction due to more aggressive bidding while being equally efficient to a continuous simultaneous ascending auction. Pitchik (2009) focus on sequential auctions stating that the sequence of sales may affect competition, price and revenue. Salmon and Wilson (2008) analyze the “second chance offer” option in a sequential auction where the seller may offer a losing bidder another unit of the item in a take-it-or-leave-it price. They show that this price generates more revenue than two sequential auctions.

In an attempt to compare sequential auctions with other auction types, Katzman (1999) focused in the examination of sequential second-price auctions with unit demand and compared them to other auction types. Using simulation experiments in simultaneous and sequential English auctions, Airiau et al., (2003) examine the results of different time horizon strategies and find that long-term strategies perform better. Comparing the performance of sequential and FPSB simultaneous auctions when synergies amongst (various) items exist, De Silva et al., (2007) found difference in bidding behaviour. On the other hand, it has been shown by Leufkens and Peeters (2007) that the first-price format has lower bankruptcy probability for bidders when item synergies exist. Mezzetti et al., (2008) provide a more extensive theoretical analysis and comparison between sequential auctions and uniform-price simultaneous auctions.

When designing a sequential auction one has to decide whether to announce the winning bid in each phase or not. Non budget-constrained bidders have a critical advantage; if they have information about budget-constrained bidders they may use this information to compel the latter to spend their full budget in early phases. When a seller has information about budget-constrained bidders, then he has to define an optimal selling sequence (*selling agenda)* in order to maximize his revenue (Fatima et al., 2004). Usually, the information concerning participants’ valuations and winning probabilities cannot be quantified. Fang et al., (2004) use fuzzy sets to model such information and show that a seller’s revenue varies for different sequences. Bidders’ behavior is not normal when the supply for next rounds is uncertain (Neugebauer and Pezanis-Christou, 2007). Cai et al., (2007b) examine sequential auctions and show that 1st and 2nd price sealed-bid sequential auctions might not be optimal when bid information is revealed after each auction.

After a series of experiments in sequential reverse auctions, Brosig and Reiβ (2007) found that suppliers’ entry and behavior strongly depends on the opportunity cost of early bid submission. Of special interest are multi-unit auction mechanisms where bidders arrive at different times during the auction process (e.g., bandwidth or CPU time allocation auctions). Immediately after the occurrence of a new bid, the mechanism must decide how many units to allocate to this bid and the corresponding price (Lavi and Nisan, 2004).

Other variations of multi-unit auctions include the following

- *Share auction*: Each bid consists of a program which defines different prices for different fractions of the item (Alvarez and Mazon, 2007).
- *Volume discount auction*: Bidders (sellers) define the price as a function of the quantity the buyer will order. This type applies in procurement auctions (Bichler et al., 2002b).
- *Split award auction*: Each supplier submits two bids, one for a fraction of the item and one for the whole item. This type also applies in procurement auctions (Wolfstetter, 1996).

Apart of the above schemes, several special variations have appeared in the literature. A recent emerging application of multi-unit auctions is the case where the seller has unlimited number of indivisible items, buyers want exactly one unit and the seller has no value for the item (Goldberg et al., 2006) This state is usually described as *unlimited supply* and has many applications (e.g., digital goods). Bikhchandani and Ostroy (2006) study another special type of multiple-unit auction, namely, the “ascending price Vickrey auction” formulating it as a linear programming problem. Iwasaki et al., (2005) propose an Ascending-price Option allocation Protocol (AOP) where sincere bidding is an equilibrium strategy being robust against false-name bids in an electronic auction environment. Jin et al., (2006) analyze a realistic case of multi-unit auction where the cost function of an additional unit follows a

U-shape structure and a bidder faces economies or diseconomies of scale, and proposes solution techniques. Hernardo-Veciana (2004) examines bidding strategy in multi-item auctions under information asymmetries for different unit sizes; among other things, he showed that when the number of units is sufficiently large then less-informed bidders tend to bid more aggressively and win more often than more-informed bidders. Issues concerning efficiency in auctions of multiple complementary units have been discussed by Elmaghraby (2005a). Finally, Bernard et al., (2005) compares bidding strategies in multi-unit Vickrey, last-accepted and first-rejected offer uniform mechanisms.

.3 Multi-item Auctions

In this auction format, a number of different items are set for sale and each bidder submits his bid to acquire a specific collection of items. The results for single-item auctions do not apply to multi-item auctions as stated by Rothkopf and Harstad (1994). The auction mechanism design and the bidding behaviour in multi-item auctions have special characteristics thus attracting significant research interest. In certain cases, dependencies or complementarities between items and/or bundles of items may exist. When the utility function of the bundle is sub-additive then items are defined as *substitutes*.

A seller who has many items to sell has to decide about selling the items as a bundle or separately. Selling items as a bundle usually incurs lower transaction and listing costs than selling them separately, either in different auctions or in different rounds of the same auction. The special case where a seller wants to sell multiple different units of different goods has been examined by Ausubel and Cramton (2004), who propose the “simultaneous clock auction” - a special auction format which is effective and simple. Studies on bundling decisions have also been presented by Chakraborty (2006). Brendstrup (2006) focuses on a methodology testing for synergies between two objects. Jehiel et al., (2007) analyse the bundling strategy formation problem when the key decision drivers are strategic issues instead of complementarities. Comparing a second-price sequential auction versus a bundle auction for procurement, Grimm (2007) found that the sequential auction is efficient while the bundle auction anticipates lower procurement costs via subcontracting.

Earlier, Bapna et al., (2000) examined the outcome of English and Vickrey multi-item auctions evaluating auctioneer’s revenue and bidders’ performance using Internet auction data. Mishra and Parkes (2009) proposed a generalized “Vickrey-Dutch” auction for multi-unit and multi-item private value settings. Ausubel (2006) proposed an efficient dynamic auction format for multiple heterogeneous items, based on the ascending-clock auction type; the seller announces a vector of prices and the bidders respond with vectors of quantities they want to buy for each price. The seller then calculates the demand and modifies the vector of prices subject to demand versus availability of items. The process repeats itself until the vector of prices is feasible and demand equals availability.

Mishra and Garg (2006) examine a multi-item Dutch mechanism for unit demand and show that allocation is efficient when sellers offer items in descending price order; moreover, they study optimal bidding strategies, optimal time for bidding and impact of market size in auction results. Recognizing the transparency of English auctions, de Vries et al., (2007), formulate a heterogeneous multi-item auction as an English mechanism and calculate item allocation as a linear programming problem where bidders are asked to set their preferred bundles in each round and bundle prices are personalized (this type of auction is also called a *Japanese* auction).

From the bidders’ point a view, in a sequential auction a bidder may be interested to acquire either bundles of items or a single unit of an item. When both types of bidders exist, the sequential ascending auction yields better revenues for the seller than sequential second-price auction (Branco, 2001). The special case where synergies and overlapping interest between bidders exist has been analyzed by Rosenthal and Wang (1996). Sørensen (2006) examines the case where bidders do not know their valuation for the second (complementary) item at the time they bid for the first object. The general case of sequential auctions where auctioned items has both common and private values has been examined by Fatima et al., (2005). They show that, given that private and common values are two extreme cases, valuation in any auction depends on the grade of uncertainty and that efficiency decreases with uncertainty.

A problem often encountered in multi-item auctions is the so-called bidders' "*exposure problem*" where a bidder wins some items but not the entire desired bundle; likewise, in a multi-unit auction a bidder may encounter the "*multiple copies problem*" where the bidder fails to obtain the desired quantity of the item. Such problems are generally referred to as "*composability problems"* and to tackle them, bidders try to compose strategies across many mechanisms without the ability to determine beforehand which auction will be next.

To deal with the composability problem, Juda and Parkes (2005), propose a methodology based on trading of rights (*options)* to purchase or sell an item at a desired (*exercise)* price. Lorentziadis (2008) examines exposure problems in reverse multi-item auctions and focuses on the cost arising for the bidder due to exposure; furthermore, he proposes and analyzes three methods (namely, minimum acceptable order, discount pricing and fixed pricing with varying percentage profit) to ensure a minimum profit. Finally, the bidding strategy problem may get more complex when a bidder wants to bid simultaneously in multiple auctions. Byde et al., (2002), propose a framework supporting bidders to develop such strategies when they want to bid for multiple items in multiple auctions operating on different protocols.

2.4.2 Combinatorial Auctions

Combinatorial auctions (CA) are auctions of complementary items (either homogeneous or heterogeneous) where bidders wish to acquire specific combinations of these items (*bundles*). In this case, the total value of the bundle is greater than the sum of each item's value (*positive complementarity)*. Bidders may set "*package bids*" (a bid for the desired bundle) or "*contingent bids*" (subject to the acquisition of other items in the auction). Cramton et al., (2006) state that research on combinatorial auctions matches aspects from auction theory, operational research and information technology, and present an extended review of combinatorial auctions and their major applications (transportation, telecom, airport slots, radio-spectrum licenses etc.). Due to their extensive applicability and attraction and the unique characteristics they present regarding bid formation, strategy and auction mechanism, combinatorial auctions are examined separately herein.

Applied research in combinatorial auctions demonstrates many implementation difficulties while experimental testing of algorithms cannot easily provide realistic and applicable results. An extensive review on the area of combinatorial auctions can be found in de Vries and Vohra (2003); additionally, Pekec and Rothkopf (2003) provide some practical guidelines for the successful implementation of combinatorial auctions. Another extended yet comprehensive review on combinatorial auctions has been provided by Abrache et al., (2004b) focusing on formats, bidding languages and the *Winner Determination Problem* (WDP). An extended analysis on combinatorial auctions and a corresponding review of recent research can also be found in Narahari and Dayama (2005), Choi et al., (2005) and Abrache et al., (2007). All these research efforts examine issues such as the design framework and parameters (like efficiency, rationality, budget balance, incentive compatibility, solution stability, transaction costs, fairness, bidding strategy etc), as well as issues concerning computational complexity and bidding languages. Finally, Lehmann et al., (2006) study the representation, the allocation and "false-name" bids for different types of complementarities.

.1 Bid Formation and Associated Complexity

From a bidder's point of view, bid formation in a combinatorial auction is a complex task requiring support from optimization tools. An et al., (2005) propose a model that supports bidders' decision for the efficient selection of bundles and evaluate relevant bundling strategies performance. Later, Leskela et al., (2007) presented a Decision Support System proposing effective combinations of items and corresponding bid prices in reverse auctions. Leyton-Brown et al., (2000b) propose a "package" of distributions named "*Combinatorial Auction Test Suite – CATS*" to simulate bidding behaviors. They also use this suite to simulate four basic applications of combinatorial auctions below:

- "*Paths in space*": establishment of connection between points (transportation networks, pipelines, etc.)
- "*Proximity in space*": establishment of neighborhood (real estate, oil-drilling, etc.)
- "*Arbitrary relationships*": normality of relationships between indivisible or multi-unit items (machine parts, collector's items, etc.)
- "*Temporal matching*": matching of time parameters (airport slots, TV airtime, etc.)

Combinatorial auctions present high communication complexity. For example, when N items set for auction, each bidder may bid for 2^N-1 different bundles (including ALL items). To reduce the complexity, a seller may allow bidding for specific bundles only. The general problem of communication requirements complexity for combinatorial allocation has been studied by Nisan and Segal (2006). When contingent bids are allowed, the auctioneer has to solve a combinatorial optimization problem in order to determine the winner. Generally, when items are complementary it is hard to estimate an items' value. A typical example to demonstrate this is the following: a travel agent wants to reserve beds via an auction for the stay of a couple in a hotel during peak season. Winning a single bed obviously has zero value. Winning two beds but in different hotels, has some value for the bidder (say, 50) but this is much lower than winning two beds in the same hotel (where, the value from the bidder's perspective is 200), while winning two beds in the same room has a value of 300; therefore, the logical representation of the bid may be formulated using the following XOR format:

{*2 beds - same room*}:**300** XOR {*2 beds - same hotel*}:**200** XOR {*2 beds - different hotels*}:**50**

The complexity in bid formation may increase when a bidder aims to acquire a bundle where analogies between non-identical items exist. This is the case, for example, of a car manufacturer wishing to buy wheels, chassis and exhaust in an analogy of 4:1:1. The problem gets even more difficult when: (i) suppliers are able to provide substitutes or parts of a bundle, or (ii) one bids not only on bundles but also on item or bundle attributes. Extensive research has been recorded in the pursuit of a coherent and widely accepted way for bidders to express their bids, that is, in the standardization of a *bidding language*. Abrache et al., (2004a) propose and analyze a flexible bidding language easily customizable by the auctioneer that is independent of the physical nature and the divisibility of the items. Cavallo et al., (2005) also propose a bidding language called TBBL (Tree-Based Bidding Language) applying in combinatorial exchanges – a generalized combinatorial auction where multiple buyers and sellers are buying and selling simultaneously.

.2 The Winner Determination Problem (WDP)

The major problem an auctioneer faces is the decision making process for the *optimal* allocation of items to bidders, referred to as the Winner Determination Problem (WDP). Typically, this problem is *NP-complete* since the number of different combinations is extremely large; this means that there is no algorithm to determine an optimal solution in polynomial time as the computational complexity is very high. When items are *indivisible* and complementary, finding an optimal allocation using *complete algorithms* is extremely time consuming. On the other hand, approximate algorithms (such as *stochastic local search*) lead to sub-optimal solutions that cannot guarantee efficient allocation.

During the last decade numerous researchers focused on combinatorial auctions and WDP with a vast amount of contributing papers. (Fujishima et al., 1999) state that research efforts to reduce complexity may be classified in three categories: a. reducing degrees of freedom of bidding, b. transferring the problem to bidders, and c. applying trade-offs between solution optimality and computational time. They propose an exact (Combinatorial Auction Structured Search – CASS) and an approximate (Virtual Simultaneous Auction – VSA) solution algorithm. An illustrative method for reducing the degrees of freedom of bidding is the one proposed by Rothkopf et al., (1998) which determines specific allowable biddable combinations. Hoos and Boutilier (2000) propose a stochastic local search (SLS) algorithm to solve the WDP and present its properties. Extending the CASS algorithm to cover multi-unit combinatorial auctions, Leyton-Brown et al., (2000a) propose the "Combinatorial Auction Multi-Search - CAMUS" algorithm. An overview of earlier approaches (exhaustive enumeration, dynamic programming, heuristics, and combination elimination) and a new approach to the WDP can be found in Sandholm (2000a).

Other interesting approaches aiming to reduce complexity of the WDP, can be found in van Hoesel and Muller (2001) (branch-and-bound algorithms and relaxation to Linear Programming), Jones and Koehler (2002) (*Incompletely Specified Combinatorial Auction – ISCA*, that is, a semi-sealed mechanism allowing the bidder to submit rule-based bids), Tennenholtz (2002) (application of *b-matching* techniques) and Ono et al., (2003) (algorithm for combinatorial ascending auction that use previous valuations of bids). Case (2001) provided a comprehensive description of when and how the WDP can be reduced from an integer programming to a linear programming problem and Schrage (2000) presents the results of the use of Linear & Integer Programming (LP/IP) methods for the solution of complementary multi-object auction WDP in reasonable time.

Sandholm (2002) introduces a search algorithm for optimal winner determination, which allows CAs to scale up significantly by capitalizing on the fact that the space of bids is sparsely populated in practice. Sandholm and Suri (2003) proposed a search algorithm called "*Branch On Bids – BoB*" that reduces search tree size, uses faster data structures and optimizes at search nodes and they generalize their findings for the multi-unit CAs that support substitutability and complementarity between units and/or items. Mito and Fujita (2004) develop and examine three heuristic search (bid ordering) methods to find sub-optimal but good enough solutions of the WDP in sufficient time. Penn and Tennenholtz (2005) apply *b*-matching techniques to solve multi-object, multi-unit and combinatorial auctions.

Conitzer et al., (2004) show that the WDP is solvable in polynomial time with the use of a tree-like item graph structure. Later, Gottlob and Greco (2007) show that it is *NP-complete* to check whether a combinatorial auction has a structured item graph even with treewidth value of 3 and investigated the use of hypertree decomposition. The WDP in combinatorial auctions can also be formulated as a "*Knapsack Problem*". Kelly (2004, 2005) presents generic formulations and summarizes WDP approaches (including knapsack) for various auction types based on the number of different items, units and bundles (Table 2.6).

Good Types	**Units**	**Bundles**	**Common Names / Examples**	**WDP**
S	S	S	First Price	Find Max
S	M	S	Double Auctions, Single-Quantity Bids	Classic 0-1 KP, Subset-Sum if #Units analogue to Utility
S	M	M	Double Auctions, XOR Bids	Multiple-Choice Knapsack Problem (MCKP)
M	S	S	Combinatorial Auctions (CA)	Weighted Set Packing (WSP)
M	S	M	Single-Unit CA, XOR Bids	Reducible to WSP via "Dummy Goods"
M	M	S	Mullti-Unit CA, Single-Bundle Bids	Multi-Dimensional KP (MDKP)
M	M	M	Multi-Unit CA, XOR Bids	MDMCKP
Note: S: Single, M: Multiple, MU: Multi-Unit, KP: Knapsack Problem, MC: Multi-Choice, MD: multi-Dimensional				

Table 2.6: *WDP Formulation for Various Auction Types (Kelly, 2004)*

Nandy and Mahanti (2004) presented an alternative algorithm called the "*Iterative Threshold Search – ITS*-Hybrid" operating as an IDA* (*Iterative Deepening A**) and DFBB (*Depth First Branch and Bound*) when the heuristic is the upper or lower bound, respectively. An overview of computational problems and some complexity reduction techniques before, during and at the end of the auction process can be found in Pekec and Rothkopf (2006). Taming the complexity problem Parkes and Schoenebeck (2004) develop *anytime mechanisms* where the optimal solution is calculated in stage-based or time-based interruptions of the process. Another algorithm (*Branch-And-Price algorithm*) has been proposed by Günlük et al., (2005) that applies on auctions with *XOR-of-OR* bid structure. (Lahaie and Parkes, 2004) support that a good way to reduce complexity in combinatorial auctions is to use protocols which minimize the communication and information revelation requirements – for example, a protocol that requires from bidders to bid on as few bundles as possible. In their article, they examine the use of learning algorithms in the design of preference elicitation algorithms. Bai and Zhang (2005) develop a *BoB*-based algorithm for CAs with reserve price which works efficiently when number of bids is not too big.

Based on the fact that the decision of which combinations are biddable and what is the best bidding priority on combinations belongs mainly to bidders, Park and Rothkopf (2005) propose a mechanism where allowable combinations are defined by bidders. In this mechanism bidders first submit bids for single items and a prioritized list of combinations they wish to bid along. The auctioneer first solves a revenue maximization problems based on these single-item bids and then solves the revenue maximization problem taking into account individual bids and each bidder's first priority combinatorial bid. They claim that the mechanism is fair and effective because bidders consider the most economically-important combinations themselves.

More recently, Sandholm and Suri (2006) study simple and combinatorial auctions and examine how side constraints and non-price attributes (budget constraints, XOR-constraints and constraints on number of winners) burden the complexity of the WDP. In their recent research Alidaee et al., (2008) use *unconstrained quadratic binary program (xQx)* in *set packing problems* (SPP) like combinatorial auctions to efficiently model and quickly solve them. Finally, Yang et al. (2009) presented a novel algorithm which is based on *nagging*, a technique that parallelizes search algorithms to reduce significantly the solution time.

.3 Combinatorial Auction Mechanism Design

The ideal combinatorial auction mechanism has three fundamental features: (i) It has an efficient winner determination mechanism, (ii) the bid pricing mechanism is incentive compatible, and (iii) it provides a way to determine imputed prices (Xia et al., 2004). Many researchers focused on iterative mechanisms ensuring efficiency and effectiveness; An iterative combinatorial mechanism ("iBundle") has been developed by Parkes (1999) and Parkes and Ungar (2000a) which later evolved as "iBEA" (iBundle Extend & Adjust) (Parkes and Ungar, 2002). Another iterative mechanism frequently used is "iterative combinatorial auction"(Pekec and Rothkopf, 2003; Parkes 2006), where bidders submit multiple bids and before a new round begins, they readjust their bids based on information they acquire from the previous round.

Pikovsky et al., (2006) studied the economic behavior of iterative combinatorial auctions in terms of allocative efficiency and auctioneer's revenues. Avenali and Bassanini (2007) designed a multi-round first-price combinatorial auction mechanism operating on the basis of *dominant* (increasing revenue in each round) and *loll* (dominant but not winning) bids to keep the number of rounds low and avoid threshold problems, respectively. Many other variations of combinatorial auctions have been developed and used. Two of them are the "ascending package auctions" and "ascending proxy auctions" (Ausubel and Milgrom, 2006b). Another variation proposed by Land et al (2006) is the Progressive Adaptive User Selection Environment (PAUSE). Studying the PAUSE auction, Mendoza and Vidal (2007) propose a set of algorithms for bidders which maximize their utilities. Day and Raghavan (2008) propose a new combinatorial auction that utilizes attributes of both the PAUSE and clock-proxy auctions which reduce the complexity by reducing number of bundles for evaluation and provide an example application for transport lanes procurement.

A mechanism widely studied recently is the "*Vickrey-Clarkes-Grove (VCG)*" where bundles of items are determined via the demand bidders reveal during the auction process. Comparing experimentally the VCG to the Simultaneous Auction mechanism Morgan (2002) shows that they both yield almost equal revenue and efficiency. Comparing efficiency and revenue outcomes for different multi-unit auction formats and the VCG format when positive complementarities exist Albano et al., (2001) demonstrated that (i) efficiency is highest in the VCG format, followed by the ascending, sequential and simultaneous formats in that order, and (ii) the revenue is highest in the simultaneous format followed by the ascending and VCG formats in that order, while the behavior of sequential formats in that case varies.

Another widely used format is the "*Generalized Vickrey Auction* (GVA)" where the allocation chosen maximizes the sum of the declared valuations of the bidders, each bidder receives a monetary amount that equals the sum of the declared of all other bidders, and pays the auctioneer the sum of such valuations that would have been obtained if he had not participated in the auction (Lehmann et al., 2002).

Jones and Andrews (2006) use the Gibbs Sampling methodology (a straight-forward application of Markov Chain Monte Carlo methods) to extract a distribution of unit prices. Neumann et al., (2007) propose a new mechanism called *Pricing-Per-Column (PPC)* which reduces the computational complexity and provides solutions which are very close to efficient. Chakraborty et al., (2008) describe the case where bidders' valuations of bundles in a combinatorial auction are uncertain and they are changing dynamically during the auction evolution due to other bidders' signals. They propose an iterative combinatorial auction mechanism named *RevalSlot* applying in airport slots auctioning, that constitutes of two processes; first it accepts valuations from bidders for a specific slot size. These values are then pushed to an ascending proxy auction.

Most recently, in order to reduce the complexity in cases where items with different attributes are considered as substitutable, Őzer and Őzturan (2009) propose the assignment of such items into classes, so bidders submit combinatorial bids for classes instead of individual items. This new formulation is referred as *multi-unit nondiscriminatory combinatorial auction (MUNCA)* problem and they propose two heuristic algorithms. Vinyals et al., (2008) focus on practical application of a special form of combinatorial auctions the Mixed Multi-Unit Combinatorial Auction (MMUCA). This type allows a participant to simultaneously buy and sell items. Focusing on a special combinatorial auction format the "*matrix bid auction*" where bidders face constraints on what subsets of items they are allowed to bid, Goossens and Spieksma (2009) analyze bidding complexity and propose two branch-and-bound algorithms for the solution of the WDP.

As can be concluded from the previous discussion on combinatorial auctions, there exists a large number of variations thus rendering extremely difficult the task of developing a universal design framework; however, such a framework depicted in Figure 2.7 has been presented by Schwind (2005), who focuses on four major design phases which are summarized as: (i) *modeling of pre and post auction,* (ii) *design of the main auction,* (iii) *modeling of the auction flow control, and* (iv) *safeguarding legal, security and stability* of the auction.

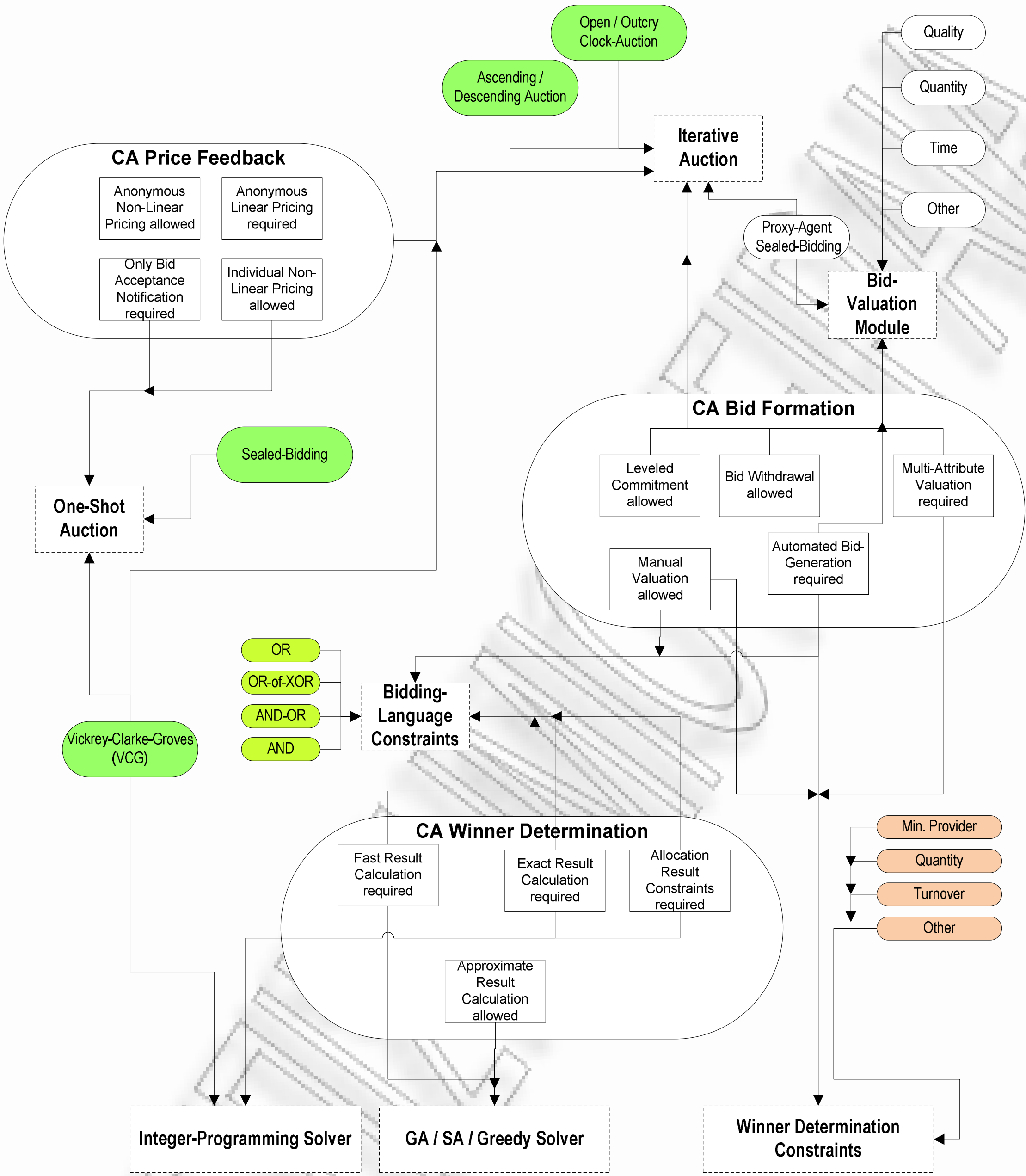

Figure 2.7: *Combinatorial Auctions Design Framework (Adaptation from Schwind, 2005)*

2.4.3 Reverse Auctions (RA)

Auctions also apply in procurement; here a buyer initiates an auction aiming to buy an item from one of several potential suppliers bidding on price (also called placing an "*offer*"). This case is defined as a "*Reverse Auction (RA)*" (or "*procurement auction*" or "*buy-side auction*"). In contrast to a forward auction, in RAs a buyer initiates the process and potential sellers compete to offer lower price. Actually this is the core difference between forward and reverse auctions, namely, price and role inversion; as a result, in reverse English auctions price decreases, while in reverse Dutch auctions price increases. When there exists only one buyer and many potential sellers, reverse auctions may be treated as a monopsony market. Nevertheless, despite these obvious analogies, auction theory aspects are not similar in general between direct auctions and RAs.

Any RA consists of some standard steps; a buyer specifies his exact needs, identifies and qualifies potential suppliers. During the auction process he monitors the bidding processes and after the auction closes, he usually signs a contract with the winning bidder(s). From a business application perspective a typical RA process cycle is outlined in Table 2.7 (Stein et al., 2003).

The Reverse Auction Process	
Step	**Activities**
Market Made	Make Market (Specifications)
	Identify Suppliers
Pre-Qualification	Pre-Award Review Contract/Schedule, Specifications, Ability to Deliver, Quality Assurance, Past Performance, Responsibilities, Set-Up Technical
	Approved Suppliers Listing
	Identify Specific Terms & Conditions
	Invite Suppliers
Pre-auction Planning	Set-Up Auction Create Auction Content, Set-Up Security, Register Bidders, Ensure Readiness, Contingency Planning
	Supplier Auction Strategy
Auction Activity	Conduct Auction Supplier Bid Real-Time, Buyers Monitor Auction, Winners Selected, Contingencies Ready
Post Auction	Contract Write-Up

Table 2.7: *Typical RA Process Cycle*

One RA format usually applied on large-scale projects is the *Unit-Price Contract (UPC auction*), where a buyer announces all inputs needed (although uncertain in terms of quantity) for the completion of a project, and suppliers (and subsidised weak suppliers) bid on each of the inputs (e.g., materials, labour, machinery etc.) (Ewerhart and Fieseler, 2003). A hybrid RA mechanism ("*sealed offer English*") combining attributes from English and sealed bid auction has been proposed by Bernard (2006).

In procurement processes buyers may set requests not only for single goods but for bundles and request combinatorial offers from potential suppliers. The overall performance of the RA depends more or less on a number of bundle-related parameters like item specification difficulty, complexity, and supply base availability which are studied by Schoenherr and Mabert (2008). Iyengar and Kumar (2008) examine the case where suppliers face production capacity constraints. Bajari et al., (2009) describe some shortcomings of reverse auction when applying in customized items (complex projects) with incomplete contractual design. They claim that for such cases negotiations are more preferable, while Huh and Roundy (2002, 2004) compare between first-price and second-price reverse auctions.

Suyama and Yokoo (2005) study the special case of a combinatorial multi-attribute reverse auction and propose the *Price-Oriented Rationing-Free* (PORF) protocol which is strategy-proof for sellers; that means that if each bidder expresses true valuation, then a dominant strategy exists no matter what other bidders do. Chen et al, (2005) propose a multi-attribute Vickrey-Clarke-Groves (VCG) - based mechanism to ensure incentive-compatibility and efficiency in multi-attribute combinatorial procurement auctions. Another hybrid mechanism for RA called *Vickrey-Dutch Auction* (VDA) when procurement items are multiple and complementary, has been proposed by Mishra and Veeramani (2007). A Data Envelopment Analysis -based approach on multi-attribute procurement auction mechanism design has been proposed by Bogetoft and Nielsen (2008) which evaluates non-realized multidimensional bids related to production and cost plans. Focusing on government procurement auctions De Silva et al., (2009) found that information revelation encourage new entrants to participate, stay active and survive in the auction process by flattening information asymmetries between them and existing incumbents.

2.4.4 Double Auctions (or "Two-sided" or "Exchanges")

Double auction is a typical case of a two-sided mechanism (or "bilateral trading") where many buyers and sellers simultaneously set bids and "asks", respectively. Research results for double auctions are relatively limited due to the difficulty in the modeling of both the buying and selling sections of a market, at the same time.

A technique often used to calculate the final allocation is to form demand and supply profiles (Feldman and Mehra, 1993) like "sell offers matching" (ascending order price) and "demand bids matching" (descending order bids). The simplest double auction mechanism is the *periodic (call market, clearing house)* where buyers and sellers submit asks and bids for a limited period. When time is up the auctioneer closes the auction and develops demand and supply curves to determine selling and buying item units for each price. This is followed by the "clearing" phase where buyers and sellers are matched and prices are defined. Prices may be the same (*uniform*) for all or different (*discriminatory*) for each participant. A more complex double mechanism format is the *continuous* (CDA) one where the auctioneer matches asks and bids immediately after a transaction or a specified period of inactivity. A typical application of a continuous double auction is the stock market. In an "oral" market, the problem gets even harder due to long duration. Rouchier and Robin (2006) examine the behavior of participants in CDA applying a combination of experimental economics and agent-based simulation.

An early, yet extensive and well structured experimental study of the double auction bidding strategy problem can be found in Rust et al., (1994). Bidding strategy and behavior in first-price sealed-bid double auctions with incomplete information, where the final price lies in a known range if mutually accepted prices exist, has been examined by Rapoport and Fuller (1995). Wurman et al., (1998) conducted a theoretical research of double auctions and proposed allocation algorithms for the case of periodic double mechanism. Gjerstad and Dickhaut (1998) studied issues on bidding behavior in continuous double auctions. A special double auction form is the k-double auction; it is a one-parameter set of rules for setting the price of trade between multiple buyers and sellers competing for a homogeneous item. The special case of sealed offer k-double auction where k is not fixed has been studied by Keller (2006). Bredin and Parkes (2005) propose a method for the design of truthful Double Auctions such that no participant can benefit from untruthful misreporting of arrival time, duration and value.

A comparison of some recently proposed double mechanisms (Trade Reduction Approach vs. Multi-Stage Reduction Approach) in terms of individual payoff, social efficiency and complexity has been performed by Chu and Shen (2007). Ma and Leung (2007) developed a new bidding strategy for continuous double auctions (CDA), namely the *Adaptive Attitude (AA)* strategy, that can be employed by software agents to submit bids and asks in a series of CDAs. Finally, Vytelingum et al., (2008) proposed a bidding strategy for CDAs which dynamically adapts aggressiveness based on short-term (immediately after each bid) and long-term (after the end of the transaction) observations.

Lately, research has been extended to include more complex cases, such as the combinatorial double auctions. The special case of mechanism design for conducting combinatorial auctions in exchanges has been studied by Parkes et al., (2002). Xia et al., (2005) examined the combinatorial double auction case and proposed a methodology to reduce it to a single-sided auction. The problem gets even more complex when auction items have many attributes and buyers and sellers submit multi-attribute bids. Fink et al., (2003) describe a solution approach for this problem using the used car exchange case. The winner determination problem in double auctions becomes extremely complex in the combinatorial case where complementarities between items exist, for example in securities trading. A winner determination algorithm for this case has been proposed by Schellhorn (2004). Ha et al., (2007) proposed a double auction protocol able to treat efficiently false bids (explained later herein) by giving disadvantage to false-name participants.

2.4.5 Special Auction Cases

This section presents special auction cases, which cannot be clearly classified in any of the formats presented up to this point. Janssen (2006) examined prices of items in the *after-market auctions* presuming that bidders are the winners of a special *pre-auction* setting. Jones et al., (2006) provided an extended analysis on a special mechanism, the *Name-your-own-price* which is similar to a request-for-proposal mechanism.

Che and Gale (1996) examined *all-pay auctions* (usually called "*charity* auctions") and found that they yield greater revenue than FPSB auctions when bidders are budget-constrained. In this model, consumers commit to prices for products or services with some uncertain attributes in exchange for possibly lower prices. The special case of all-pay auctions where a bidding company is interested on buying shares of a competing firm has been examined by Konrad (2006). An extensive general analysis on bidders' behaviour and auction revenue has been given by Noussair and Silver (2006) and an experimental study has been presented by Gneezy and Smorodinsky (2006). Finally, Cohen and Sela (2008) found that the outcome of all-pay auctions is larger when the number of prizes auctioned is greater than 1 due to enforcement of bidders' effort.

Maille and Tuffin (2004) compare Progressive Second Price (PSP) and multi-bid auction mechanisms used for telecommunication networks bandwidth allocation. In the former bidders submit their bids at different periods while in multi-bid auctions each bidder submits multiple bids once. Extending the usual single static case Perugini et al., (2005) examine the case of dynamic bidding in multiple simultaneous combinatorial auctions and study the *Provisional Agreement Protocol (PAP)* which supports bidders to participate interactively in multiple auctions at any stage, reducing bidding effort and complexity.

Ausubel and Milgrom (2002) and Ausubel and Milgrom (2006b) propose the "ascending proxy auction" that is a direct revelation mechanism better than VCG mechanism where bidders express their interest to a proxy bidder (electronic agent or the auctioneer) who then formats and submits bids on bidder's behalf. Ausubel et al., (2006) examined the "*clock-proxy*" auction, which is a hybrid type providing transparency, easiness and price discovering through a procedure consisting of an iterative "clock" phase and a final "proxy" round, stating its properties over the simple Vickrey auction.

When auctions are used to sell reservations (e.g., tickets, hotel rooms) winners (usually buyers) should be able to cancel their reservations getting a refund which normally is less than the winning bid. Huang and Matsubara (2007) propose *a refundable* auction based on a novel partially refundable mechanism named *Decreasing Cancellation Fee Auction (DCFA)* for advance reservation operations where winner's show-ups are uncertain and their personal information is unknown. Raviv and Virag (2009) examine a special "gambling" auction combining elements from an auction and a lottery applying either as auction or as a gambling game. Before the auction, the auctioneer announce the highest bid allowed, the maximum number of bids allowed and bid submission fee. When the auction ends, the winning bid is the highest unique bid.

2.5 Auction Mechanism Parameters – Impact on Bidders' Behavior and Auction Outcomes

Mechanism design has many research implications. Recent literature introduces complex auction mechanisms and studies the impact of new special parameters on auction results. In addition, during the design of an auction, an auctioneer has to make many decisions concerning the operation of the mechanism. A number of parameters affecting the mechanism operation are available and the auctioneer is free to select which one will be employed to improve outcome, efficiency and other auction attributes. The selection and formation of proper parameters is crucial for the overall auction operation; selection of improper parameters or unsuccessful usage may prove disastrous. Some important and widely-used auction parameters will be discussed in the next paragraphs, with their usage and impact on auction operation. It is important to state that all parameters must be known to bidders and must be binding for the auctioneer.

A number of the most representative parameters (starting price, reserve price, duration, number of bidders, reputation, item value, currency, category and bidder experience) and their effects on the price formation process (evolution and its first and second derivatives – velocity and acceleration) during auctions has been the subject of a work by Bapna et al., (2008a) based on samples from 1009 electronically conducted C2C auctions in the same day. These parameters and related published works are presented in the sequel. Reynolds et al., (2009) examine how some auctioneer-defined parameters (opening price, auction length and hidden reserve price) affect auction outcomes related to number of bids and item type.

2.5.1 Reserve Price and Buy Price

When a seller wants to avoid selling an item if all bidders' valuations are too low, then he may set a minimum price (*reserve price)*, which is binding for him to sell the item. If there is no bid higher than the reserve price, then he does not sell the item. If the reserve price is lower than the seller's valuation and winning bid lies between them, then the seller's revenue is reduced. Obviously, if a winner is willing to set an even higher bid, the reserve price has a negative result for the seller. Inversely, if a winner's bid is above reserve price and the second higher bid is below reserve price, then the reserve price yields a negative result for the winner and a positive result for the seller; therefore, deciding the reserve price level is very important.

For uniformly distributed bidders' valuations, the optimal reserve price is the average between the seller's valuation and the highest bidder's valuation. For the benchmark model, all four basic auction types are optimal when an optimal reserve price has been defined. In contrast to common-value auctions, optimal reserve price on private-value auctions depends on other parameters like auction type and number of bidders. Under IPVM assumptions, reserve price is independent of the number of bidders and higher than the seller's cost. For affiliated values, an increased number of bidders leads to more certain valuations and marginal revenues. In this case, the reserve price should be lower (McAfee and McMillan, 1987a). Klemperer (2002) stated that in an ascending auction, an insufficient reserve price may lead to collusion phenomena (collusion is explained later herein).

The reserve price definition is more complex when the winner has the opportunity to resell the item (Haile, 2000). After a seller defines the optimal reserve price, he has to decide about announcing or not the reserve price level. Vincent (1995) presents some positive results and proves that hiding the reserve price level, encourages bidders to participate. One may ask what happens when auction closes and reserve price is not reached. In this case, typically the seller reconsiders the reserve price and sells the item through a new auction, or bargains for the item with the higher bidder(s) (Menezes and Ryan, 2005). As a result, a reserve price may serve as a tool for a seller to communicate his private information about item's value to bidders (Cai et al., 2007a). Bichler and Kalagnanam (2006) proposed a new methodology for the definition of reserve-price based on buyer's risk statement; this approach applies in reverse multi-attribute auctions and enables the definition of differentiated reserve prices in buyer's requests for each negotiable attribute.

Sometimes a seller decides to set and announce a *buy price* at which a bidder may buy the item directly, at which point, the auction ends. Budish and Takeyama (2001) announced results for certain basic auction types subject to different bidders' risk attitudes and stated that the buy price reduces bidders' risk because of the announcement of a maximum winning price. As a result, English auction yields better results than FPSB and Dutch auctions when bidders are risk averse. Hidvegi et al., (2006) stated that a buy-price may apply as *permanent* (valid for the entire process), *temporary* (disappears when a new bid exceeds reserve price), or *limited* (valid for a short period) and examined the application of permanent buy-price in an English auction. Mathews and Katzman (2006) examine auction outcomes and buyer's risk when a temporary buyout (buy-now) price option is offered while Bose and Daripa (2009) present a two stage indirect mechanism based on a posted price stage and a subsequent (in case the good is not sold in the first stage) auction stage with a buy-now price.

Finally a seller may also apply a visible *starting price;* a low starting price may attract more bidders easily but the revenue may be less than expected. A high starting price may discourage potential bidders from participating so the item remains unsold. Yu et al., (2005) focus on the estimation of the optimal starting price in an auction

2.5.2 Participation Fees and Entry Cost

From a bidder's point of view, joining an auction incurs high cost consisting of bid preparation cost, communication expenses, travel expenses, participation fees, etc. (Stegeman, 1996). An extensive research on bid (offer) preparation costs as part of the total participation cost and bidders' attraction reimbursement strategies has been studied by Gal et al., (2007).

It is on the seller's benefit to incorporate a participation fee to the auction mechanism and each potential bidder has to pay this fee in order to participate; in this case, the seller wins the sum of fees paid. Obviously, a number of bidders whose valuations u_i are less than a *critical valuation* u_0, may abandon the auction thus decreasing the competition. In the extreme case that just one bidder remains with valuation $u_i > u_0$, but no bidder has placed a bid, the remaining bidder wins the item paying a price equal to the participation fee! To avoid this, a seller has to calculate both an optimal participation fee and an optimal reservation price.

As in the case of reserve price, participation fees are more preferable in common-value settings. Meyer (1993) empirically examines application of entry fees in a FPSB private-values setting. Bag (1997) examines parameters like e*ntry fees*, *reserve price* and discrimination among bidders in optimal mechanism design for procurement auctions when pre-bid cost-reducing investment is present. Similarly, Kjerstad and Vagstad (2000) study the impact of entry fees in procurement auctions and conclude that sellers (or procurers) should be cautious when trying to implement complex mechanisms. Ivanova-Stenzel and Salmon (2004) study impacts of participation fee as a function of the auction format. Hernando-Veciana (2006) shows that in certain cases the incorporation of entry fees may be sub-optimal because of heterogeneity in bidders' beliefs about the number of rivals, auctioneer's uncertainty about bidders' beliefs and the optimal entry fee. Matros and Zapechelnyuk (2008) examine seller's listing and closing fees in 2^{nd} price auctions where resale is possible.

2.5.3 Bid Increment

Another important auction parameter which applies mainly in open-cry auctions is bid increment. A predefined bid increment (e.g., minimum, integer, etc.) enhances mechanism robustness against collusion since bid announcement may serve as a "signalling" tool for colluding bidders (Klemperer, 2002). Several researchers study results from setting bid increment against a number of bidders, participants' attitudes mix and overall outcomes. (Bapna et al., 2001b) use simulation to analyse the impact of starting bid and bid increment in Yankee auctions. Bapna et al., (2001a), also distinguish between three types of bidders, namely, evaluators, participators and opportunists, according to their attitudes against minimum increment, and conclude that the bid increment (K) has high impact on total revenue (Table 2.8). (David et al., 2007) show that in a classic English auction type it is optimal to apply a decreasing bid increment.

Bidder Classification	Key characteristics	Classification by bid increment (K)		
		K=5	*K=10*	*K=20*
Evaluators	Early one-time high bidders who have a clear idea of their valuation Bids are, usually, significantly greater than the minimum required bid at that time Rare in traditional auction settings – high fixed cost of making a single bid Bounded rationality	59%	41%	23%
Participators	Derive some utility (incur a time cost) from the process of participating in the auction itself Make a low initial bid equal to the minimum required bid Progressively monitor the progress of the auction and make ascending bids never bidding higher than minimum required	21%	38%	50%
Opportunists	Bargain hunters Place minimum required bids just before the auction closes	20%	21%	27%

Table 2.8: *Bidders' Classification Aggregated by Bid Increment (Adapted from Bapna et al., 2001a)*

2.5.4 Auction Duration – Number of Rounds

The designer of an auction mechanism must define the way according to which the auction ends (*closing rule)*. This rule should be announced to bidders before the auction begins and is binding for the auctioneer. Typically a sealed-bid auction closes in a predefined time while open-cry auctions may close with one of the following rules:

- Going, going, gone: Auction ends when no new bids are submitted.
- Absolute time (hard-closing): Auction closes at a predefined date and time.
- Relative time (soft-closing): Auction ends after a predefined time without new bid submission.

Onur and Tomak (2006) analyze the impact of the ending rule to seller's revenues in C2C consumer e-auctions with the use of a new variable named *Winning Bid Ratio (WBR)*, defined as the ratio of the winning bid to the buy (or market) price of the item. They also demonstrate that a hard-closing rule has negative results to seller's revenue. An interesting comparison on bidding strategies adopted by bidders between hard and soft closing auctions has been presented by Duffy and Ünver (2008) using simulation. They also show that hard-close auctions yield lower revenue for the seller.

2.5.5 Number of Bidders

Although the number of bidders is not an endogenous parameter, it is affected by the characteristics of the auction mechanism. (Klemperer, 1999) has shown that for IPVM and the majority of auctions studied with CVM, an ascending auction without reserve price but with *N*+1 bidders is more profitable than any other mechanism with *N* bidders. When each bidder has partial information, then the information aggregate permits convergence between sales price and actual value; however, when information acquisition comprises additional cost to bidders and the number of bidders increases, the sale price does not converge to the true value. McAfee and McMillan (1987a) stated that when the number of bidders increases then second-higher bidder valuation increases on average. For an infinite number of bidders, price tends to maximum valuation. It has been proven that for the English auction without reserve price, a seller should invest on magnifying market rather than on acquiring information and designing an optimal mechanism (Bulow and Klemperer, 1996). This result extends to all auction types. Monderer and Tennenholtz (2000) study optimal mechanism design and conclude that seller's revenue approaches the theoretically calculated revenue when the number of bidders is very large.

An important question relates to the announcement or not of the number of bidders. When a mechanism does not provide information about the number of participants, bidders usually overestimate this number; moreover, their estimations are higher than seller's estimation. As a result and to the seller's advantage, bidders submit bids more aggressively. Ascending auctions often fail to increase the number of bidders because they allow some bidders (stronger or better-informed) to discourage others; furthermore, in CVM auctions with incomplete information, the *winner's curse* phenomenon is more likely to arise. In such a case, stronger bidders are more likely to win but the winning bid exceeds item's actual value (overpaying) (Klemperer, 2002). It is therefore on the seller's advantage to conceal the number of participants in ascending auctions. The same problem exists for other auction types, when participation costs and asymmetries are very high.

Sealed-bid auctions do not require bidder's presence, so bidders are not informed about the actual number of participants. To overcome this, an auctioneer may require *contingent bids* and bidders submit lists with different bids for different number of participants. In general, the publicity of an auction affects positively the attraction of more bidders, so an auctioneer should invest on this. When size asymmetries between bidders (e.g., different economies of scale or production capacity) exist, then increasing the number of bidders does not always yield better results (Elmaghraby, 2005b). Cremer et al., (2006, 2007) study the cost searching, contacting and providing prospective bidders with necessary information.

2.5.6 Royalties and Incentive Contracts

When an item's current value cannot be estimated and the winner's actual profit can be observed after the auction, a seller may use *royalties*, which are additional winner's payments to seller. These additional payments depend on the profit the winner has from the use of the item. Some examples are oil drilling rights and book publishing rights. Based on the *Linkage Principle*, a seller benefits using royalties to link the price a winner pays to the item's actual value (Milgrom, 1989). An auctioneer may incorporate royalties in an auction mechanism in many ways:

- By defining royalty rate and asking for bids
- By defining a fixed payment and asking for bids on royalties
- By asking for simultaneous bids on fixed payment and royalties.

The fact that the winner may dynamically distort any royalty-determining variable is of great interest. For example, a book publisher may alter book sales using advertising media, and a manufacturing firm may alter daily capacity. When a royalty rate is high, winner's effort and income after the auction may decline and seller's revenue may decrease (*moral hazard)*; therefore, setting the proper royalty rate is crucial for seller. Moreover, payments to the seller depend not only on information after the auction but on the winner's behaviour too. Giebe and Wolfstetter (2008) examine the use of royalty contract auctions where losers are granted to sign a contract too, in a license auction.In the case of procurement auctions, a seller may alter payments based on the costs the winner undertakes in order to fulfil his commitments against the seller, who may use an *incentive contract*. An early analysis on the auctions of incentive contracts has been presented by Laffont and Tirole (1987).

2.5.7 Other Auction Parameters

Several other parameters are available to the auction designer in order to enhance the auction mechanism, the most common of which are discussed in the sequel.

.1 Subsidizing

When the magnitude of asymmetries between bidders is large, a seller may use techniques to flatten these asymmetries and increase competition. A commonly used technique is *subsidizing* (e.g., as a percentage of bid) of weaker bidders (Cramton, 1998) showing *favoritism* to them. An extended analysis of favoritism (which may also have a negative impact) along with some results extracted from the case of public road construction project can be found in Marion (2007). An efficient way to perceive the breadth of asymmetry is to gather bidders' comments.

.2 Competition-strengthening Parameters

To increase competition, a number of techniques are available to the auctioneer. Some of them are: getting payments from losers, re-entry possibility, increasing the number of bidding rounds, restrict bid-setting duration, information revelation policy, allowing simultaneous submission of two bids where the winner pays his lowest bid if this is higher than the highest bid submitted by opponents (Ivanova-Stenzel and Sonsino., 2004), etc.

.3 Resale Opportunity

Classic auction theory assumes that transactions between bidders are not allowed when an auction ends. Nevertheless, Zheng (2000, 2002) proposed an optimal mechanism when *resale* is unavoidable, that applies under strict limitations. Haile (2003) provided an extended analysis on auctions with resale opportunities where the winner of the primary auction becomes the seller in a secondary auction market.

.4 Bidders' Eligibility Check

Usually it is on the seller's discretion to set participation criteria so that only eligible bidders join the auction. This is very useful when one wishes to exclude uninterested or untrustworthy bidders. A common technique is to compel potential eligible bidders to pay a deposit before the auction begins, or to impose penalties to insolvent bidders. A mechanism may check for bid eligibility during the auction process and accept or reject a participant.

.5 Bidders' Identity Revelation

It may be on the bidders' interest to be informed about rivals' identities before they join an auction and to decide participation or not depending on this information. It is up to the seller to evaluate this interest and decide whether to announce participants' identities or not. Even if identities are not announced before an auction begins, they may be announced during the bidding process which is also important. In an extensive research on externalities between bidders, Varma (2002) proved that a seller may improve mechanism efficiency by setting and applying a bidder's identity revelation policy.

.6 Winning Bid Announcement

Future bidding behaviour depends heavily on quantitative information feedback (such as the winning price) a bidder obtains after winning or losing an auction. To study this behaviour (Neugebauer and Selten, 2006) experimentally investigated the results of a FPSB auction applying Learning Direction Theory.

.7 Pre-auctioning

Kagel et al., (2008) examine the case of indicative (non-binding) bidding as a pre-auction process to establish a short-list of bidders, which is applicable when auctioned items have a very high value. Pre-auction selling mechanisms are useful when they focus to the "top" potential bidders in terms of valuation, avoiding potential misallocation through the auction, as demonstrated by (Kirkegaard and Overgaard, 2008) who also examine pre-auction results for the cases of first- and second price auctions.

.8 Re-entry

When re-entry is permitted, bidders may re-evaluate their bids and reenter at will. For example, a weak bidder may observe and get signals from strong bidders' behavior and decide to re-enter at a specific time; on the other hand, strong bidders are able to estimate weak bidders' behavior. The case of re-entry possibility in English auctions has been examined by Izmalkov (2003).

2.6 Vulnerabilities and Security of Auction Mechanisms

Security is a critical characteristic of any auction mechanism. An auction mechanism must be durable and secure against fraud. Either auctioneer or bidders may manipulate an auction to their advantage. Different auction types have native characteristics allowing occurrence of fraud phenomena. From the beginning, an auctioneer is able to influence information asymmetry to maximize earnings. A crucial question deals with how rigour an auctioneer should be against bidders' fraud. Amongst pure auction types, sealed-bid auctions are in general easily manipulated by sellers while open auctions are easily manipulated by bidders. In the sequel, threats, results, and some prevention techniques are discussed.

.1 Collusion (Ring Formation)

Collusion (or "ring formation") between bidders is "a subset of the set of bidders that agreed to submit only one essential bid, namely the bid of the designated winner" (Guth and Peleg, 1996). During the original auction, the designated winner sets bids without getting compensation from the other bidders. After the original auction ends, the designated winner sets the item in a new auction where participants are cartel members and usually the winner is the bidder having the second highest valuation in the original auction. An early analysis of bidders' collusion behaviour and results in single auction settings has been provided by McAfee and McMillan (1992) while Aoyagi (2003, 2007) studied the dynamic case of collusion in repetitive auctions with a coordinator and with communication before the auction, respectively.

Efficiency of collusion depends heavily on the auction type (first vs. second price) and the structure of the ring (control on bid coordination vs. control on bid submission) (Marshall and Marx, 2007); in general, first-price auctions are more durable against collusion. There exist cases where bidders collude to penalize an opponent; remarkably, this case may rise price and increase seller's earnings. Tan and Yilankaya (2007) show that standard efficient cartel mechanisms (e.g., pre-auction knockouts) are not ratifiable by cartel members in 2nd price auctions with participation costs.

Laffont and Tirole (1991) studied collusion between the auction designer (not auctioneer) and bidders (mom-fair favoritism). In other cases, the collusion may be organized and coordinated by a third party via a side contract with colluding bidders (Dequiedt, 2007). Skrzypacz and Hopenhayn (2004) examine the case where cartel members participate in sequences of auctions, have no communication and the only information they have is the identities of winners in previous auctions. They show that this form of collusion may yield some profit to the cartel but it cannot extract full surplus.

Basic auction types may be ranked according to vulnerability in collusion starting from weaker: English, uniform second-price, discriminatory first-price and Dutch auction (Feldman and Mehra, 1993). Obviously, colluded bidders prefer the English type because they are able to observe and control ring members.

While in second-price auctions a ring is always stable, this is not generally the case in first-price auctions. Indeed, in second-price auctions, the designated bidder may set a very high bid and remaining bidders set zero bids so the collusion is self-enforced (Wolfstetter, 1996). On the other hand, in first-price and Dutch auctions any ring member may set a bid slightly higher than the designated winner's bid. In most cases, colluding bidders restrain other bidders from participating, in order to diminish competition and avoid development of competitive rings. A repeated auction in general becomes weak against collusion because ring members enforce their signalling techniques.

Ring members usually define the designated winner via a pre-auction and the designated winner is obliged to make side payments to the other ring members. The sum of these side payments is typically equal to the difference between the main auction winning price and the pre-auction's second highest price. The winner's payoff is then equal to the payoff that would have been obtained via an English auction without collusion. In other cases, an interested winning bidder pays rivals to resign (*bribing*) with an amount defined either by the interested bidder or by rivals (Eso and Schummer, 2004). The case of collusion in repeated first-price reverse auctions has been studied by Blume and Heidhues (2006). Bajari and Summers (2002) examine techniques for early detection of collusive behavior in reverse auctions. Conti and Naldi (2008) use average bid approaches to support the detection of extremely low bids ("*abnormal*" or "*anomalous*" bids) in procurement auctions. Che and Kim (2008) analyze collusion behavior and its treatment when bidders have different incentives and beliefs for participation in collusive rings making them to retire from the collusion ring.

Importantly, collusion is completely different from "joint bidding" (Hendricks and Porter, 1992), which allows bidding companies to pool resources and is encouraged or allowed when the auction items comprise large capital investments like oil drilling leases.

.2 Shill Bidding

A native problem of open-cry auctions is that bidders are able to distort the outcome via *shill bidding* aiming to acquire the item or simply aiming to punish the seller or the bidder. Sealed-bid auctions suffer from shill bidding too, but the shill bidder is the seller, when he is able to learn bidders and their bids. To avoid this, Vickrey (1961) proposed the use of a reliable intermediate (*public market agency)* responsible to collect bids and unveil them to winner.

.3 Late Bidding ("Snipping")

A long-lasting auction may give the opportunity to a bidder to set a bid a few moments before it closes (*sniping or late bidding)*. In that case, remaining bidders may not have the time to react. Auction prolongation is an effective technique to tackle this problem (Ockenfels and Roth, 2006). Hou (2007) experimentally found that late bidding results in a lower winning price (in forward auctions).

.4 Bid Retracting and Jump Bidding ("Shielding")

When a second-price auction allows *bid retracting*, two bidders may collude and apply *bid shielding*; the first bidder sets a very low bid and the second bidder sets an extremely high bid (*jump bidding*) aiming to discourage other bidders and force them to retire. Then the second bidder retracts his bid and the first bidder wins the auction with a very low bid. A common technique to hinder bid retraction is the application of a penalty. Avery (1998), Dodonova and Khoroshilov (2006) and Isaac et al., (2007) have all dealt with jump bidding.

.5 Signaling

Pure open-cry auctions allow *signalling* between bidders; for example, bidders use bid type attributes (such as one or two bid digits or decimals) to exchange information during auction (*code bidding)*. Signalling may be restricted to a certain extent by applying counter measures such as standard bid increment.

.6 False-name Bidding

When the auctioneer is unable to check bidders' individuality and physical existence, then any bidder is able to bid using multiple identities thus altering auction results (*false name bidding)*. This phenomenon is more common in auctions conducted over the Internet. Yokoo et al. (2001) propose a combinatorial auction protocol against false-name bids which supports bidding rationality and incentive compatibility.

.7 Cheating

A common vulnerability of all sealed-bid auctions occurs when sellers or bidders are able to *cheat*. An extensive study on cheating in auctions and corresponding loss of revenue is presented by Porter and Shoham, (2005).

.8 Untrustworthiness

In many cases, auction participants fail to carry out their obligations in terms of quality, quantity or time or they are not able to provide the item at all (*untrustworthy participants)*. Braynov and Sandholm (2003) examine the design of reverse multi-dimensional auctions with a trustworthy buyer and sellers with different levels of trustworthiness.

.9 Corruption

Corruption is another factor of vulnerability in any auction mechanism. (Menezes and Monteiro, 2006) examine the case where a seller or - more likely - an auctioneer may give a bribe to the highest bidder in order to persuade him to reduce him bid near the second-best price. They also study corruption and bribe formation in first-price auctions. Parkes and Ungar (2000b) showed that iterative mechanisms are not robust to manipulation and proposed a methodology ("proxy agents and price-adjustment") which prevents manipulation. In other cases, in a first-price auction the auctioneer may solicit bribes from potential bidders agreeing to pay the second winning bid (Koc and Neilson, 2008). McAdams and Schwarz (2007) analyse corruption problems and claim that a trustworthy auctioneer with proven reputation is able to safeguard the auction process from cheating. Finally, a technique to avoid manipulation by seller in a Vickrey auction has been proposed quite early by Miyake (1996).

.10 Other Vulnerabilities

Multi-round auctions show some special forms of vulnerability: stronger bidders may easily recognize weak bidders after a number of rounds, so it is advisable to reveal bidders identities; late bidding is a common problem so it is more preferred to ask for sealed-bid in each round. To ensure that bidders are reliable and they have consistent behavior, an auctioneer may ask for "*eligibility*" of bidders; to be eligible, bidders should pay a deposit and declare the items they are interested on. In case an eligible bidder submits a bid for a not pre-declared item, the bid is rejected. On the other side, bidders may acquire bundles of items not interested on and face the "*exposure problem*". Sadeghi et al., (2002) propose a secure protocol for the multi-item multi-round auction case based on a sealed-bid mechanism.

Vickrey auctions suffer from two security-related problems: the auctioneer may reveal one's bid to opponents and also may use bid information to seller's advantage prior to auction end. Many researchers proposed special cryptographic Vickrey auction (CVA) protocols to secure Vickrey auctions. An extended review on previous research and two new protocols can be found in Bradford et al., (2008).

2.7 Applications

It is obvious from the above that auctions are a commonly accepted market institution over the years, for trading of a wide range of products and services whose value is uncertain or variable. The range of applications is very wide and includes industrial procurement, logistics services, art masterpieces, collectibles, electricity, network markets, initial public offerings, natural resources, radio spectrum licences, livestock, construction projects, government projects and procurement and many others. Depending on parameters like trading item's characteristics, market size, bidders' characteristics, scope of trade and many others, a number of auction types, formats and attributes as previously discussed, are available aiming to support the trading process in an efficient and effective way for all participants.

Major applications found in recent (last decade) literature are listed in Table 2.9 accompanied by a short description. It is important to state that a wide and emerging range of applications of electronic auctions related to Logistics markets and services is excluded from this chapter and are presented separately; auctions that are carried out in an electronic environment will be presented and further analysed in next sections of the present chapter.

Application	Reference	Notes
Medical	Macie (1983)	Application as a curative game in geriatric programs
Government projects	Ashenfelter and Genesove (1992)	Application of auctions for selling condominiums in US was not successful as a result of winner's curse phenomenon
Financial Services (Stock Exchange)	Domowitz and Wang, (1994)	Analysis of continuous double auction and periodic single-price auction
Oil companies	Hallwood, (1996)	Special type of auction, the so-called "invited tender-bid" that has been used by oil companies to procure intermediate goods and services
Communications	Ausubel et al., (1997)	Federal Communication Commission (FCC) auctions of personal communication services Examination of local geographic synergies (complementarities)
Homogeneous Security, Government Bond, Emissions Permit, Company's Share Stock	Ausubel and Cramton (1998)	Comparison between discriminatory and uniform price auction
Education	Brozik and Zapalska (2000)	Procurement via an auction as part of a business management simulation game
Education	Goldfarb (2000)	Methodology for teaching students in

		auction disciplines
Labor market	Julien et al. (2000)	Job candidates auction their labor services to employers Matching under capacity constraints
Electricity market	Oren (2001)	Auction design for ancillary services procurement
Rail networks	Parkes and Ungar (2001)	Use of multiple simultaneous auctions to allocate pairs of entry and exit times for train scheduling. Each train company bid for the right to use specific railways to complete its journey from its origin to its destination in specific timeframes
Emission permits, securities and import quotas	Sunnevag (2001)	Theoretic overview of multi-unit auctions and application in emission permits, securities and import quotas.
Electricity generation capacity Greenhouse gas emissions Initial Public Offering (IPO)	Ausubel (2002a)	Study of new developments in market design
IPO	Ausubel, (2002b)	Using auctions instead of the corruptible book-building procedure
Computing services	Cooper and Garcia-Molina (2002)	Proposition of *bid trading*, a double mechanism aiming to help web-sites to buy and sell digital archive storage space.
Electricity market	Cramton (2002)	Analysis of market design issues focusing on deregulating markets
Electricity market	Thomas et al,. (2002)	Experimental analysis of power markets
Rail networks	Affuso (2003)	Checking feasibility of auctions for capacity allocation of train paths
IPO	Biais and Faugeron-Crouzet, (2003)	Comparison between book-building and auctions
Stock (IPO) auction	Chen et al., (2003)	Auction theory aspects testing
Network industries	McDaniel (2003)	Analysis of the reasons why classical auction outcomes and benefits (winner is the bidder with highest valuation and revenue is maximized for the auctioneer) do not apply in auctioning access to network services (electricity, telecoms etc.). A brief description of the key characteristics of network industries is also provided.
Electricity and gas networks	Newbery (2003)	Extensive analysis on network capacity auctions focusing on electricity and gas networks
Mobile communication capacity - congestion	Ng et al., (2003)	Auction mechanism for dynamic resource allocation
Electricity market	Oren and Ross (2003)	Bidders' manipulation avoidance strategy
Allocation of emission permits	Sunnevag (2003)	Application of ascending-clock and Vickrey "share" auction formats for the allocation of emission permits
Marketing	Wood and Suter (2004)	Use of auctions for student education in Marketing mix discipline
Computing services	Bhargava and Sundaresan (2004)	Preliminary research Use of contingent auctions – simulation and analysis
Deregulation / Privatization	Cantillon and Pesendorfer, (2004)	Application of multi-unit auctions to award contracts of bus routes via combinatorial bids
Electricity market	Deng et al., (2004)	Study of point-to-point congestion revenue rights (Financial Transmission Rights – FTRs)
Logistics Supply Chain formation	Babaioff and Walsh (2005)	Coordination of buying and selling goods in multiple markets using combinatorial auctions
Project management	Elfving et al., (2005)	application of auctions in large construction projects result in rework and cost increase, reduction of cooperation

Spectrum license auctions	Morris, (2005)	Efficiency analysis
Two-sided market (Meal voucher services)	Roson (2005)	Application of auctions in a two sided-market (meal voucher services) (other two-sided markets: intermediation services, media, publishing software, internet search engines etc.)
Computing services	Schnizler et al., (2005)	Application of multi-attribute combinatorial auctions to trade Grid computing services
Education	Shubik (2005)	Application of a simultaneous double auction mechanism to teach students how to construct process models of economic phenomena.
Financial Services (Stock Exchange)	Comerton-Forde and Rydge, (2006)	Analysis on special form of Double Auctions ("Call auctions") at the close of the markets
Electronics industry	Elmaghraby and Oh, (2006)	Procurement auction in the presence of learning by doing
Electricity markets	Oh and Thomas (2006)	Bidding model for electricity auctions where demand is categorized in one group that highly values reliability and one group that does not
Communications (UMTS)	Scandizzo and Ventura (2006)	Empirical investigation in UMTS auctions in Italy
Power systems reserve	Swider and Weber (2007)	Bidding strategy in multi-unit procurement auction
Electricity markets	Crawford et al., (2007)	Introduction of Bid Function Equilibria multi-auction model for electricity markets
Communication networks Network bandwidth allocation	Dramitinos et al., (2007)	Application of multi-unit Dutch auctions
Electricity market	Zhang et al., (2007)	Study of electricity generators' (bidders) behavior in electricity auction (New York Independent System Operator – NYISO)
Electricity market	Aparicio et al., (2008)	Analysis of producers' (bidders) behavior
Spectrum license auctions	Cramton et al., (2008)	Impact of telecommunication incumbent's simultaneous participation in one auction for non-incumbents only closed and one auction for all carriers
Spectrum license auctions	Gandhi et al., (2008)	Dynamic real-time auction
Communications (UMTS)	Gebhardt and Wambach, (2008)	Proposition of two auction formats (jumping English and multi-unit)
Mobile telecommunications	Mackley (2008)	Review on winner's curse problem and a search on possible appearance on European 3G mobile telecommunication auction
Government projects	Ubbels and Verhoef, (2008)	Private road building Auction design
Computing services	Schnizler et al., (2008)	Application of multi-attribute combinatorial auctions to trade Grid computing services
Company takeover	Eckbo (2009)	Empirical research on corporate takeover auction
Electricity markets	Genc (2009)	Comparison of results between uniform price and discriminatory electricity auctions when bidders face capacity constraints.
Cattle auctions	Zulehner (2009)	Analysis of bidder's behavior in sequential cattle auctions

Table 2.9: *Literature Sources for Applications of Auctions*

2.8 Electronic Auctions

2.8.1 Introduction

Electronic auctions (e-auctions) have emerged during the last two decades primarily due to the technological advances related to ICT. They not only contain all types, forms and characteristics of traditional, physical auctions but they also possess additional attributes, properties, characteristics and functionalities enabled from the environment they operate. Fogelgren-Pedersen et al., (2002) distinguish between three e-auction forms, namely: (i) e-auctions that can be conducted over Internet or offline with digital or analogue result format (e.g., fax page), (ii) *Digital auctions* as a subset of e-auctions where the outcome is always digital (e.g., pdf document), and (iii) *Internet auctions* as a subset of digital auctions conducted only over the Internet. The term "e-auction" will be employed inclusively herein to host the terms "*digital auction*", "*online auction*", "*Internet auction*" and "*web (or WWW) auction*"; wherever necessary, the exact term will be used.

In their general form, e-auctions require fewer intermediaries than traditional auctions. The core intermediary in any type of e-auction is the auctioneer who promotes the auctions, provides the communication platform between suppliers and buyers, transforms bids to transactions, supports market liquidity, allocates connections for value-adding services and ensures fair and unprejudiced evolution of the process. In addition, the auctioneer gathers, organizes and evaluates information which is dispersed to participants and decides on the price of the item and the final allocation based on bids. The role of the auctioneer is thus central in the operation of an e-auction. Same as with traditional auctions, e-auctions also entail two more types of participants, namely, the auction initiator (seller or buyer for the forward and reverse auction respectively) and the bidder, who rely on the (e-) auctioneer, to interact over the Internet and carry out C2C, B2C and B2B commercial transactions.

In the course of time, many services and tools have been developed to support and automate the overall e-auction process and to safeguard the trade. These services are typically provided by third party service providers, software providers, application services providers (ASP's), or the auctioneer himself. A delegation of some of the most representative such services is shown in Table 2.10. The context of applications where e-auctions are encountered falls within the following three categories as specified by Bapna et al., (2001a): (i) Business-to-Consumer (B2C) where participants are early trend setters, want to clear excess, aging or perishable inventory, the equilibrium is consumer-driven and defined by demand-price, (ii) Consumer-to-Consumer (C2C) operating as secondary flea markets with community centric highly sophisticated architecture and, (iii) Business-to-Business (B2B) supporting mainly transactions related to supply chain operations such as efficient procurement through multi-criteria evaluation and global coverage.

E-auctions and their applications have attracted the interest of several researchers. Beam and Segev (1998) performed an early research on B2C and C2C auctions, on a sample of over 100 auction web-sites and analyzed issues related to participants, transaction types, trading items and auction mechanisms. Quite at the same time, Lucking-Reiley (1999) surveyed more than 140 auction web-sites focusing on mechanisms, cost, participation, and market size issues; not surprisingly, he predicted that "*in the near future, e-auctioning of services will increase dramatically*". Herschlag and Zwick (2002) processed about 700 articles on e-auctions in popular and business (not scientific) literature between 1996 and 1999, focusing on time (real-time, duration), bid types (sealed, open-cry), bid modification rate (seller or buyer driven), bid evolution (increasing or decreasing), relation between bid and cost, negotiation parameters (price only, quality, times), etc. An overview and a brief history of e-auctions can be found in (Wurman, 2004). Dholakia (2005) commented on recent research on e-auctions from an e-marketing perspective. A most recent literature review of that kind was provided by Wood (2006).

Service / Tool	Usage	Provider	User	Example
Search tools	Locate auction web sites and items	ASP	Bidders	Online Auctions Network – (online-auction.net) Internet Auction List (internetauctionlist.com) Yahoo-auctions.yahoo.com Bidder's Edge (biddersedge.com) Turbobid (etusa.com)
Alerting and notification services	Alert bidder about auction evolution	ASP, S/W	Bidder	Auction Watch, auctionservices.com
Certification	Certify and check eligibility	ASP	Bidder, Initiator	BidSafe-auctions.com
Advertisement	Auction site advertisement	ASP	Auctioneer	illumix.com, auctionwizard.com
Bid evaluation and comparison tools	Bid evaluation, winner determination for complex auction mechanisms, comparison with bid in other auction sites	S/W	Auctioneer, Initiator	BidFind.com, freemerchand, AuctionWatch.com
Monitoring	Simultaneous monitoring of many auction sites	S/W, ASP	Bidder	BidMonitor (brucelay.com), EasyScreenLayout (auctionbroker.com)
Sniping	Automated bidding in soft-closing auctions	S/W, ASP	Bidder	
Proxy bidding	Automated bidding on behalf of bidder	S/W, ASP	Bidder	
Communication tools	Mailing lists, message boards, chat groups etc.	S/W, ASP	Bidder	
Billing and payment collection services		ASP	Bidder, Initiator, Auctioneer	PayBWeb.com, PayPal, BidPay.com
Escrow services		ASP, Physical service provider	Bidder, Initiator	tradeenable.com, guzooescrow.com, escrow.com
Credit card payment services		ASP	All participants	billpoint.com, CcNow.com
Carrier and postal services		Physical service provider	Bidder, Initiator	iship.com, auctionship.com, stamps.com (USPS)

Table 2.10: *Support Services and Intermediaries for e-auctions*

Reasons for using e-auctions and analysis of the research work concerning the design parameters and relevant outcomes of e-auctions (with a primary focus on the B2C case) can be found in Pinker et al., (2003). In the same context, Sashi and O'Leary, (2002) investigated the impact and usability of e-auctions for B2B transactions while Dans (2002) demonstrated that the English format is by far the most-commonly used in e-auctions for all market dimensions (B2C, B2B and C2C). Parente et al., (2004) acknowledged the limited empirical research in B2B e-auctions and proposed a conceptual framework for the analysis of e-auctions based on systems theory; they used this framework to obtain answers in basic questions that arise when forming an e-auction setting. Finally, Dixit et al., (2008) presented a taxonomy scheme of Internet-based pricing strategies describing amongst other the properties of e-auctions.

A summary of major benefits and risks from the application of e-auctions in B2B transactions are shown in Table 2.11 (Ku and Malhotra, 2001; (Sashi and O'Leary,2002; Halstead and Becherer, 2003).

Advantages	**Disadvantages / Risks**
Market enlargement	Increase of competition
Global coverage – no time zone restrictions	No face-to-face contact
Inventory reduction	Possibility of shortage
Reduced transaction costs	Intermediary fees
Cost savings	Unknown supplier
Market for 2nd hand products - liquidation	No middleman
Efficient pricing	Lower profits
Lower risk of collusion	Requirement for prequalification
Real-time transaction	New forms of vulnerabilities
Quick transactions	Transaction security
Easiness	IT/IS compatibility
Price testing	Hard to physically inspect items
Interactivity	Delay due to unicast instead of multicast
No need for physical presence	
Disintermediation	
Complement traditional store	
24-hour operation	
Asynchronous operation	
Collaboration	
Development of communities	
Reduced search costs	

Table 2.11: *Advantages and Risks of B2B e-auctions*

Even from the early '00s numerous e-marketplaces facilitated e-auctions; thus, participants have to decide on the selection of an e-auction marketplace. Walczak et al., (2006) analyzed the factors affecting sellers' decisions related and employed a model to classify these factors as follows; (i) Personal (ease of use/learning, fun, convenience), (ii) Social (community, market/customer type), (iii) Economic (market/customer type, bid amount, cost of listing and conversion, traffic), and (iv) Reputation (name recognition, trust, reputation, security, integrity/responsiveness). Later, Ho (2008) proposed a methodology to extract brand-specific visual statistics from a C2C auction web site assisting the buyer, the seller and the auctioneer to make decisions related to *where to search*, *where to sell* and *how to promote*, respectively. Their methodology was based on a topological model which acknowledges a wide range of operational parameters, such as, gross activity, net activity, participation, seller diversity, seller experience, buyer diversity, buyer experience, matching, dueling, stashing, sniping, retailing and proxy bidding (which will be discussed later herein). The selection of an e-auction marketplace is largely dependent on the participants' prior experience and cognitive beliefs. Yen and Lu (2008) studied empirically buyers' repurchase intentions and their determinants applying the *Expectancy Disconfirmation Theory (EDT).*

2.8.2 Organizational Issues

In most cases e-auctions are integrated within electronic marketplaces (*e-marketplaces*) which are Internet-based information technology applications that bring together buyers, sellers, value-adding service providers and other participants. Besides a well-structured auction mechanism, any e-auction marketplace should be equally well-designed and comprehensive from a user perspective. Technology and infrastructure largely affect the design and development of an e-auction setting and require special attention when examining e-auctions. Kumar and Feldman (1998) were among the first to investigate issues concerning mechanisms, security requirements and transactions during all stages of e-auctions, proposed a generic auction development architecture which may be integrated with ERP systems and defined the most common functional requirements for any e-auction setting, which are:

- Registration: Certification and identification of participants
- Setup: Description of items and auction rules (auction type, begin and end time, negotiation parameters, closing rules, etc.)
- Publicity: Advertisement, definition of items mix (e.g., low and high value items)
- Bidding: Rule keeping, bidders' notification
- Bid evaluation and closing: application of closing rule, item allocation, notification etc.
- Settlement: billing, item dispatching, payment, collections etc.

A generic workflow of the evolution of a simple e-auction is depicted in Figure 2.8.

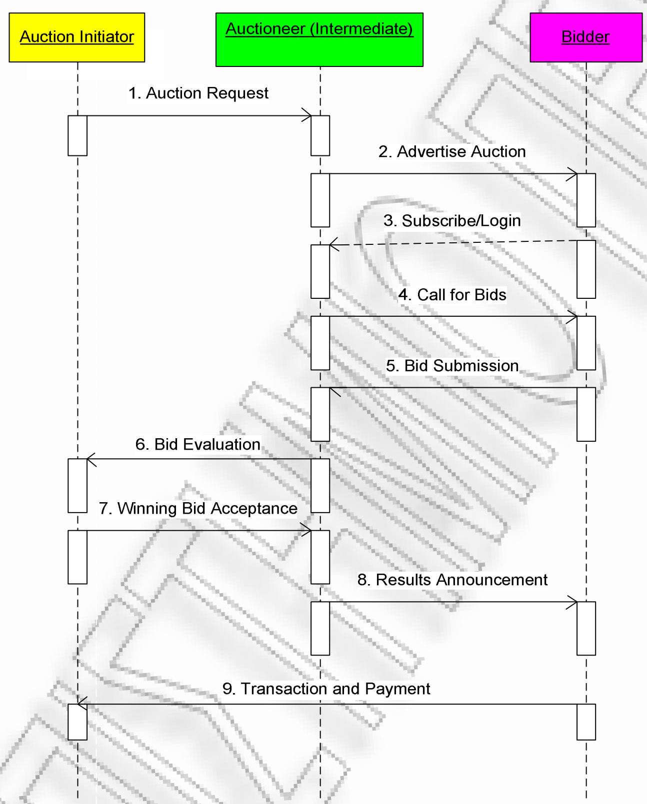

Figure 2.8: *A Typical e-auction Workflow*

Rolli and Eberhart (2005) proposed a participant-centered e-auction model (*Auction Reference Model – ARM*) on the basis of participants' intentions, offering for the description and implementation of e-auctions. Fasli and Michalakopoulos (2005, 2008) underlined the need for the design and development of auction simulators and developed a generic auction simulator (*Generic Auction Platform Supporting Customizable Market Games – "e-Game"*) which supports parameterisation, development and operation of auction-based market games.

Rumpe and Wimmel (2001) presented the architecture of an e-auction system and described in detail some technical (security, performance, robustness and compatibility-related) and functional requirements. Ezhilchelvan and Morgan (2001) designed a scalable decentralized auction service implemented in geographically dispersed servers satisfying the requirements of reliability and fairness between bidders in terms of chance of bid submission. In an attempt to alleviate the problems associated with network delay and servers overload Hillston and Kloul (2001) proposed the transferring of computing tasks from one server to a structured set of *active* nodes responsible not only for routing but also for bid checking, storage of recent bids, price information etc. Sheldon et al., (2002) presented an e-auction development methodology based on the combined use of *Unified Modeling Language (UML)* and *Object-Oriented Analysis and Design (OOAD).* The proposed model satisfies the essential e-auction site requirements of easiness of use, adaptability, maintainability and reusability.

A key success factor for an e-auction setting is real-time operation and the ability to simultaneously transmit messages to all intended bidders (*multicasting*). While early e-auction settings were non real-time due to delay in information transmission in the Internet, technological advances enabled real-time (live) auctions and allowed bidders to use information from one e-auction in order to formulate their bids for another e-auction. At the end of the millennium, Buganis et al. (1999) presented the design of a real-time e-auction prototype based on distributed computing and Liu et al., (2000b) proposed a real-time multi-auction (*RTMA*) environment and designed a viable prototype allowing bidders to search, select, register and participate in many e-auction web-sites simultaneously (a highly complex task, indeed). Bornhovd et al., (2000) proposed and designed a Meta-Auction Web site acting as broker between multiple auction sites.

An equally important technological factor for the successful design of an e-auction marketplace is the expected workload during the whole auction lifetime and the resulting performance especially for multi-round auction formats. An empirical estimation of auction website workload in terms of bidder type (human / proxy), number of bids, arrival rate, period of day, bidding activity analysis during auction period, rate of price increase and winner behavior has been attempted by Menasce and Akula (2003). This research has been later extended by Akula and Menasce (2007) using two-level analysis of workload. Liu et al., (2003) analyzed the communication requirements for e-auctions as performance metrics (Table 2.12) and propose a multicast open-cry e-auction model. Liu et al., (2003) analyze the communication requirements for e-auctions as performance metrics (Table 2.12) and propose a multicast open-cry e-auction model.

Quality of Service to online auction users	**Communication Performance Metrics of Online Auctions**
Fast response	Response time
No site failures	Traffic reliability
Predictable response	Predictability
24 X 7 services	Availability
Low transaction fee	Costs
Secure	Security
Fairness	Information sharing

Table 2.12: *Performance Indices for e-auctions (Adapted from Liu et al., 2003)*

In addition to the technical requirements, special attention should be given to the usability of the application or web site so that any participant is well-informed about the usage of the application software, the auction mechanism, the available bidding options, the available auction mechanism and their implications (Kumar and Feldman, 1998). Hahn (2001) identified three dimensions of effectiveness of an e-auction marketplace to be: (i) technostructure (configuration and management), (ii) ease of navigation, and (iii) item display; he concluded that the auction interface is critical for the effectiveness of the auction. Lin and Joyce (2004) categorized success factors for an e-auction web site which –in brief are: design, content (appearance, personalization possibility), (online) participants' instruction, security (secure payment, escrow service and privacy), customer service (guides, interactivity), online community options (discussion board, chat room) and positioning.

Several quality measurement tools have been proposed to evaluate auction web sites. Minimum user requirements for any auction web site are friendly interface, direct access, minimal user effort for installation and operation, minimum (or zero) software and hardware costs, equality, option to attend and participate multiple auctions, autonomous bidding, historical data provision, notifications security and identification (Buganis et al., 1999). Barnes and Vidgen (2001) used *WebQual 3.0* methodology to assess user perceptions based on the evaluation of site-related qualities (6 parameters), information quality (7 parameters), interaction (7 parameters) and domain-specific qualities (7 parameters) and compare between 3 e-auction web sites. Pouloudi et al., (2001) proposed an empirical research framework for the definition of an e-auction business model consisting of four evaluation factors, namely, the auction model, motives and results, exchange processes and stakeholder relationships. Halstead and Becherer, (2003) analyzed the relationship between the size (revenue) of seller, types of auctioned items and the degree of utilization e-auctions as a marketing channel.

2.8.3 Bidding Behavior

The outcome of an auction may be affected by parameters such as, the minimum bid, the buyout price, the duration, the seller's reputation or other bidder characteristics (which may even include perceptions and culture). A sample of these parameters is depicted in Figure 2.9. Song and Baker (2007) performed an extended literature analysis on the effects of seller's controlled parameters, provided a classification scheme for these, and extended the research on their impact, based on data from e-auctions of consumer electronic goods. Bland et al., (2007) examined the options managed by sellers that may affect auction success and final price. A practical guide for bidders was given by Lancaster (2002).

Unlike traditional auction theory where the number of bidders can be easily predicted, the number of bidders in e-auctions may change dynamically. Vakrat and Seidmann (2000) examined empirically bidders' arrival rate in an e-auction and its effect on auction results. Using statistical analysis they found that the number of item units, the length of the auction and the value impact positively the number of bidders while a high minimum bid has a negative impact on the number of bidders. Wilcox (2000) examined empirically the role of a bidder's experience and concluded that experienced bidders have an advantage especially when strategic dominance is strong. Through a market-oriented empirical research, Massad and Tucker (2000) compared bid evolution and final price between an e-auction with reserve price and a traditional auction without reserve price; they found that the first type leads to higher final price and that an auction may facilitate a"buy-it-now" feature which also conveys information relevant to item value. Yoo et al., (2006) and later Anderson et al., (2008) experimented on that and found that a rational buy-it-now feature leads to more efficient auction outcomes and higher winning price. Vragov et al., (2008) experimented on the dynamic modification of the buyout price during the auction and also confirmed that the overall auction efficiency improves.

Segev et al., (2001) modeled an e-auction as a Markov chain to determine the optimal selling size and predict the final allocation price. Ghani and Simmons (2004) used data mining techniques in eBay auctions (classified in seller features, item features, auction features and temporal features) to predict auction end-price. Dholakia et al., (2002) focused on bidders' *herding bias* phenomenon which is observed in cases where bidders tend to submit bids in auctions with many existing bids without searching or comparing to find more attractive auctions for the same item. They examined two groups of factors affecting herding bias, namely, the auction attributes and the bidder's experience.

Vishwanath (2004) examined bidders' behavior according to the item-relevant information obtained from the auction web site, and found that the major motivating parameters are the starting price, the image of the item, the quality of information and the reserve price. Bapna et al., (2004b) examined empirically bidders' behavior in a Yankee auction and proposed a behavior classification system applicable to software development and agent development based on entry decisions, quit decisions and number of bids. The participation (entry) fee, often applied by sellers in an attempt to increase their revenue, also plays its role in shaping the behavior of bidders. (Ivanova-Stenzel and Salmon, 2004) examined the effects of participation fees for various auction types and suggested that participation fees in e-auctions may prove repulsive because bidders (buyers) have the opportunity to choose another e-auction for the same item.

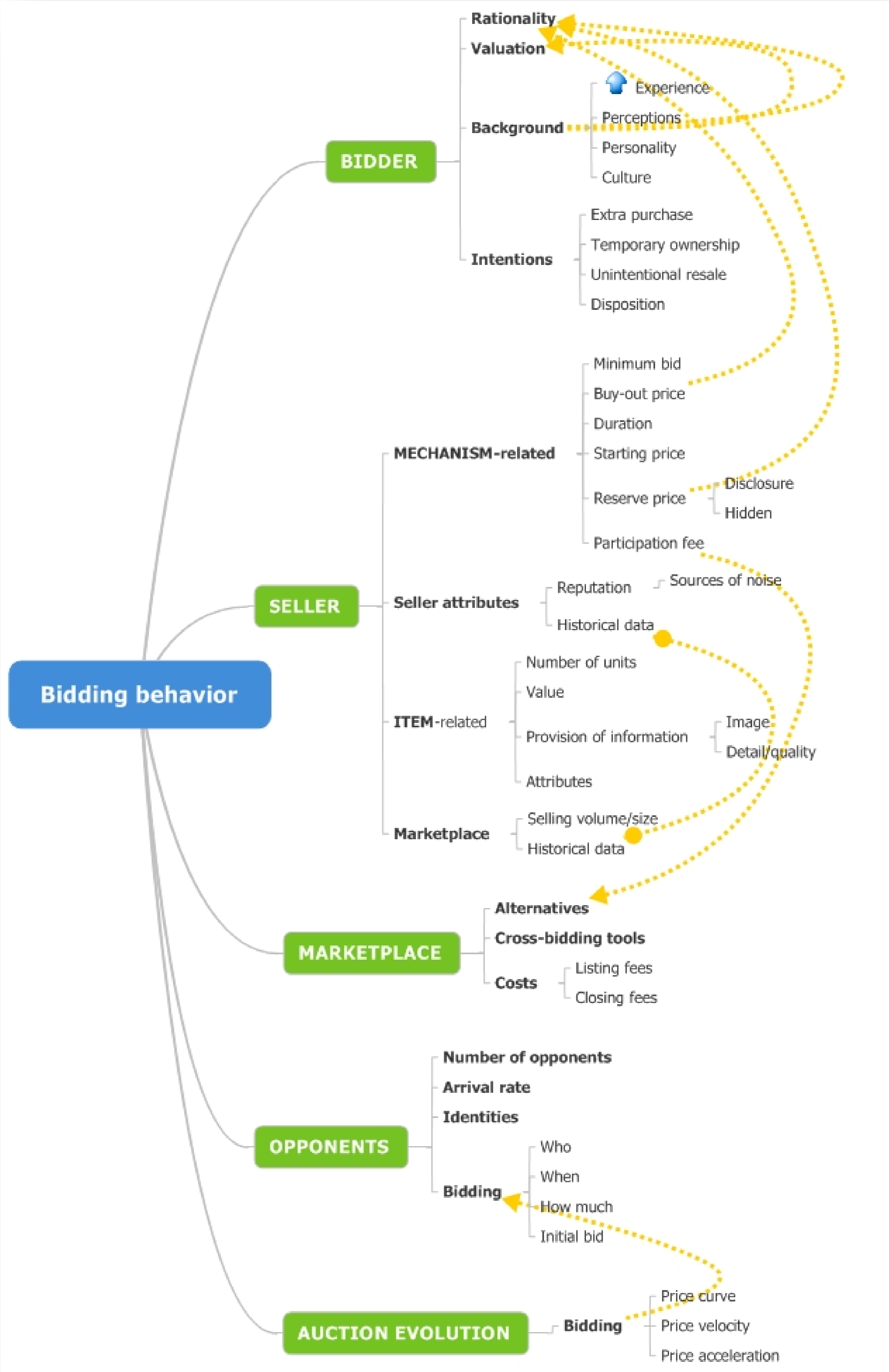

Figure 2.9: *Classes of Bidding Behavior Parameters*

The rapid increase of e-auction applications, sites and resulting data, enabled the structured and experimentally verifiable generation of research works. Park et al., (2005) approached the problem of modeling the bidding behavior as a framework consisting of three key components: who has bid, when and how much. Walley and Fortin (2005) studied final price and auction interest as a result of bidders' behavior and decision making process and investigated how this is affected from reserve price, reserve disclosure and initial bidding. Reiley (2005) conducted a field experiment to examine whether theory related to endogenous entry of bidders applies in e-auctions.

A year later (Reiley, 2006) examined the effects of reserve price while Xuefeng et al., (2006) examined how to predict the final price of an e-auction based on seller's and item's attributes, the attributes of the auction instance and historical data. Using realistic data, Anwar et al. (2006) examined bidding behaviour and winning prices for auction web sites with (almost) zero bidding cost, allowing bidders to participate and bid in many auctions simultaneously for exactly the same item (*cross-bidding)*. The existence of the same item in a electronic retail (e-tail) web site may amplify the winner's curse phenomenon, since the winner can access value-related information more easily (Amyx and Luehfing (2006). Tabarzad et al., (2006) used the TAC (Trading Agent Competition) environment (http://www.sics.se/tac) to simulate and test internet-based English, nth-price English auction and Continuous Double Auction (CDA).

Deltas and Jeitschko (2007) analyzed the effect of introducing listing fees when the participation of heterogeneous buyers and sellers is endogenous. Hou (2007) dealt with the effect of cultural differences and background in the outcome of auctions through the comparison of bidders' strategies from different countries (US and China) for the same e-auction. Kim (2007) proposed an agent-based simulation system to test and evaluate bidders' personalities and auction parameters affecting auction outcomes by comparing English and Yankee auctions. Assuming that C2C auctions enable consumers to act as resellers, Chu and Liao (2007) studied their resale behavior and examined cases of resale of extra purchase, resale after temporary ownership, unintentional resale and disposition.

Matros and Zapechelnyuk (2008) examined widely-used retail second-price e-auctions with reserve price and resale ability and found that the optimal strategy for the auctioneer is to use zero listing fees and to set only a closing fee as a percentage of the winning price. Price formation process depends on what Bapna et al., (2008a) perceived the price formation process as the conceptualization of *price curve, price velocity* and *price acceleration*. They empirically examined key price formation variables of e-auctions and how these influence the price curve during the evolution of the auction process, underlying the need for price formation techniques during the early and middle stages of the e-auction. In a companion paper, Bapna et al., (2008b) examined information acquisition and processing capabilities of multi-unit e-auctions to study bidders' behavior and willingness to pay.

Etzion and Moore (2008) simulated three cases in a retail company offering goods through simultaneous multiple channels, namely: (i) use of open-cry auction and posted prices (dual channel), (ii) sealed-bid auctions and posted prices (dual channel) and, (iii) only posted prices (single channel). Comparing their outcomes they found that the dual (posted prices/open-cry auction) channel outperforms the dual (posted prices/sealed-bid) and both outperform the single channel because bidders use bid history information from the auction channel. Using actual historical data from eBay, Bertsimas et al., (2009) designed optimal dynamic programming algorithms for optimal bid formation in single and simultaneous multiple auctions.

Similar to conventional auctions where reputation systems are usually stated as *"Word-of-Mouth – WOM"*, in e-auctions they are characterized as *"Word-of-Web (WOW)"*. Many auction web sites apply reputation indices to participants aiming to smooth problems of participants' anonymity. Any bidder or seller may be rated by other bidders or the seller (*"bidirectionality")* after the completion of an e-auction (Weinberg and Davis, 2005). A seller with high reputation rate is most preferable to bidders and the final price is most likely to be higher. (McDonald and Slawson, 2002) examined empirically the role of reputation measures in bidder's behavior and sources of noise. Yang et al., (2007) showed that although a reputation system cannot discourage participants from dishonest behavior, it is generally improving the trust level of the auction. Zhou et al., (2008) applied a framework to examine how reputation systems influence participants' decisions and focused on vulnerabilities of these systems (changing of identification, shilling and failure to leave feedback) and on how these problems can be overcome.

2.8.4 Supported Advanced e-auction Formats

E-auctions boosted the development and implementation of advanced multi-dimensional auction mechanisms; compared to physical auctions, e-auctions are far more efficient in the development and support of such complex auction settings. The electronic environment within which e-auctions take place, enhances a bidder's ability to acquire information. This section pays special attention to the bidding strategies which are much richer as a result of information dissemination and to the resulting auction outcomes; furthermore, it enumerates core research findings related to implementation results and exhibits how e-auctions differ in that aspect from traditional auctions. Importantly, core characteristics and mechanism parameters of physical auctions are retained in e-auctions; thus, the following paragraphs avoid repeating them and the reader is advised to consult Section 2.4 for a detailed analysis.

.1 Multi-Unit Auctions

Multi-unit auctions, as already explained above, is a term used to describe auctions of sets of multiple identical items. Pinker et al., (2001) examined optimal policies for decision-making on the required number of auctions, lot size and duration of each auction. They showed that the average price per unit often decreases when the lot size increases due to economies of scale, while, smaller lot sizes require more sequential auctions to be sold. Häkämies et al., (2003) compared performance between offline English-clock auctions and Internet-based multi-unit auctions and found that they have similar outcomes in terms of equilibrium price, allocative efficiency, and buyers and sellers' profits. Gopal et al., (2005) focused on the risks and loss of revenue of sellers offering multiple identical items through e-auctions (for example liquidation auctions); they examined the use of *options* (a contract which gives a buyer the right to buy at an agreed upon price or by a certain deadline) as a tool to manage the corresponding risk of loss revenue.

.2 Multi-Item Auctions

Multi-item auctions, are also auctions of sets of multiple items which, however, are not identical. Teich et al., (1999a, 1999b) assumed market stability and efficiency in electronic marketplaces to propose some heuristic algorithms for market matching and to evaluate them in terms of quantity and value of items traded, stability of market and efficiency. Bapna et al., (2001b) dealt with the applicability of auction theoretical principles in the B2C multi-item progressive e-auctions (*MIPEA*) and concluded that the RET does not always apply in the case of multi-item e-auctions. Blum et al., (2004) isolated the case of goods with practically unlimited supply- such as *digital items* where bidders may arrive one at a time and each requires exactly one copy of the item- to promote the appropriateness of e-auctions. Later, Blum and Hartline, (2005) examined the properties of such items and compared between auctions and posted price mechanisms.

.3 Multi-attribute Auctions

Multi-attribute auctions, denote auctions where the negotiating parameter is not solely the price but also other negotiable endogenous or exogenous –usually qualitative- attributes of the auctioned item. The majority of research on multi-attribute e-auctions focused on the design and development of decision-making tools. Bichler et al., (1999) presented a computerized intermediate (e-Broker) which offers decision and controlling tools for participants. Teich et al., (2001) designed the *NegotiAuction* platform which combines negotiation and multi-attribute B2B transactions, and supports forward and reverse mechanisms; this platform has been further developed by Teich et al., (2006) by incorporating a "suggested price" option.

Koppius and van Heck (2002) introduced the *e-auction information architecture* concept which defines the type, time and place of information revealed. They also examined how this is affecting efficiency and Pareto optimality in the multi-attribute e-auctions context. Teich et al., (2004) presented a detailed approach to multi-attribute e-auctions and some corresponding B2B applications in procurement. Reyes-Moro and Rodriguez-Aguilar (2005) presented a Decision Support System (*iAuctionMaker)* which helps auctioneers to separate items in bundles based in items' attributes, and aims to improve auction outcomes based on data from market and experts' knowledge. Fairchild et al., (2005) provided a comprehensive analysis on the case of a Pan-European auction marketplace, (Eutilia - now Worldbid.com); they highlighted its critical role as a market maker and they described the types of multi-attribute auctions used. Some optimal bidding strategies in multi-attribute e-auctions have been presented by David et al., (2006).

Karimi et al., (2007) developed a new Multi-Attribute Procurement Auction mechanism (MAPA) for Supply Chain operations, where seller's strategies are highly affected by their risk characteristics. Goyal et al., (2008) simulated and analyzed the case where bidders form their strategies based on their attitudes, modeling themas fuzzy variables; they proposed a decision making framework which supports: (i) different weights for each bidder, (ii) expression of fuzzy preferences for alternative solutions, and, (iii) bidders' different judgments on solution criteria.

.4 Combinatorial Auctions

Combinatorial auction is a term used to describe auctions of multiple items characterized by positive complementarity which leads to superadditive valuations of bundles. Combinatorial auctions are either multi-unit or multi-item and sometimes (but not necessarily) may be multi-attribute. IT infrastructure enables the conduction of complex combinatorial auction formats by integrating sophisticated decision-making tools, such as, algorithms for optimal winner(s) determination. Bichler et al., (2002b) provided an overview and summarized types of winner determination problems for a wide range of multi-dimensional auctions through the design of an object model for the allocation framework. An extensive review of combinatorial e-auctions and some applications can be found in Pekec and Rothkopf (2003) and later in Narahari and Dayama (2005). These researchers described a design framework, analyzed the related parameters (efficiency, individual rationality budget balance, incentive compatibility, solution stability, revenue maximization, cost minimization, low transaction costs και fairness) and studied computational complexity issues.

.5 Electronic Reverse Auctions (eRA's)

The evolution of electronic Reverse Auctions (eRA's) was synchronous to the evolution of Internet and related software applications. eRAs operate optimally when the number of suppliers is large, the capacity availability is high and the buyer dominates in their relation (Emiliani, 2000). The core differences between procurement through physical ("traditional") auctions and eRAs have been underlined by Parente et al., (2001). An extensive review of eRAs has been presented by Jap (2002) focusing on their differences from traditional (physical) auctions, application conditions, development, implementation methodologies and benefits. Jap, (2000, 2003) examined the managerial implications of the use of eRAs and concluded that suppliers often believe that buyers act opportunistically – especially in open-cry auctions. Germer et al., (2004) provided a methodology for literature review and presented a structured literature review on the area of RAs and eRA's from 1986 to 2004. Barret and Pugh (2003) indicated some important properties of eRAs when used for procurement and Settoon and Wyld (2003) focused on use of auctions for government procurement. Arnold et al., (2005) identified the major differences between traditional procurement methods and eRA's and examined the potential for cost reductions of the eRA-supported procurement process by estimating Total Cost of Ownership (TCO) before, during and after the auction transaction process.

A major part of the literature on eRA's focuses on the relationships between suppliers and buyers, as well as on their individual behavior and the factors that affect it. Smart and Harrison (2003) interviewed buyers from 6 cases of eRA to identify the impact on relationships between buyers and suppliers. (Stein et al., 2003) showed that in most cases an eRA is more beneficial for buyers than for suppliers. Carter et al., (2004) examined the use of eRA's from both the buyer and seller perspectives and identified the main parameters affecting auction success. Ding et al., (2005) studied bidding behaviour in electronic reverse auctions and found that the increase of web-site perception and use of subsidizing strategies are two important ways to increase profits. Daly and Nath, (2005) proposed some techniques that can make eRAs more relationship-friendly: subsidizing supplier's investments, negotiation of price and specifications after the closing of the auction and losers' compensation.

From an implementation point of view, electronic reverse auctions adoption may be perceived as an organizational learning process. Hur et al. (2006) broke down this process into five enabling practices, namely: (i) e-auction competencies, (ii) knowledge management, (iii) holistic sourcing process, (iv) total cost of ownership philosophy, and, (v) experiment on e-auctions. Losch and Lambert (2007) examined a small sample from the automotive manufacturing sector and found that information behavior (seeking, exchanging and using information), equal treatment of suppliers and communication quality may affect relationships. Gattiker et al., (2007) used simulation to compare between face-to-face negotiations, e-RAs and e-mail negotiations; they examined how the mechanism affects the trust between participants as a function of complexity and information richness attributes. They found that electronically conducted processes generate less trust than face-to-face interaction and that this trust attenuates when complexity increases; on the other hand, an increase of information richness may enhance trust. Schoenherr (2008) conducted a large scale online survey to examine the diffusion of e-RAs for three types of companies (early, late and lagging adopters) based on internal (firm size, learning) and external (savings, use of bundles) factors.

A significant part of the literature also dealt with the factors affecting the success of eRAs. Wagner and Schwab (2004) indicated major critical success factors of eRAs in terms of cost reduction and underlined the importance of crisp item specification and competition enhancement. Kaufmann and Carter, (2004) examined the feasibility and appropriateness of an eRA as the synthesis of several success factors, namely: specificability of the item, separability between price and non-price elements, rivalry strength, internationality, e-capabilities, auction integrated format, buyer's reputation, productivity and transparency. Talluri and Ragatz (2004) focused on the organization and operation of *multi-attribute* eRAs. They analyzed auctioneer's decisions factors (auction format, selection of suppliers for bidding, type and amount of information disclosure), they presented the technical requirements and they proposed an AHP-based methodology to determine the winners. Finally, Hur et al., (2007) examined factors affecting the economic viability of eRAs.

The eRAs have been applied for procurement processes in the Supply Chain Management (SCM) business operations. Smart and Harrison (2002) analyzed how eRAs support flexible supply chains when items have low complexity, switching cost is low and suppliers have similar quality and delivery reliability capabilities. The appropriateness of various procurement methods subject to the number of suppliers and product complexity are summarized as follows:

- Low number of suppliers and low product complexity: buy-side applications
- Low number of suppliers and high product complexity: Catalogues
- High number of suppliers and low product complexity: eRAs
- High number of suppliers and high product complexity: electronic marketplaces

Reyes-Moro et al., (2003) presented *Quotes* an Internet-enabled commercial software tool for e-sourcing tasks offering DSS capabilities for winner determination, multi-attribute scoring and automatic creation and submission of optimal offers. Jin and Wu, (2006) designed a reverse e-auction mechanism that supports the coalition between competing suppliers before the announcement of an order and they specified related requirements (individual rationality, private and distributed information, observability, controllability, market efficiency compatibility, maintenance of competition and financial balance).

Kameshwaran et al., (2007) described a realistic model for industrial procurement, based on a reverse, multi-unit, multi-attribute auction with volume discounts. Their model is based on *Configurable Bids* consisting of both price-related elements such as Price and Volume Discount Price, and attribute-related elements defined through fixed values, range of values, optional attributes, etc. They examined some special characteristics from a buyer's perspective and proposed a methodology for bid evaluation in an e-auction context using weighted Goal Programming.

Despite the wide acceptance of eRAs, a considerable number of researchers proved critical against them and presented some useful and realistic reviews. Emiliani (2000) supported that the adoption of eRA for procurement may hinder the application of emerging strategic supply chain management practices and supply chain integration,. Emiliani and Stec (2001, 2002) criticized on the application of eRAs by discovering incompatibilities in terms and conditions between traditional procurement and eRAs; they corroborated their claims by presenting possible losses that may lower expected benefits.

Stein et al. (2003) analyzed a case of an eRA where the process was beneficial for both the supplier and the auctioneer but not for the seller due to high participation costs. Griffiths (2003) underlined potential misuses of eRAs asserting that it is on buyer's discretion to create climate of faith to bidders; on the other hand, in order to maximize their revenue, coalitions between suppliers may occur. Tassabehji et al., (2006) examined the case of eRAs from a seller's perspective and concluded that, in general, sellers dislike the eRA for a number of reasons most important of them being the deterioration of trust; to support their argument, they proposed a model of factors affecting sellers' trust.

Finally, Jin and Wu, (2006) examined requirements such as, individual rationality, market efficiency compatibility, maintaining competition, observability, controllability and financial balance, and presented a suppliers' coalition model. Hartley et al. (2004), summarized the benefits and threats of eRAs in SCM for both buyers and suppliers (Table 2.13). They compared between adopters and non-adopters of eRAs, finding that large organizations are first-movers in the adoption of eRAs; moreover, IT expertise and procurement of standardized parts are the most important parameters for adoption.

	Benefits	**Threats**
Buyers	Lower transaction costs Shorter order-cycle times Competitive purchase price Access to suppliers worldwide Increased supplier competitiveness Ability to find the most capable supplier Gather and analyze market information Strategic sourcing	Understate quality, service, delivery Understate relationships Possible problems with non-standard items Administrative costs Supplier qualification issues Process manipulation by suppliers
Suppliers	International access Access to market information Better management of excess capacity Understanding of buyer’s financial goals Information about competitor’s cost structures Better forecast / planning	

Table 2.13: *Benefits and Threats of eRAs in SCM*

Emiliani and Stec (2001) describes and analyze the types of terms and conditions that accompany purchasing contracts which namely are: re-negotiation frequency, commitment to offer, base unit, termination rules, acceptance of terms, pricing, continuous improvement, charge-backs, payment terms, inventory and transportation costs and lead-time. Later, Emiliani and Stec (2002) examining the reasons for which purchasing managers in custom-designed machine parts use eRAs and they conclude that the savings usually reported are overestimated compared to actual. Finally Emiliani and Stec (2002a) ask some criticism on the use of eRAs for the custom-designed manufacturing components.

2.8.5 Intelligent Agents (IAs)

Participation in electronic auctions requires rapid bidders' decisions on how, how much and when to bid; this triggered many research efforts which focused on the development of software tools to automate this process. Recent developments in the *Artificial Intelligence* (AI) area, in particular, introduced a special class of software applications, defined as *Intelligent Agents* (IAs). These applications are programmed to automatically execute bidders' intentions and negotiate in WWW-based marketplaces and electronic auctions. Hayes (1999) defined an IA as *"an entity (either computer or human) that is capable of carrying out goals and is part of a larger community of agents that have mutual influence on each other. Agents may co-exist on a single processor, or they may be constructed from physically, but intercommunicating processors*". He also presented a comprehensible introduction to agent characteristics, technologies and applications. Benameur et al., (2002) summarized various definitions from the literature and enumerated their major properties as follows:

- Situated or embedded in a particular environment;
- Designed to fulfill specific roles;
- Clearly identifiable entities with well-defined (and limited) resources and interfaces;
- Autonomous in the sense that they have control over their behavior;
- Capable of exhibiting flexible behavior which can be reactive, proactive, sociable or persistent.

From an IT-engineering point of view, IA’s aim to make computers work rationally applying artificial intelligence and distributed computing technologies and methods. Binmore and Vulkan (1997) predicted that agent technology evolution should follow the *Graphical User Interfaces (GUI)* evolution: it will gradually evolve from an optional software element to a standard feature in most commercial applications.

E-auctions constitute an ideal landscape for the application of IAs; even for simplest auction formats, participants have to rapidly analyze data to formulate and apply complex strategies. IAs are used in auctions, in order to automate parts or the whole commercial transaction on behalf of participants (either buyers or sellers or both) and are usually characterized as *proxy* agents. In the general case, the use of IAs in auctions includes participation, bidding and transaction processing. Since IAs are able to react faster, reduce participation costs and process vast volumes of data more conveniently, they typically outperform human participants in the majority of the routine processes; furthermore, they are able to execute repetitive, time-consuming processes, they enhance or even secure anonymity and are able to control the overall bidding process. Obviously, an agent is efficient when its design, implementation and use offer at least equal or ideally better results than human market participants. In the remainder of this section, the term *agent* will refer to proxy IAs.

Many research efforts have been supported from the development of IAs-enabled auction platforms. Wurman et al. (1998b) developed *AuctionBot*, which is a laboratory auction platform where several experiments related to the use of IAs in auctions have been carried out. Collins et al., (1998) developed an efficient multi-agent third-party model *(Multi-Agent Negotiation Protocol – MAGNET*) which supports multiple complex negotiation protocols for procurement auctions that can be integrated in each tier of a marketplace. Garcia et al., (2001) designed an agent-based generic auction platform (AgILE) where agents are assisting buyers, sellers and auctioneers. He and Jennings (2004) used a successful IA (SouthamptonTAC agent) to make bidding strategy decisions and predict auction closing prices under uncertainty using fuzzy logic techniques. They tested their IA in a series of interdependent auctions to purchase travel packages (multiple independent auctions instead of combinatorial auctions) and underline potential for use in real auction settings.

Parkes, et al. (1999) examined factors affecting suitability of IA's in different auction formats depending on bidder's effort reduction, estimation of value and communication costs.

In a real marketplace setting, the e-auction model usually supports agents developed by third parties (Lee, 2001). In their simplest form, proxy agents are offered by the auction web site especially in auctions having long duration helping bidders to gradually submit bids (less than a predefined maximum bid) whenever a new rival bid arrives (Ku and Malhotra, 2001).Ideally agents should be flexible enough to apply simultaneously to several auctions with different attributes and various user preferences. Wurman (2001) identified generic inputs in any auction bidding agent (user preferences, a list of rules for the auctions and a market model of rival bidders) and proposed a flexible trading agent able to help decision making in various auctions. A year later, Wurman et al., (2002) proposed a set of parameters as a basis for the development of an auction description language, consisting of bidding rules, clearing rules and information rules, claiming that this language may be used for the implementation of agents auction applications.

He et al., (2003) provided an extended analysis of the roles of agents in B2C and B2B trading contexts and described relevant technologies (interaction languages, protocols, development tools and platforms). Sunderam and Parkes (2003) examined the use of proxy agents which gradually store information about revealed preferences from bids and submit bids automatically whenever they collect enough information. Airiau and Sen (2003) proposed an agent strategy supporting bidders participating in multiple auctions aiming to acquire different quantities of specific items (bundle bidding). Of special importance is the degree of intelligence these agents possess. For most common bidding processes and auction formats, *zero-intelligence* (*ZI)* and zero-intelligence-plus (*ZIP*) agents are perfect and in many cases outperform human traders. Cliff (2003) engaged *Genetic Algorithms* to test the performance of IAs in auctions where the rules are also controlled by these genetic algorithms; he argued that ZIP-type agents will be able to operate well, not only in complex auctions like the CDA but also in hybrid mechanisms as well.

Raghavan and Prabhu (2004) proposed an agent-based market framework which operates in three phases, namely, e-Negotiations, e-RA and e-Settlement. The eRA phase is based on a multi-attribute e-RA where the buyer defines preferences via weights in both objective and subjective criteria. The winner determination problem is solved using an algorithm based on multi-attribute preference theory. Gregg and Walczak (2006) designed a Decision Support System (DSS) (*Auction Advisor*) for buyers and sellers based on statistical methods and heuristics. The DSS consists of three cooperating types of agents responsible for information retrieval, data analysis and bidding and aims to support their decision making process for strategy formulation.

Auction-based marketplaces are often heterogeneous regarding the participation and the auction process. Participants and especially, proxy agents, face problems when they must switch between marketplaces or simultaneously participate in many electronic auctions (Rolli et al., 2006). To overcome the problem they proposed a *Descriptive Auction Language (DAL)* which smoothes the problem of describing and implementation of new auction designs, through the automatic understanding of the rules and formulation of strategy. Many researchers and practitioners engaged IA's to massively collect data from multiple auction sites in order to study related issues; for example, Shmueli et al., (2006) developed a suite named *AuctionExplorer* which uses IA's *("web spiders")* to explore databases of online auctions and process data and to visualize results.

Wu (2001) focused on knowledge management in multi-agent auctions and examined issues related to coordination and cooperation between them. Sim and Wong (2001) designed a *society* of trading agents able to automatically select bidding strategies based on market changes; its operation is based on the *engineering* aspects of these agents, being the specification of auction rules, the agent interaction protocol, the characteristics of the agents, the determination of the initial price range and the management of strategies. Benameur et al., (2002) claimed that many applications require the simultaneous use of multiple agents (*Multi-Agent Systems – MAS*) enabling the distribution of knowledge, action and control between them to cooperate, compete or coexist depending on the context. They examined the application of MAS in multi-unit auctions where the quantity of available units is not fixed.

A significant number of researchers studied the application of agent technologies in various auction formats acting on behalf of bidders (*proxy agents)* to select auctions and decide when and how much to bid; furthermore, bidders are able to simultaneously submit bids in multiple electronic auctions (*pooling*) using specialized agents (*ShopBots)* able to search auctions to find particular trading items. Preist (1999) presented an agent-based iterative double auction mechanism combining attributes from both the Continuous Double Auctions (CDA's – auctions where buyers and sellers submit their buy and sell offers asynchronously) and the call auction (an auction where buyers and sellers privately propose information to an auctioneer about how many units they want to buy or sell at a given price and finally trades are realized at the same price). Later, Preist (2000) focused on simultaneous multi-unit auctions and proposed algorithms for agents supporting buyers in the submission of bids in multiple auctions and the maximum bid as well in order to buy the required number of items. Das et al., (2001) conducted a series of experiments and found that agents obtain greater revenue than human competitors in CDA's which constitute a common auction format for equities, commodities and derivatives markets. Park et al., (2004) proposed a stochastic modeling approach of the CDA process and define *p-strategy* that may incorporated by relevant agents. Li and Smith (2004) proposed an agent-based framework supporting bidding and speculating decisions in CDAs where demands and supplies changes dynamically from period to period. Bagnall and Toft (2004) examined the performance of *Autonomous Adaptive Agents (AAA)* in First and Second Price Sealed Bid (FPSB and SPSB) private value auctions.

Bellosta et al. (2004) proposed a reverse English multi-attribute mechanism based on reference points allowing buyer's agent to better control the bidding process instead of weighted sum method. Wurman et al. (2004) proposed an algorithm supporting auctioneers in iterative combinatorial auctions to compute bidders' allocation based on "inflection points" (bid for a new bundle, change in the set of current allocations, withdrawal of an agent). Finally, Zeng et al. (2004) focused on buyers' bidding in multiple combinatorial auctions and proposed a set of models that can be incorporated in buyers' agents to formulate optimal purchasing decisions across posted-price markets and coordinate bid activities across two sealed-bid auctions.

2.8.6 Vulnerabilities and Security in e-auctions

Vulnerabilities of physical auction mechanisms are also inherited to e-auctions. The use of Internet entails additional forms of vulnerabilities most important of which relate to difficulties of user authentication and data transmission delay. Moreover, Internet has weaknesses which allow occurrence of fraud affect negatively bidders' faith. The most important of these weaknesses have been enumerated by Liao and Hwang (2001):

- Internet is an "open" environment, thus all bids are exposed to attacks
- It is hard to verify participants reliability and rule keeping
- Payment transactions are not secure (especially in C2C e-auctions)
- Participants' real identities cannot be determined.

These shortcomings are the source of several associated vulnerabilities, such as:

- Bid *shielding*: a bidder may manipulate the mechanism (if no counter-measure exists) using a *phantom* bidder name to set extremely high bid during the first steps of the auction in order to discourage other bidders and force them to quit; then, this bidder retracts his phantom bid and submits a lower one.
- Bid *shilling*: the seller manipulates the mechanism by setting a phantom bid; the impact is similar as in bid shielding.
- Provision of misleading data (e.g., descriptions, photos)
- Subjective criteria or ambiguous scales for the evaluation of the auction item
- Undefined or unclear shipping and handling costs from the beginning
- Lack or inaccuracy of information about the actual condition of the item

Some fraud-related differences between traditional auctions and e-auctions have been studied by Bywell and Oppenheim (2001) who also provided a comprehensive and realistic summary of major fraud threats. An extended analysis on electronic auction fraud based on a real-data investigation and some guidelines to avoid fraud has been given by Gavish and Tucci (2006). Antony et al. (2006) analyzed the factors affecting C2C participants' decisions to use or not use an escrow service. They examined a set of 5 factors; risk attitude, perceived risk, reputation, price, and fraud rate.

Hinz (2007) discovered experimentally a number of factors making participants in a bidding community providing false information in e-auctions when they do not have incentives for that (i.e., frustration). Jenamani et al., (2007) classified the major categories of vulnerabilities based on who (bidder or seller) induced the fraud and compared bidders' expected utility and seller's expected revenue for three auction types (English, FPSB and SPSB) and different probabilities of cheating. Finally, Zhang et al., (2008) proposed an algorithm to detect fraud and classify participants (buyers and sellers) who act as groups.

E-auctions also suffer from the lack or non-adequacy of a legal framework (Ba et al., 2003) since; (i) law regulations cannot easily follow the rapid growth of e-transactions, (ii) although e-auctions apply globally, law typically applies locally, and, (iii) application of legal rules may be unprofitable especially for low-value transactions. eRAs may be affected by participants unethical behavior. Carter et al. (2004) present a range of such risks in eRAs.

The most common techniques widely used to cope with fraud are:

- Participant certification and use of evaluation service.
- Item rating service
- participants feedback services
- Use of escrow services
- Application of penalty in case of withdrawal.

Major research questions dealt with the design and application of secure mechanisms even when participants tend to violate rules. Generally, an e-auction should ensure bidders' privacy, stability of the winning bid, anonymity, fast evolution and fairness. Some of the most common threats are presented briefly in the following paragraphs.

.1 Payment Methods

Since participants in e-auctions cannot contact each other personally, payment and money transfer entails high risks especially in B2C and C2C auctions. Major payment methods, their properties and a comparison between them have been enumerated by Li and Zhang (2004) who also presented the properties and shortcomings for each of them and their dependencies on product attributes and product characteristics. Later, Zhang and Li (2006) analyzed the factors affecting the selection of a payment method based on risk, convenience and cost data. They found that qualitative product attributes are more important than seller's sales volume and reputation. Finally, Chae et al., (2007) analyzed the case of credit card *phantom* transactions realized as collusion between buyer and seller where the seller borrows money to buyer via a credit card at a very high interest rate. They spotted three factors serving as a tool to detect this type of fraud, namely: high opening bid, short auction duration and seller credit.

.2 Shill Bidding

Shill bidding is still a typical vulnerability of multi-round e-auctions where sellers themselves submit (multiple) bids to increase artificially the price using a false name (or an agent) resulting in market failures (Wang et al., 2002). In many cases, bidders apply strategies like "jump bidding" and "last minute bidding – sniping" to collude, lowering the efficiency of the market. Vragov (2005) estimated experimentally these losses and Kosmopoulou and De Silva (2007) examined the effect of shill bidding on seller's revenue, finding that shill bidding is more likely under the presence of a low reserve price and large number of bidders.

Kauffman and Wood (2005) analyzed the reserve price shilling case, where sellers submit a low bid which is higher than the predefined starting bid to eliminate auction fees when they are relevant to the starting bid. Yokoo et al., (2004) found that none false-name proof combinatorial auction protocol is Pareto efficient and the VCG strategy-proof mechanism is not false-name proof. Many e-auction web sites operating on the basis of the English auction format, engage methods like minimum bid, deadlines and reserve price to reduce the impact of such behaviors.

.3 Use of IA's for Late Bidding

Agent technology has been widely used to develop (proxy) agents to alter auction results. Typical examples of such IA's are *sniping agents* which allow a bidder to specify his maximum bid and desired bidding time or frequency. Roth and Ockenfels, (2002) examined theory, actual data from B2C and C2C auction web sites, surveys, quotes and experiments to analyze the reasons for sniping and its occurrence related to the item types (categories) and bidders' experience. Bapna (2003) examined the conditions under which sniping agents are able to deteriorate auction results and propose mechanism rules against this. Shang and Ling (2004) claimed that the English auction mechanism is most susceptible to late bidding because it reveals other's bids and suggests that an effort to increase the variety of bidders may reduce the impact of late bidding.

If, however, the auction operates on the basis of a hard-closing mechanism, the use of sniping agents cannot be perceived as unethical, especially when participants has easy access to such sniping tools. A vast amount of such sniping software applications is currently offered from several application providers. These sniping agents are available in various forms, for example, as standalone applications, as web-based online applications, or as add-ons to other applications (usually browsers). An indicative list of such agents is shown below (accessed October, 2010):

- *http://www.auctionlotwatch.co.uk/lotsnipe.html*
- *http://auctionsniper.com/*
- *http://www.gixen.com/index.php*
- *https://www.bidnapper.com/*
- *https://addons.mozilla.org/el/firefox/addon/180644/*
- *https://www.ezsniper.com/*
- *http://www.hidbid.com/*

.4 Secure Protocols, Privacy and Encryption

Security and sometimes anonymity are vital issues for the trustworthiness and success of electronic auctions. They both apply for certain auction mechanisms and refer to privacy of both participants' identity and relevant bidding data. Chang and Chang (2003) proposed a simple efficient method based on public and private keys to secure anonymity, verifiability, non-repudiation, accountability, variability of bids and fairness. Pathak (2003) focused on sequential multi-unit auctions and proposed a secure auction mechanism (*Closed-Cover Multi-round Auction Protocol / CC-MAP*) eliminating multiple-identity (false-name) bids. Xiao and Ping, (2004) proposed a secure protocol that ensures bid secrecy by assigning a *Registration Number* to each bidder that allows them to submit their bids. Wang and Leung (2004) analyzed security and privacy issues in e-CDAs and proposed a secure protocol ensuring anonymity, traceability, impossibility of impersonation, unforgevability and verifiability. A secure and fair cryptographic-system-based protocol for electronic first-price sealed-bid auctions has been proposed by Juang et al., (2005) ensuring soundness, security, anonymity, certifiability and verifiability.

Trevathan et al., (2006) improved the protocol proposed by Wang and Leung securing bidders' anonymity and blocking the creation of bidders' profiles. Shih et al., (2006) proposed an efficient protocol for Vickrey eRA's to ensure the certification of the winning bid and the hiding of losing bids. Hidvègi et al., (2007) stressed that multi-unit auctions are even more vulnerable to false-name bidding – a native vulnerability of e-auctions – and designed a special multi-unit sealed-bid mechanism defined as "*Binary Vickrey Auction – BVA*" which is based on the submission of bids for bundles of power-of-two items and analyse its robustness.

Many auction web sites provide services which enhance robustness. Ba et al. (2003) described the most common of them (user rating feedback systems, insurance or guarantee and escrow services) and concluded that these services are often inefficient. For example, a low-rated bidder may re-register in an auction using a new e-mail account while any bidder may intentionally leave a subjective wrong feedback for another participant. Moreover, guarantees and escrow services apply with strict value restrictions – maximum and minimum value respectively. They also proposed a *trusted third-party (TTP)* mechanism to authenticate reputation feedbacks as an extralegal enforcement. Ekstrom and Bjornsson, (2002) claimed that credibility rating tools have a strong weakness: all participants' ratings have the same weight implying that all raters are equally credible and trustworthy. They proposed *TrustBuilder*, a rating tool that weights ratings based on raters' credibility. Perrig et al., (2001) proposed a secure marketplace architecture (SAM) based on trusted hardware instead of a trusted auctioneer. Jaiswal et al., (2004) proposed some methods (subscription, cryptography and anonymous identification) to resolve related vulnerabilities.

2.8.7 Applications and Business Cases

E-auctions apply in a wide range of business and commercial transactions. A delegation of applications examined in the literature is presented in Table 2.14. A more focused review of applications of auctions in the area of capacity-related service markets (e.g., tourism, SCM and freight transportation) will be presented in Chapter 6.

Application	Reference	Aim / findings
Livestock trading	Atkins (1998)	Market does not require transportation of the animals Focus on the innovative characteristics of the auction market
Spectrum licences (FCC auction)	Guala (2001)	Analysis of the design, testing and implementation
Privatization of productive assets	Maskin (1992)	Examination of which forms of auctions are more efficient
Government property allocation	Anandalingam et al., (2005)	Review
	Ferro and Dadayan (2006)	Complementarity between eBusiness and eGovernment Revenue generation, incentives, transparency
	Schwartz (2003)	Magazine article – trend (G2C,G2B)
Financial markets	Bichler and Segev (2001)	Application of multi-attribute auction in derivatives
	Domowitz and Wang (1994)	Analysis of the application of electronic order book
Initial Public Offerings (IPO)	Biais and Faugeron-Crouzet (2003)	Analysis of performance of the auction mechanism
	Hurt (2005)	Analysis of performance
Internet keyword search)	Kitts and LeBlanc (2004)	Analysis and evaluation of an agent through simulation (pay-per-click)
	Lim and Tang (2006)	Analysis of bidding behavior (search results order)
	Liu and Chen (2006)	Analysis of the weighted unit-price contract (UPC) auction mechanism and bidding behavior (search results order)
	Edelman and Ostrovsky (2007)	Empirical analysis of bidding behavior (sponsored links advertisement)
Airline seats reservation	Morris and Maes (2000)	Prototype supporting bidding and negotiations *(System for Airline Reservations, Demonstrating the Integration of Negotiation and Evaluation – SARDINE)* Fuzzy matching
	Morris et al., (2000)	Seller's perspective in *SARDINE*
Product configuration	Snir and Sobol (2005)	Methodology for configuring products using cost and auction data
Service allocation	Vulkan and Jennings (2000)	Modification of English auction for trading of services, analysis of the mechanism and potential for application of agents
IT Services (software development)	Snir and Hitt (2003)	Bidding behavior
Secondary markets	Snir (2006)	Application when a market does not have reference prices from a physical counterpart
Public procurement	Soudry (2004)	Application of eRA and comparison with traditional sealed-bid auction
	Kierkegaard, (2006)	Clarification of EU directives
Negotiations	Strobel (2000)	Criticism on auctions – they cannot support complex negotiation

Table 2.14: *Indicative Applications of e-auctions*

2.9 Summary

Auctions constitute an important price formation tool used for centuries for the efficient allocation and/or procurement of goods and services between businesses, consumers or both of them. The growth of the application of auctions during the last decade is enormous, also assisted by the evolution of IT. This trend is highly reflected in the growth of research works since Vickrey's foundational work, in various auction-related issues (e.g., auction theory, optimal mechanism design, bidding strategies, applications etc.) and other complementary disciplines like Information Technology, Games Theory and Operations Research firmly integrated to auction mechanisms and processes. A number of innovative auction types and formats has been developed and applied to support almost all kinds of trading needs and preferences. These auction types have formed a challenging and attractive research landscape for researchers creating a vast literature.

This chapter has confined its scope mainly on the last decade, and over four-hundred articles have been retrieved from major bibliographic databases and examined in preparing the review on physical auctions. Some articles published earlier than the last decade were considered as fundamental papers, and were thus examined and referenced in this chapter in order to ensure the scientific and contextual integrity. In addition, more than two-hundred articles have been identified and referenced, focusing on auctions conducted over the Internet.

The topics presented in this review cover systematically the design and implementation of auctions; analysis of auction types, review of special auction formats, parameters, vulnerabilities and applications are examined. The contribution of this chapter is manifold:

1. It summarizes the most significant research contributions in the area that have been published during the last decade;
2. It provides a comprehensive overview of the auction theory focusing on the core issues of auction mechanism design and associated bidding behavior;
3. It identifies major mechanism design parameters and their impact on both bidding strategy and revenue outcomes based on findings from the literature;
4. It presents a comprehensive overview of emerging multi-dimensional auctions and examines important works related to bid formulation and winner determination problems;
5. It provides an overview of auctions electronically conducted and underlines the major organizational prerequisites which are perceived as success factors for practical implementation;
6. It isolates the new types of vulnerabilities which emanate from the electronic infrastructure;
7. It expands with technological advances related to intelligent agents and describes how agent applications serve to support bidder's and auctioneers' intentions;
8. It sheds light to emerging applications.

The major findings of this review will be utilized in Chapter 3; these findings, in particular, will serve as a knowledge base for the development of auction customization tools.

Chapter 3

Auctions Classification Ecosystem (ACE)

The results from the extended analysis provided in Chapter 2 are used as building elements for the development of the generic, comprehensive and practical 2-Level auction customizing model presented herein, which is conceptually defined as *Auction Classification Ecosystem (ACE)*. This chapter first explains the need for the establishment of this model and then presents the construction elements. Then it presents in detail the model along with its extensions to complex auction mechanisms concluding with research and practical implications. The reader is encouraged to consult the analysis in Chapter 2 wherever needed for more information in the construction elements, their use and effects. This chapter contains material appeared in our publications[5].

This chapter is structured as follows: Section 3.1 introduces the need for an auction classification model. Section 3.2 describes the 1st Level of the proposed classification model while Section 3.3 presents a set of plug-ins which supports multi-dimensional auctions. Section 3.4 extends the model to a 2nd level by incorporating parameters to the auction mechanism. Section 3.5 provides an extended example of the use of the model and Section 3.6 gives some guidelines and clarifies instances of use. Finally, Section 3.7 concludes.

[5] Marentakis and Emiris (2010b), Emiris and Marentakis (2010b), Emiris and Marentakis (2009)

3.1 The Need for a Complete and Comprehensive Model

The range of auction types and corresponding characteristics along with their properties and interrelationships, leads to a very wide range of auctions mechanisms serving for theoretically unlimited applications and market instances; auction designer is armored with a bunch of auction elements and is free to select and use the most appropriate in order to design an auction mechanism which is applicable, efficient and robust. In order to better organize the available mechanisms and characteristics, many research works used tree-like structures of auction mechanisms representing the classification-related features of the mechanism. Wurman (2001) criticized over these representations commenting on the lack of commonalities between auctions, and first presented a systematic approach to describe the basic and fundamental parameters of auctions through parameterization.

The need for a unified classification scheme that encompasses both the auction features and the mechanism design parameters has provided the motivation for the development of a more complete, practical and usable scheme aiming not only to classify auctions but also to serve as a tool for the study and development of auction mechanisms depending on application requirements. This scheme has several practical implications and can be used to:

- Make sure we design correctly
- Make sure we design progressively
- Make sure that all "ingredients" are taken into account in forming the auction "recipe"
- To know what are auctions
- To play with alternative scenarios

The proposed Ecosystem, encompasses, unifies, and expands previous efforts and enriches the classification mentality with the necessary perspective for specific and focused parameters. The term "Ecosystem" is attributed to the following reasons: (i) it contains the most important works of the last decade in the area, (ii) it classifies these works under the auction design prism into appropriate hierarchical and logical categories, and (iii) the majority if not entirety of works to-date fall within these categories. The template is evolving as a result of maturity which reflects the specialization, refinement and elaboration, which are the products of experience and expertise.

This novel scheme corresponds to a most complete and updated taxonomy as it is based on the literature examined in Chapter 2 and takes into account the most recent research results and conclusions. It is referred to as *Auctions Classification Ecosystem (ACE)* since it encompasses all known taxonomical parameters. Due to its completeness and the unification between features and mechanism design parameters, it may also serve as the basis for analysis and development of future works and applications.

The proposed ACE in its current form has several properties:

- It is quite complete (a significant part has been mapped, nevertheless there may exist "unexplored" areas)
- It is practical
- It is integrated
- It is expandable, updateable and adaptable.

3.2 ACE Level-1: Auction Mechanism Customization

The first level of the proposed taxonomy Ecosystem, combines and interfaces the works of Wurman (2001), Fasli and Michalakopoulos (2005), and He et al. (2003). In particular, the first level illustrates the contributions of each of these works, fine-tunes the terminology and categories of characteristics for classification and indicates the branching of criteria that when combined lead to the fundamental auction types outlined in the bottom of the scheme.

The results and benefits of this integration that occurs in the first level are the following: (i) the researcher is assisted in selecting the auction type most appropriate for his application and in determining instantly the necessary values of the auction characteristics, and (ii) the researcher and the practitioner have the ability to contrast and compare a desired auction type with other potential ones that result by altering the value of one or more auction characteristics. The ACE-Level-1 is depicted in Figure 3.1.

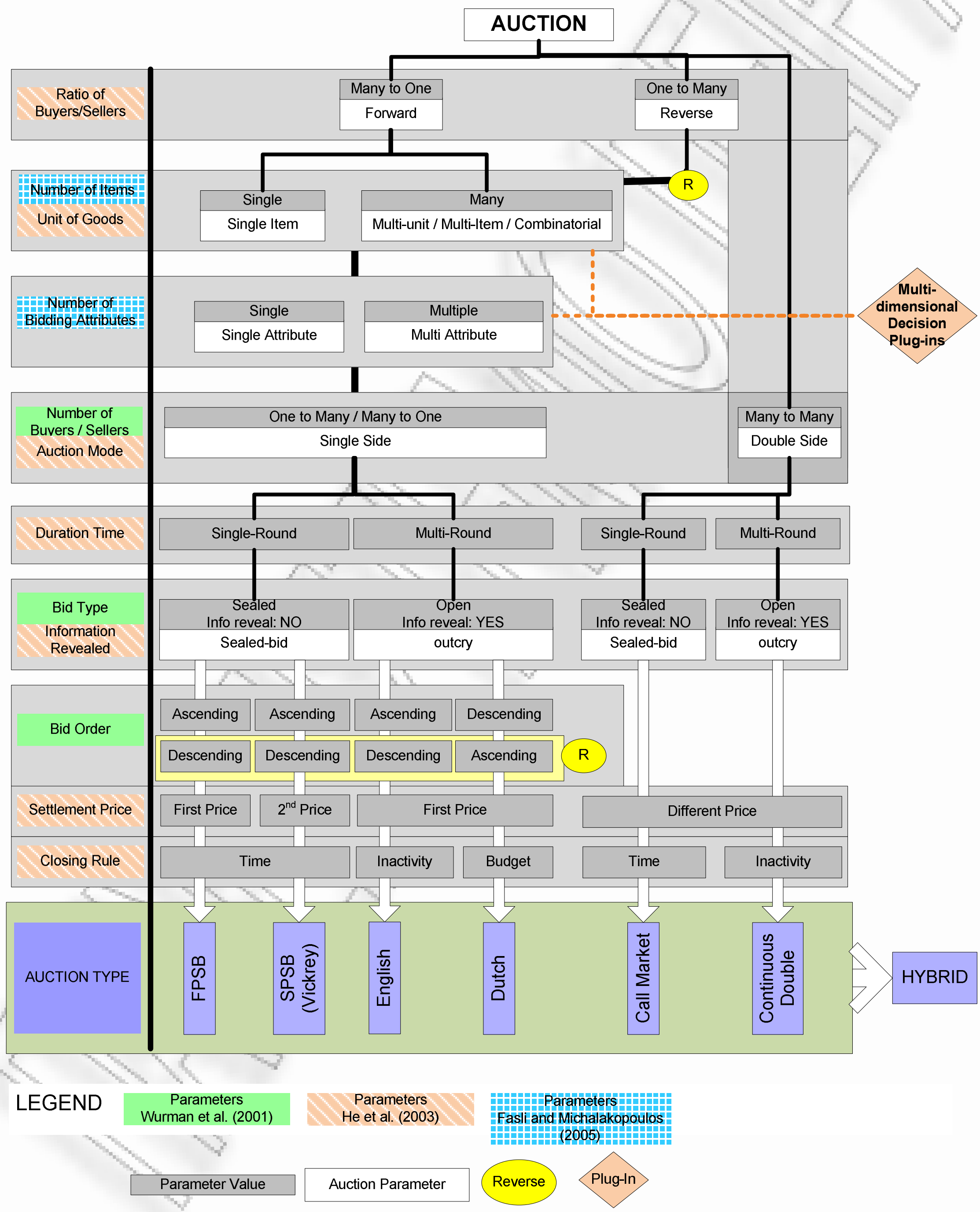

Figure 3.1: *Auction Classification Ecosystem (ACE) – Level-1*

The leftmost area of the scheme contains the parameters that characterize an auction beginning from the ratio between buyers and sellers. Each of these parameters has been retrieved from the three research papers stated before which are characterized with the use of different colors and filling patterns. For each of these parameters, available parameter values are presented on the rightmost area of the model. For each of these values, the corresponding auction characterization is presented in a box located underneath. Alterations for reverse auctions are clearly stated with the use of the “R” character. Focusing on multidimensional auctions, a special gateway integrates the 1st level with plug-ins for decision-making for multi-dimensional auctions. At the bottom of the model the most common auction types are characterized based on the values assigned to the parameters. Finally combinations of common auction formats lead to the creation of hybrid auction mechanisms.

The customization process begins with the definition of the ratio between buyers and sellers; this is a central question which characterizes the market as a “seller-initiated” (corresponding to forward auctions), “buyer-initiated” (corresponding to reverse auction), or “exchange” (corresponding to double auction), based on the analogy between participating buyers and sellers. The next two decisions relate to the multi-dimensional nature of the auction, based on decisions related to the number of items, units and valuated attributes. After that, the next decision relates to the number of rounds through which the auction will evolve, characterizing the mechanism as “single-“or “multi-round”. The next decisions relate to the visibility of bids (characterizing bids as “sealed” or “outcry”, and the ordering of bids in the auction process characterizing bids as “ascending” or “descending”. Notably, the order of bids is inverted in auctions that have been characterized as reverse and marked with the letter “R”. The next decision associates the auction winning price with the winning bid which can be the 1st best, the 2nd best or different for each bidder. Finally, the last decision defines the closing conditions of the auction. After this step-by-step customizing approach, the ACE Level-1 leads to one of the basic auction types.

3.3 ACE Level-1 Plug-ins: Multi-dimensional Auctions

The inherent complexity of multi-dimensional auctions has given rise to the study of three main problems, namely, (i) the bidding language problem, (ii) the bid formation problem, and (iii) the winner determination problem. Not surprisingly, the majority of the works reviewed in Chapter 2 deals with one or more of these issues, since these also are the link between auction theory and other research areas, such as operational research, information technology, etc. A summary of the critical decisions that participants face before, during and after the auction according to the literature is shown in Table 3.1.

As an example, if an auctioneer wishes to sell a specific quantity of air tickets, some of the decisions to be made are: the order of selling them (one-by-one or simultaneously), the accepted bid format (e.g., price only, price as a function of quantity, price as a function of specific ticket attributes like air company, direct flights, departure date and/or time) and the method to evaluate accepted bids, to determine the winner and the paying price. At the same time, depending on the mechanism parameters, a bidder must decide on what tickets to bid for, when to submit bids, how much to bid and the possible trade-offs between price and tickets attributes. The bidder, for instance, may wish to submit two bids, one for tickets with desired airline and travel date and time and one without constraints (e.g., airline, departure time, etc.) but at a lower monetary price. In the 1st level of ACE a gateway links the mechanism design process with a set of special plug-ins which supports decision-makers (auction designer and bidder) in multi-dimensional auctions. The present section culminates with the presentation of four decision models that help the auctioneer and bidder in shaping their strategy for any multi-dimensional auction.

		MULTI-DIMENSIONAL AUCTION TYPE			
		Multi-Attribute	**Multi-Unit**	**Multi-Item**	**Combinatorial**
DECISION	**Bidding Protocol**	Allowable combinations of attributes	Bid-submission process and activity rules	Bundles / separate - testing for synergies	Communication complexity
		Allowable number of winners	Sequential / Simultaneous	Sequential / Simultaneous	Bidding language
					Allowable bundles
	Bid Submission	Optimal bid formation	Bid amount relevant to units and budget	Selection of (number of) items	"Package" or "Contingent" bid formation
	Bid Evaluation	Complexity reduction	Item allocation	Item allocation	WDP - optimal solution complexity (winners, bundles, prices)
		Selection of bidding attributes	Winning price	Winning price	
		Attributes' relative importance (weight)			

Table 3.1: *Overview of Decision-Making Problems for Multi-Dimensional Auctions*

The rest of the present chapter presents graphical summarization of the relevant research on the major decision-making problems in the area of the multi-dimensional auction formats. In these figures, the various components are categorized as: (i) *decision elements*, where the designer has to reach a decision, (ii) *options*, which may also include methods and techniques from which the designer may select in order to reach a decision, (iii) *constraints*, which are factors that affect the auction design, (iv) *methods and techniques* proposed in the literature and (v) *auction types* that correspond to specific combinations of the decision elements. The notation is shown in Figure 3.2.

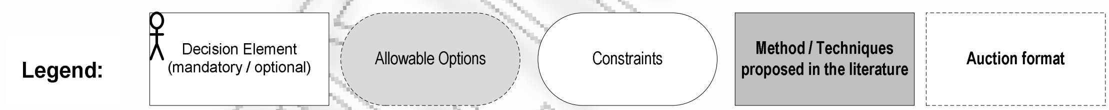

Figure 3.2: *Decision-Making Components Schematics*

In this depiction, the humanoid picture clarifies these elements where the auction designer needs to provide input, either by selecting among options or by entering data. The schematic formulation uses solid rectangles for the decision elements, dashed ovals for the allowable options and solid ovals for constraints. The methods and techniques proposed in the reviewed literature are clearly shown as shaded rectangles while the resulting auction formats are depicted by dashed rectangles; wherever needed, dependencies between elements are shown with dashed lines. The employed notation is generic and although it resembles to, yet it does not fall into any standard modelling method or a notation format for the development of software architectures; nevertheless, it intends to contain and associate the core information for the further design of applications independent of modelling tool or language.

The proposed mapping may serve as a tool for the coherent communication of the auction parameters to interested bidders and a means for fair treatment since the full auction representation is clear; moreover, bidders may use this representation for the selection of decision tools and methods to support their bidding strategy.

Finally, the proposed representation is useful for researchers wishing to standardize research on auction formats, their parameters and interdependencies. The current segmentation (bid formation, bid submission and winner determination) permits the study of the entire auction lifecycle, the transition and interaction between different stages, and may serve as a common and comprehensive language for the description of the mechanism to application designers, in which case, the model may provide required information at a glance.

3.3.1 Multi-attribute Auctions

Important decisions to be taken, consider primarily bid formation, bid submission and winner determination issues as described above. Based on the models of the literature that have been examined, the decision-making scheme in Figure 3.3 has evolved. The indicative graphical representations serve as templates to map the core decision areas an auction designer faces, namely, the allowed bids and related parameters, the bid submission procedure, and the method for winner determination and price paid. In these illustrative representations, the auctioneer needs to define parameters on the format of the accepted bids (where bids consist of a price and attribute value vectors) and allowable combinations of attributes in each bid. A set of various types of constraints, such as, reserve price or predefined bundles of attributes for bidding, may be set to maximize the auctioneer's revenue or simplify the post-auction processes. Another decision area may focus on the evolution and closing of the bidding procedure, where the auctioneer defines the number of bidding rounds, the bid ranking, the bid visibility and how the bidding process terminates. In most cases these parameters lead to one of the standard or hybrid auction types denoted with dashed rectangles in the right side of the decision box. Once the bidding process is completed, a number of available options can be combined to determine the winner(s) and the price paid. In this stage, the auctioneer may define the bid comparison criteria, the bid evaluation function, the number of winners and the degree of results revelation through a range of available options. His/her decision may be affected by a number of exogenous or item-related constraints such as comparability of offers or weights.

Quite often, decision elements are interconnected according to the selected option; for example, if the auctioneer selects to sell the item through a multi-round iterative auction in the bid submission phase, then he should select whether to maintain or revise the bid evaluation function in each round. The shaded boxes in the Figure 3.3 are used to show methods and techniques proposed in the literature to cope with specific decision elements; for example, Analytical Hierarchy Process (AHP) may be used to estimate price and attribute values either by bidders (bid formation) or by the auctioneer to make estimates on bidders' behavior. Overall, the proposed representation can be used by the auctioneer to develop detailed models of auction mechanisms; these models are extendable and may be further analyzed and extended in the design of electronic auctions, and/or can be enriched with more options, constraints and auction mechanism elements.

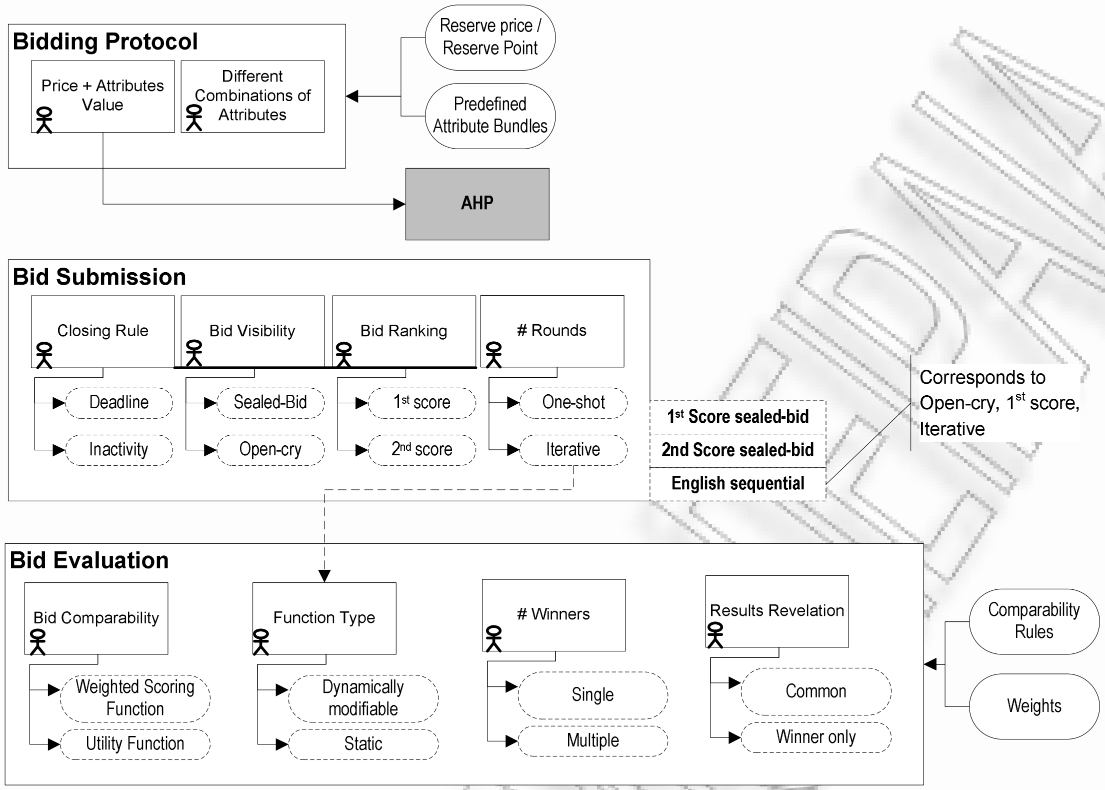

Figure 3.3: *Decision-Making Issues in the Design of Multi-Attribute Auctions*

Similar representations are also analyzed for multi-unit and multi-item auctions in the respective sections.

3.3.2 Multi-unit Auctions

Based on the findings described in Chapter 2, a graphical overview of important decisions on bid formation, submission and winner determination issues as described before is given in Figure 3.4. In the multi-unit auction the designer has to decide on the format of the accepted bids. Since the number of units is >1 he has to decide whether bidders are allowed or bound to submit a single bid for a specific number of units or multiple bids for different number of units. In any case he has to apply constraints related to the activity rules. Depending on these rules a number of hybrid auction formats are available for use.

The next step in the customizing process deals with the design of the auction workflow and restriction during the bidding phase. The basic decisions which may alter the mechanism are the closing rule, the visibility of each bid, the bid ranking and, the number of rounds. For each of them, a set of available options are present which are ground to the customizing process of the ACE Level-1. This customizing process results –usually- in hybrid mechanisms, for example a *sequential* auction mechanism (if the engineer decides to iteratively auction the units of the item). In this case he has to decide and define in detail custom (and non generic) parameters – for example whether the mechanism will provide information about the winning bid in each round. On the other hand he is able to use a knowledge base to select from sets of appropriate methods for example to estimate the optimal unit ranges in each round. In any case the designer is able to apply special constraints in order to enhance the robustness of the mechanism.

The final step deals with the definition of the winning bids and the corresponding payments. For the first decision, the designer has to select from a set of available options, for example N highest or N which exceed (in the forward auction) a predetermined threshold price, which defines a minimum acceptable unit price. Next, he has to select the payment calculation rule from a set of options (e.g., pay-your-bid, all winners pay same bid, weighted bid etc.). Depending on the payment calculation rule, several hybrid mechanisms are available for use which can further be hybridized to generate more efficient auction mechanisms.

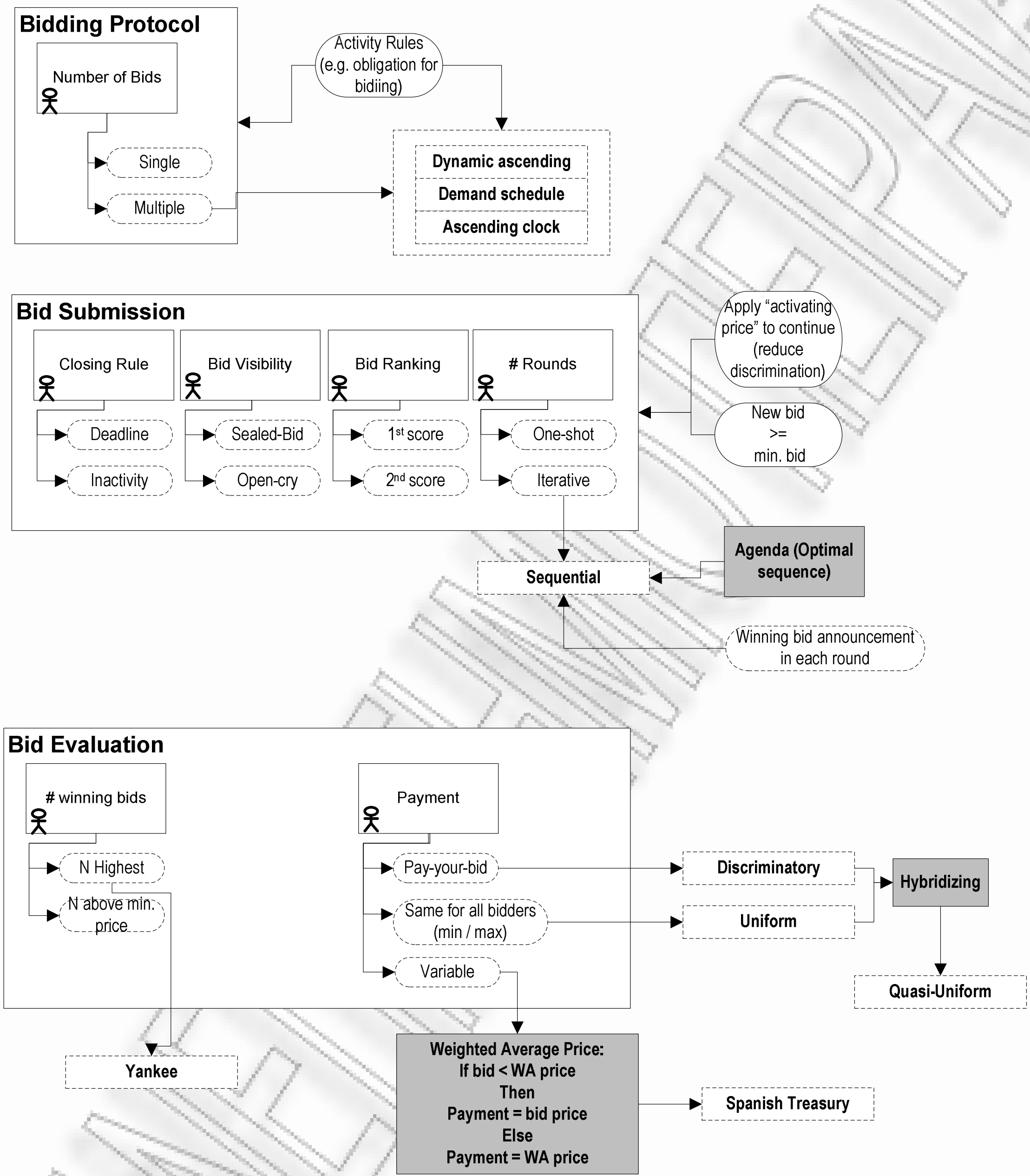

Figure 3.4: *Decision-Making Issues in the Design of Multi-Unit Auctions*

3.3.3 Multi-item Auctions

A graphical overview of some important decisions on selling method, bid formation and integration with multi-unit and combinatorial auctions is given in Figure 3.5. The core decision in the multi-item auction relates to the degree of complementarity between auctioned items which can be evaluated and checked with the use of synergy-testing method. Based on the results, he decides whether to set items for auction separately or in bundles and use a heterogeneous multi-item mechanism or a combinatorial one, respectively.

Finally, in both cases the auctioneer has to define whether the auction will evolve through a single or multiple rounds, characterizing the auction mechanism a *simultaneous* or *sequential* respectively.

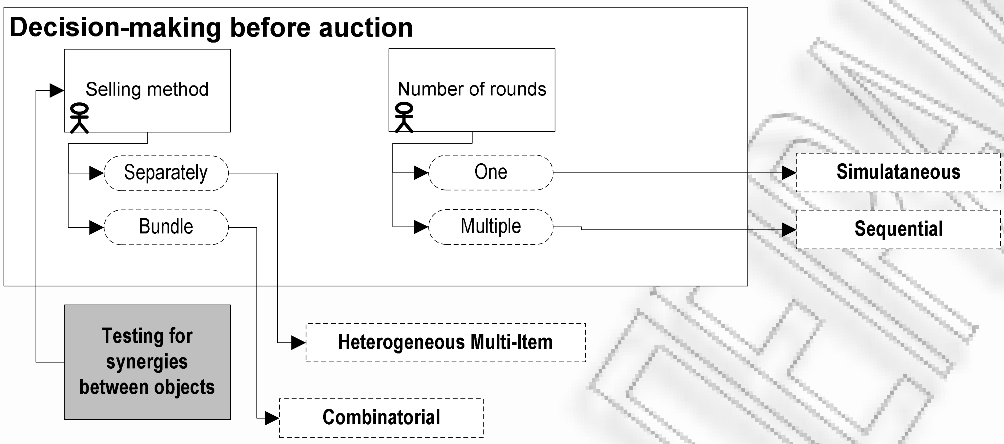

Figure 3.5: *Decision-Making Issues in the Design of Multi-Item Auctions*

3.3.4 Combinatorial Auctions

Since combinatorial auctions constitutes a special and sophisticated form of multi-item auctions, it is assumed that a “testing for synergies between objects” technique has been applied (described in the previous paragraph) to assure that complementarities between items exist. A graphical overview of some important decisions on selling method, bid formation and integration with multi-unit and combinatorial auctions is given in Figure 3.6.

Assuming that positive complementarities between items exist, the designer has to decide on several other parameters which relate to the number of acceptable bids from each bidder, the desired number of auction rounds, the number of items and units and the ratio between buyers and sellers. Specific combinations of values for these parameters lead to more advanced hybrid auction mechanisms beyond simultaneous and sequential for example, “dynamic ascending”, “demand schedule”, “ascending clock” and “simultaneous clock” which can be enhanced with activity rules to enhance, safeguard or restrict the available bidding processes. For more complex cases (i.e. double combinatorial auction) the designer may consult supportive methods for example, the *Tree Based Bidding Language (TBBL).*

Equally complex problems in combinatorial auctions, relate to the design of the bid submission stage of the auction. Same as before, the designer has to decide on the closing rule, the bid visibility, the bid ranking, the number of rounds and –most importantly- on a complete, informative, safe and comprehensive *bidding language* expressing bidder’s requests for *bundles* or *contingent bids*. After that, the designer then has a bouquet of standard combinatorial auction mechanisms proposed in the literature to select from. If the auction is sequential, then the designer has to setup specific strategies for revelation of information after each round.

The final stage relates to the Winner Determination Problem which is native to the combinatorial auctions; the auctioneer has to allocate *optimally* bundles of auctioned items based on combinatorial bids set by the bidders. The WDP is a typical *knapsack problem* which is *NP*-hard and it is studied mainly by operational researchers. Many research findings exist and many solution (mostly suboptimal) algorithms and methodologies have been proposed in the literature and are stated in the model.

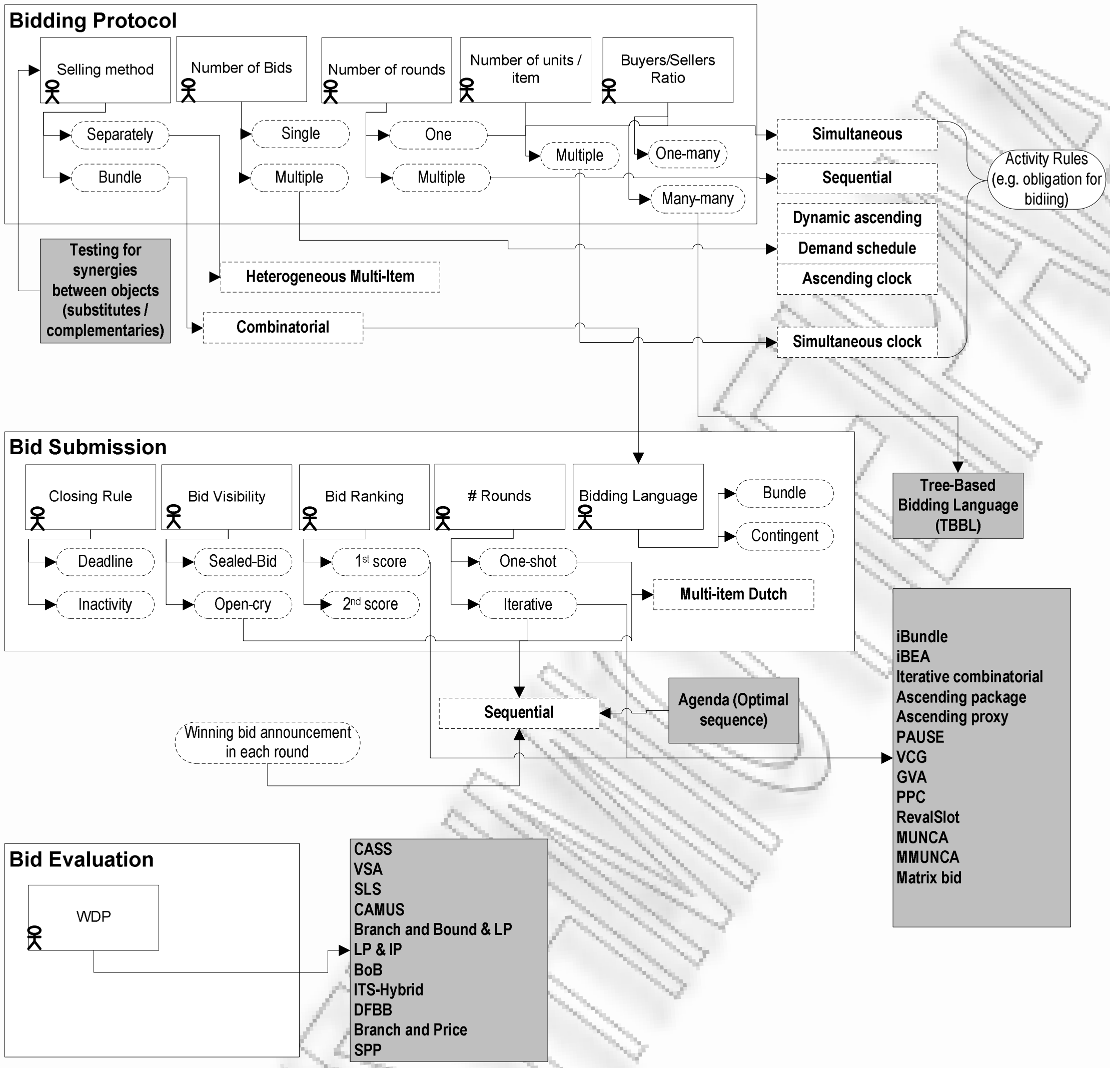

Figure 3.6: *Decision-Making Issues in the Design of Combinatorial Auctions*

3.4 ACE Level-2: Auction Characteristics

The expansion of the classification of auctions to a second level comes as a necessity. The second level depicted in Figure 3.7, in essence digs into detail the auction parameters and further crisps the taxonomy and design effort. It is incorporating additional mechanism design parameters on these fundamental auction types to enhance their effectiveness and robustness. Specific single or combined parameters infuse improvements in various auction properties like outcome, rivalry, security etc. and they are able to alter the efficiency and outcomes of the process to a considerable degree.

The first and second tier of the classification scheme ("*Parameter Class*" and "*Parameter Group*") has been defined through a broad literature review in the area of auctions and auction theory and applications as described in Chapter 2. Needless to say, the parameters stated in each group may be further extended in order to generate more sophisticated mechanisms; furthermore, additional groups may be used to support the contemporary auctions conducted over electronic and mobile networks. The interrelationship between these parameters and the possible effects lies outside the scope of this thesis.

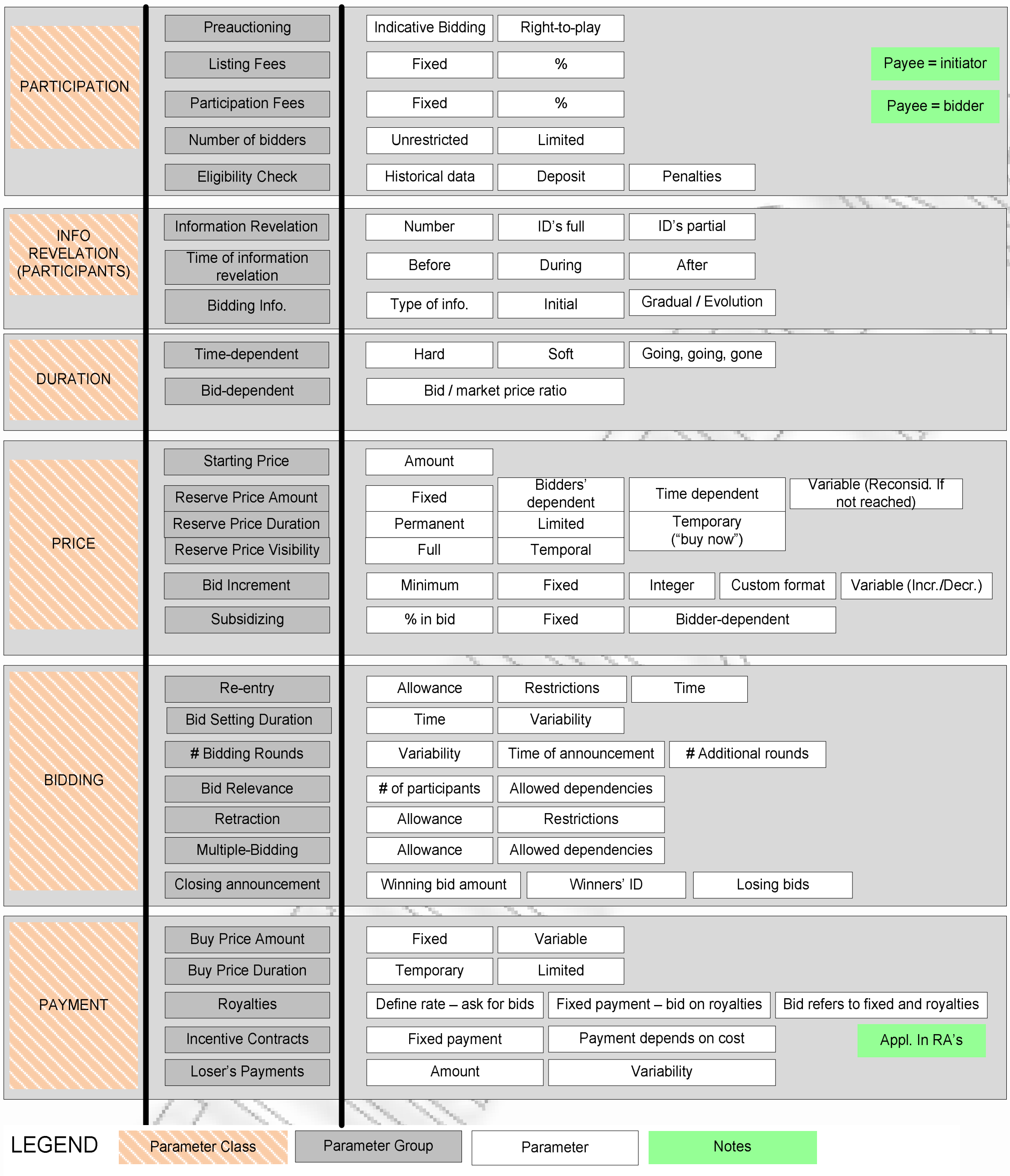

Figure 3.7: *Auction Classification Ecosystem (ACE) – Level-2*

At the core of the 2nd level are the *groups of parameters* denoted by grey rectangles. These have been classified in corresponding *classes of parameters* denoted by patterned rectangles. Each group contains several *parameters* obtained from the literature. The format and value range for each parameter is predefined according to specific data types shown in Table 3.2.

Parameter Class	Parameter Group	Parameter	Type	Range
Participation	Preauctioning	Indicative bidding	Currency	>0,00
		Right to play	Currency	>0,00
	Listing fees	Fixed	Currency	>0,00
		%	%	>0,00
	Participation fees	Fixed	Currency	>0,00
		%	%	>0,00
	Number of bidders	Unrestricted	Binary	Yes/No
		Limited	Numeric	Integer>2
	Eligibility check	Historical data	Numeric/Text	
		Deposit	Currency	>0,00
		Penalties	Currency	>0,00
Info. Revelation	Info. Revelation	Number	Alphanumeric	Unlimited Length
		ID's full	Alphanumeric	Unlimited Length
		ID's partial	Alphanumeric	Unlimited Length
	Time of Information Revelation	Before	Time	DD/MM-HH:MM
		During	Time	DD/MM-HH:MM
		After	Time	DD/MM-HH:MM
	Bidding Info	Type of Info.	Alphanumeric	Unlimited Length
		Initial	Alphanumeric	Unlimited Length
		Gradual/Evolution	Alphanumeric	Unlimited Length
Duration	Time-dependent	Hard	Time	DD/MM-HH:MM
		Soft	Time	DD/MM-HH:MM
		Going, going, gone	Time	DD/MM-HH:MM
	Bid-dependent	Bid/market price ratio	%	>0,00
Price	Starting price	Amount	Currency	>0,00
	Reserve price amount	Fixed	Currency	>0,00
		Bidders' dependent	Currency & Numeric	>0,00 & Integer >0
		Time dependent	Currency & Time	>0,00 & DD/MM-HH:MM
		Variable (dynamic)	Currency	>0,00
	Reserve price duration	Permanent	N/A	N/A
		Limited	Time	DD/MM-HH:MM
		Temporary	Time	DD/MM-HH:MM
	Reserve price visibility	Full	Binary	Yes/No
		Temporal	Binary	Yes/No
	Bid increment	Minimum	Currency	>0,00
		Fixed	Currency	>0,00
		Integer	Currency	>0
		Custom format	Alphanumeric	Unlimited Length
		Variable (Incr/Decr)	Currency	Real number
	Subsidizing	% in bid	%	>0,00
		Fixed	Currency	>0,00
		Bidder-dependent	Currency	>0,00
Bidding	Re-entry	Allowance	Binary	Yes/No
		Restrictions	Alphanumeric	Unlimited Length
		Time	Time	DD/MM-HH:MM
	Bid-setting duration	Time	Time	DD/MM-HH:MM
		Variability	Alphanumeric	Unlimited Length
	# Bidding rounds	Variability	Binary	Yes/No
		Time of announcement	Time	DD/MM-HH:MM
		# Additional rounds	Numeric	Integer>1
	Bid relevance	# of participants	Numeric	Integer>1
		Allowed dependencies	Alphanumeric	Unlimited Length
	Retraction	Allowance	Binary	Yes/No
		Restrictions	Alphanumeric	Unlimited Length
	Multiple bidding	Allowance	Binary	Yes/No
		Allowed dependencies	Alphanumeric	Unlimited Length
	Closing announcement	Winning bid amount	Currency	>0,00

		Winner's ID	Alphanumeric	Unlimited Length
		Losing bids	Alphanumeric	Unlimited Length
Payment	Buy price amount	Fixed	Currency	>0,00
		Variable	Currency	>0,00
	Buy price duration	Temporary	Time	DD/MM-HH:MM
		Limited	Time	DD/MM-HH:MM
	Royalties	Define rate – ask for bids	Currency	>0,00
		Fixed payment – bid on royalties	Currency	>0,00
		Bid refers to fixed ad royalties	Currency	>0,00
	Incentive contracts	Fixed payments	Currency	>0,00
		Payments depend on cost	Currency	>0,00
	Losers' payments	Amount	Currency	>0,00
		Variability	Currency	>0,00

Table 3.2: *ACE-Level-2 Parameters and Data Types*

The 2nd level currently contains 6 classes of parameters, namely: (i) Participation, (ii) Information Revelation, (iii) Duration, (iv) Price, (v) Bidding, and (vi) Payment. These are briefly explained below:

- The *participation class* contains parameter groups related to the number of eligible participants, the pre-auction screening process, the imposition of listing and/or participation fees, etc. Each of these groups contains a pool of parameters to select from and valuate; for instance, the designer may decide to impose participation fees (so he activates this parameter group) and he then has to select whether the participation fee will be a fixed amount prior to the auction or a percentage of the revenue generated in the auction after the completion of the process.
- The *participants' information revelation class* contains parameters related to the extent of the information that will be revealed and the exact timing; for instance, the designer here can choose to reveal full participants' IDs before the beginning of the auction as well as the evolution of the bids (actually these parameters emulate the "going-going-gone" physical auction).
- The *duration class* contains parameters that may define, affect or alter the duration of the mechanism, classified in two basic parameter groups, the time-dependent and the bid-dependent parameters. Time dependent parameters define whether the auction will close at a fixed time or after a specific time of inactivity, while the bid-dependent parameters define closing points based on indices which are functions of the market/reserve/bid price.
- The *price class* contains parameters that may apply to reveal information, to safeguard the process, and to strengthen competition. Its parameters are grouped according to the starting price (amount if selected), the reserve price (amount, visibility, and temporality), the acceptable bid increment (fixed, dynamic, number of decimals etc.) and the bidders' subsidizing (fixed, percentage or bidder-dependent).
- The *bidding class* contains the parameters that define the bidding process; the groups of parameters in this class imply the "rules" of the bidding process - most important of them being the allowance to re-enter a bidding process after quitting (also the allowed time and the relevant restrictions), the time window to submit a bid (and extensions), the number of rounds for multi-round auctions (and options and conditions for extensions), the bid relevance to the number of participants (requiring revelation of participants before or even after the auction process), options for submitting multiple bids (especially in simultaneous auctions), and the information revealed after the end of the auction.
- Finally, the *payment class* contains parameters which define or alter the market revenue. These parameters are assigned to groups related to buy-price options

(application, format and temporality), to royalties (bid relevance to rates or royalties), incentive contracts (fixed or contractual payments) and application of losers'-payments (for example in charity auctions).

The second level is valuable for the expert auction designer who wishes to shape the auction by determining mechanism parameters not evident in the first level. As an example, the parameters group under the Price label contains the starting price, the reserve price amount, duration, visibility, the bid increment and subsidizing. Evidently, these are parameters that affect the evolution of an auction; yet, they are to be handled by designers with expertise and familiarity with these concepts. As a result, the benefits of the classification exposed in the second level are that: (i) it constitutes a natural extension and deepening into the study of auction design and handling, (ii) it serves as a tool to design efficient, fair, and structured (thus safer) auction schemes, (iii) it further crisps the taxonomy effort and, (iv) infuse improvements in various auction properties like outcome, competition and security.

3.5 An Example Application

The present section illustrates an application of the ACE-Level-1 and 2 in the freight transportation area in order to show its superiority against other classification schemes. We select four multi-dimensional freight transportation auctions from the literature and use the widely-used tree-like representation to describe them. Then, we select one of these mechanisms and customize it using the ACE Level-1 and 2.

3.5.1 Conventional Classification Systems

A comprehensive exploration of latest and current research material on the application of auctions in freight service trading shows that the majority of research attempts focuses on the design, analysis and application of special auction formats with non-standard characteristics applying for selling (forward), procurement (reverse) or both (double) purposes. Some of the most important and widely-studied auction formats belong to multi-dimensional auctions and exchanges which have been adopted in freight services by Caplice and Sheffi (2003), Sheffi (2004), Garrido (2004), Agrali et al., (2008). These are:

- *Multi-attribute freight auctions*. This format applies when the negotiating parameter is not solely the price but various other load/truck or trip related attributes either endogenous or exogenous. These attributes are given a weighted value and applied as a coefficient in the monetary bid.
- *Multi-unit freight auctions*. This format applies when for example the buyer needs to buy sets of multiple identical services. The same applies for the forward auction case. When trips are not identical then the auction is characterized as a multi-item freight auction.
- *Combinatorial freight auctions* (stated also as "combined-value" auction). This is a special but very useful and widely applied format that supports positive complementarities between freight transport itineraries. In this case, carriers submit contingent bids for multiple continuous freight transport lines aiming to increase their revenues from "economies of scope" (i.e., line continuity, freight consolidation).
- *Double freight auction.* This format supports the simultaneous bid and offering from carriers and shippers operating as a bidding "exchange". This format is difficult to analyze and operate as it shows strong complexity.

Table 3.3 summarizes a combination of classification schemes transforming the tree-like structure adapted for ACE Level-1 into a tabular form.

Feature	Value	Description	Value	Description
Ratio of Buyers/Sellers	Many to one	Forward	One to Many	Reverse
Nature of Traded Goods	Single Good	Item(s) of same type	Combinatorial	Item(s) of different type
Item Units	Single	Bid for a single item	Multi	Bid for bundles of items (similar, complementary or different)
Dimensions (Attributes)	Single	Price is the only criterion for bid formation and evaluation	Multi	Multiple criteria for bid formation and evaluation
Sides	Single	Buyer or seller set bid	Double	Buyer and seller allowed to bid
Duration	Single-round	One-shot	Multi-round	Outcry
Bid Type	Outcry	Each bidder has information on other bids	Sealed-Bid (SB)	Only auctioneer has access to all bids
Price	First	Winner pays his bid	k-th	Winner pays the price of the k-th ranked bid
Bid order	Ascending	Increasing bid order	Descending	Decreasing bid order
Closing rule	Time	Deadline	Non-time	Inactivity / Budget

Table 3.3: *Tabular Classification Scheme*

Tree-like auction classification schemes have being used by many researchers to date when referring to auction classification; nevertheless, the association with the design parameters is not evident in this representation. Emiris and Marentakis (2009) used this scheme to present in tabular form the customization result for some indicative auctions in the freight transportation business area as described in the literature (Table 3.4)

Reference	[2] Caplice and Sheffi, 2003	[3] Sheffi, 2004	[4] Garrido, 2007	[5] Agrali et al., 2008
Ratio of Buyers / Sellers	One to Many (Reverse)	One to Many	Many to Many	One to Many (Reverse)
# Items - Unit of Goods	Multiple lines (package bids)	Multiple lines (package bids)	Multiple lines (package bids)	Single lane (Full TL)
# Bidding Attributes	Single (price)	Multiple attributes (Level of Service)	Single (price)	Price
# Buyers / Sellers - Auction Mode	Single Side	Single Side	Double Side	Single Side
Duration	Single and Multiple rounds	Single round (preferable)	Multiple rounds (sequential)	Single round
Bid Type - Info. Revealed	N/D	N/D	N/D	Sealed-bid
Bid Order	Descending	Descending - Price modified according to Price/Service Trade-off	Depends on demand / offer	Descending
Settlement Price	N/D	Modified package	N/D	Second-lowest
Closing Roule	N/D	N/D	N/D	Instantaneous
AUCTION TYPE	N/D	N/D	N/D	SPSB (Vikcrey)
N/D: Not Defined				

Table 3.4: *Classification of Some Indicative Freight Auctions*

Obviously the number of research resources presented in this table is limited; they have been selected to provide a rough-cut illustration of the preliminary configuration template; previous findings, however, from an extended literature research showed that the auctions selected here are representative for the most frequently used freight auctions.

3.5.2 Applying ACE for Auction Customization

We will now demonstrate a respective customization of a more complex freight auction (Emiris and Marentakis, 2010b) using ACE. This freight transportation auction is more complex and advanced compared to the mechanisms described in the previous section since it entails additional mechanism-enhancing parameters.

For the ACE 1st Level the description notation will be as follows:

PARAMETER ➔ PARAMETER_VALUE ➔*AUCTION_CHARACTERIZATION*

In the following table (Table 3.5) we provide the case description and transform the elaboration into auction mechanism.

The auction is initiated by a logistics center (auctioneer) for procurement of freight transportation services for a number of shipments auctioned in rounds (one shipment per round). Several carriers participate and compete in the auction, offering their services	RATIO_BUYERS/SELLERS → ONE_TO_MANY → *REVERSE*
The logistics center sets for auction a single freight each time	NUMBER_OF_ITEMS → SINGLE → *SINGLE_ITEM*
Submitted bids from carriers have only monetary dimension so the bid evaluation criterion is the bid price	NUMBER_BIDDING_ATTRIBUTES → SINGLE → *SINGLE-ATTRIBUTE*
Each round of the auction deals with a single shipper's shipment while several carriers compete for the project	NUMBER_BUYERS/SELLERS → ONE_TO_MANY → *SINGLE-SIDED*
The auction evolves in a series of rounds – one for every shipment	DURATION_TIME → MULTI-ROUND → *MULTI-ROUND*
The bid amount is proposed by the auctioneer, it evolves gradually and the bid evolution is visible to all bidders	BID_TYPE/INFO_REVEALED → OPEN_INFORMATION_REVEALED → *OUTCRY*
The evolution of bids (controlled by the auctioneer) is increasing	BID_ORDER → REVERSE → *ASCENDING*
The settlement price is not defined using a standard mechanism so this parameter is ignored in this design stage. Nevertheless, it will be customized in the 2nd Level.	-
Finally, the auction process ends when the price reaches the designated winning bidder's budget restrictions reflecting his valuation	CLOSING_RULE → *BUDGET*

Table 3.5: *Customizing the Auction Mechanism*

These parameters are visualized in the 1st level of ACE using red circles. The customizing process results to an auction mechanism which has the characteristics of the Dutch auction mechanism (Figure 3.8).

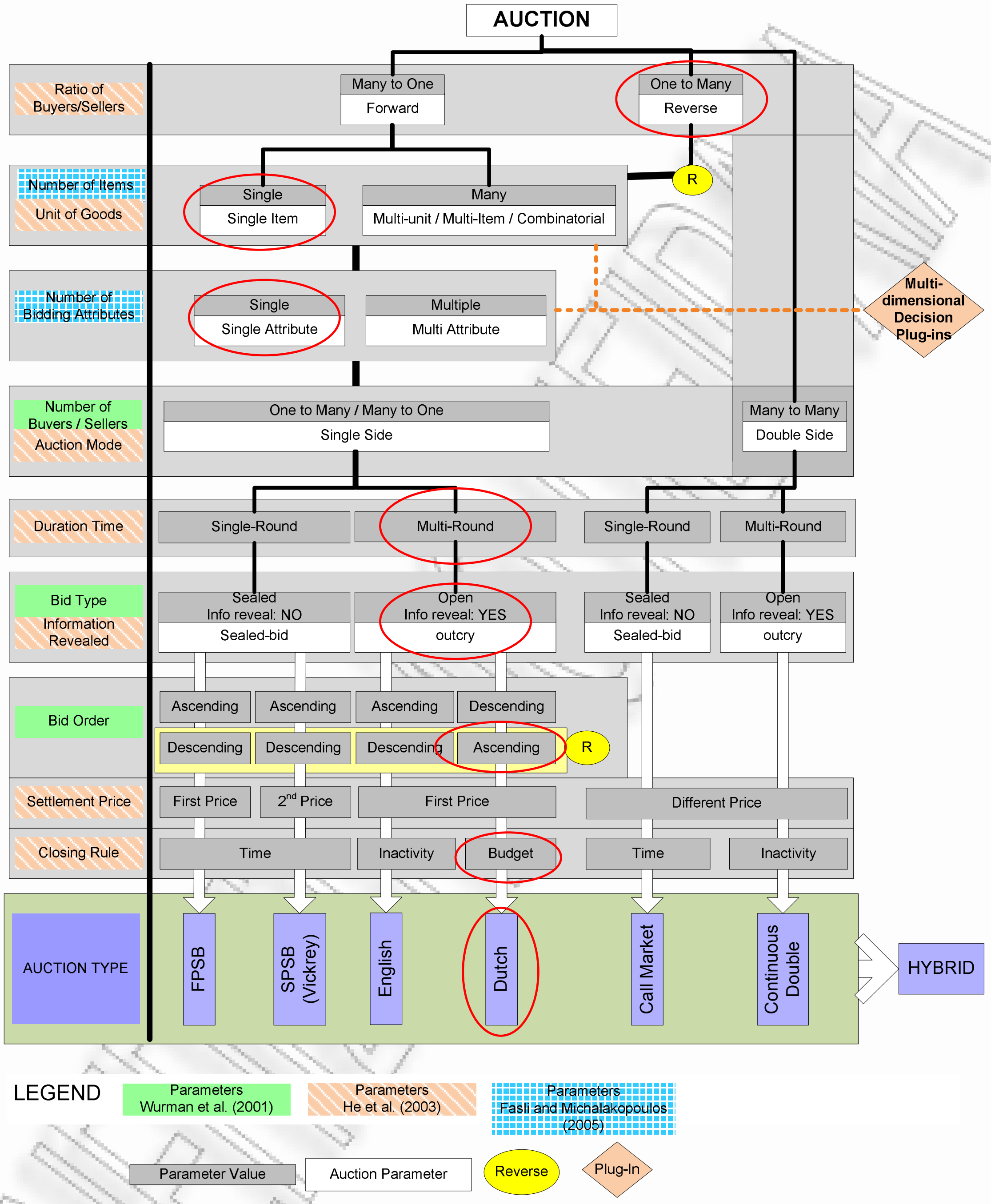

Figure 3.8: *Customizing ACE Level-1*

The resulting mechanism from Level-1 is further expanded and strengthened in ACE Level-2 which is used for the detailed customization of these additional parameters. For the ACE 2nd Level the description notation will be as follows:

PARAMETER_CLASS ➔ GROUP ➔ PARAMETER

In the following table (Table 3.6) we provide the case description and transform the elaboration into auction parameters.

GROUP1 The first group of parameters controls participation characteristics.	
The revenue-generating mechanism for the auctioneer is based on collecting fees from auction initiators which are expressed as a percentage of the market price	PARTICIPATION ➔ LISTING_FEES ➔ %
In order to attract only seriously-interested bidders the number of invited bidders is limited and each of them pays a participation fee which is a % of the market price	PARTICIPATION ➔ PARTICIPATION_FEES ➔ % and PARTICIPATION ➔ NUMBER_OF_BIDDERS ➔ LIMITED
Eligible bidders are registered in auctioneer's database paying a subscription fee which is used as a security deposit	(PARTICIPATION ➔ ELIGIBILITY_CHECK ➔ DEPOSIT
GROUP2 The second group of parameters controls the information revealed to participants	
In the current auction each participants identity is visible to all participants before the auction begins	INFO_REVELATION ➔ INFORMATION_REVELATION ➔ ID_FULL INFO_REVELATION ➔ TIME_INFORMATION_REVELATION ➔ BEFORE
The information related to the bidding process is gradually provided to participants (which is an intrinsic process for the Dutch auction)	INFORMATION REVELATION ➔ BIDDING_INFO ➔ GRADUAL/EVOLUTIONARY
GROUP3 The third group of parameters controls the duration of the mechanism	
By nature, the Dutch auction has a fixed and non-expandable duration (a maximum duration and an actual duration which is realized when the winning bidder stops the auction)	DURATION ➔ TIME-DEPENDENT ➔ HARD
GROUP4 The fourth group of parameters corresponds to the control the auctioneer has over the price	
The reverse Dutch mechanism begins from a low price and gradually increases. Here, the low price is a specific amount equal or lower to participating bidders' cost	PRICE ➔ STARTING_PRICE ➔ AMOUNT
The maximum allowed price equals to the market price and is reached if none of the bidders stops the auction	PRICE ➔ RESERVE PRICE AMOUNT ➔ FIXED
This maximum price is announced to all participants and remains the same until the end of auction	PRICE ➔RESERVE_PRICE_DURATION ➔ PERMANENT
In the reverse Dutch auction the price increases gradually with a constant combination of increase rate and speed pattern	PRICE ➔ BID_INCREMENT ➔ FIXED
In the specific auction the auctioneer plans to subsidize bidders (carriers) which can take up the project sooner with a premium which is a % of the winning bid	PRICE ➔ SUBSIDIZING ➔ % IN_BID and PRICE ➔ SUBSIDIZING ➔ BIDDER-DEPENDENT
GROUP5 The fifth group of parameters controls and safeguards the bidding process.	
Every eligible bidder is free to participate in any of the auctions in a series. A restriction applies for fairness which does not allow a winning bidder to re-participate for the next three auctions	BIDDING ➔ RE-ENTRY ➔ RESTRICTIONS
The available time for bidding is constant, common and known to all bidders and is being defined by Dutch auction's clock	BIDDING ➔ BID-SETTING_DURATION ➔ TIME
The number of auctions for the same item may be more than one, when for example, none bidder express his interest, so the item is re-set for auction	BIDDING ➔ #_BIDDING_ROUNDS ➔ VARIABLE
When a bidder stops the Dutch auction clock, the auction ends and he wins the project. Both the winning bid and the winner's data are announced to the non-winning participants	BIDDING ➔ CLOSING_ANNOUNCEMENT ➔ WINNING_BID_AMOUNT and BIDDING ➔ CLOSING_ANNOUNCEMENT ➔ WINNER'S_ID
GROUP6 The sixth group of parameters concerns special parameters related to future payments that are not applicable in the example examined here	

Table 3.6: *Customizing the Mechanism Parameters*

The selected parameters are represented graphically in Figure 3.9.

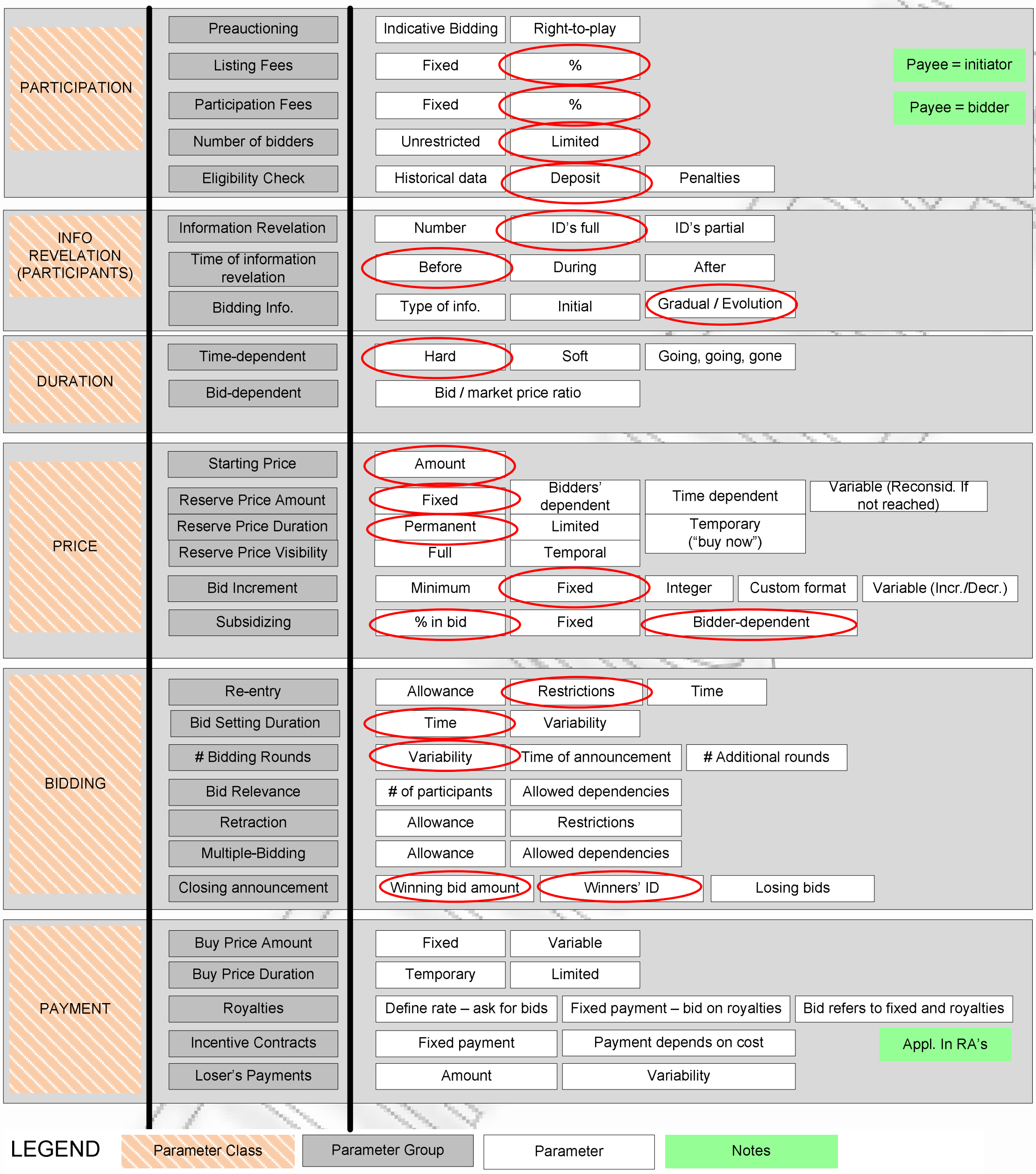

Figure 3.9: *Customizing ACE Level-2*

It is obvious that the methodology based on ACE model is more systematic, complete, integrated, informative, applicable and comprehensible. The auction designer may see at a glance the parameters of the auction mechanism; in addition, he may see what other parameters are available if he wants to expand or improve an already used mechanism.

3.6 A Note on Graphical Representations

The graphical representations are not primarily purposed to serve as a "how-to" guide for auction design; rather, they are systematic formulations and depictions of approaches presented in the majority part of the literature. These approaches are pertinent to the most important decisions that affect and define the auction design. Although alternatives to determine trading characteristics such as pricing, exist in the literature and in practice

(Laitinen, 2009; Lijun, 2008; Yan and Wang, 2009), the present Chapter is confined in examining such issues under the prism of auctions. Moreover, the aim of the plug-ins is not to evaluate the efficiency of the models that researchers have presented through the years, neither to assess the computability, convergence to the equilibrium or other mechanism characteristics in these models. Rather, the plug-ins focus on collecting and categorizing these scientific efforts and on decoding these models with respect to their inherent decision making attributes.

The decision making schemes developed in this section provide the general guidelines and framework to construct an auction and at the same time, they maintain the flexibility that is needed in order to adapt the auction in the particular application; moreover, the provided schemes are open-ended and they can be expanded as needed and enriched with new findings in the future. The purpose of the graphical representation is to isolate and classify problems bidders and auctioneers (or sellers) face in multi-dimensional auctions. Further to the selection of an auction type, the special decisions related to multi-dimensional auctions can be roughly categorized in three major categories, namely, the applied bidding protocol, the bid formation and the bid evaluation problems. An auctioneer's role is typically to decide on these special parameters and make them clear to interested bidders. The auctioneer has thus to design a robust and attractive auction mechanism with respect to the quantity and characteristics of the trading items, which will contain the bidding protocol (how and when to bid) and the bid evaluation method (winning bid, amount and winner). These mechanism characteristics should be clearly announced to interested bidders. Additionally, based on this information, each bidder has to decide on how to format his/her bid, aiming to acquire the desired items at the right quantity and quality.

3.7 Conclusion

The ACE unifies and expands previous classification efforts for auctions in a complete *Ecosystem* incorporating mechanism design parameters in order to serve as a platform for the design and study of complex contemporary auction schemes. This platform supports the development of research in an integrative manner between various auction types and parameters. The Ecosystem is based on all important research works of the last decade, including some earlier fundamental articles in order to satisfy scientific integrity, and classifies them under the auction design prism into appropriate hierarchical and logical categories. In Chapter 5 of the Thesis, the main guidelines of the present work will be followed and expanded in a 3rd level to incorporate auctions conducted over the internet as well as mobile auctions (e- and m- auctions, respectively).

The presented Ecosystem offers a comprehensive overview for practitioners in economic and game theoretic issues and can be used in:

- *Structured design of auctions*: The auction designer can use the ACE to develop an auction effectively, based on market, items and participants characteristics and to fine-tune auction parameters to match the needs of the auction or the auctioned items. It may also serve as the basis for the development of an auction setting description standard.
- *Auction analysis*: Researchers can use the ACE to empirically or experimentally analyze an auction setting. Starting from a specific state, the auction designer has an overview of the alternative parameters and related design issues, and is thus able to determine and evaluate the course of actions that need to be taken in order to make an auction fair and effective.
- *Literature and research classification*: Literature reviews may incorporate this standard to classify and assign research according to specific parameters.

- *Development of data models and software architectures*: The ACE may be used as the basis for the development of detailed data base tables, their relationships and information flow.

Last but not least, the topics presented in the present chapter cover systematically the design and implementation of multi-dimensional auction types from a decision-making perspective in both physical *and* electronic environments.

Chapter 4

Mobility and Location-Aware Auctions

Auctions conducted over Wireless Networks constitute an attractive, emerging class for m-commerce applications. The combined use of auctions with modern Location-Based Services (LBS) formulates a procurement negotiation tool supporting the announcement and execution of geographically focused auctions. LBS resulted from the unification of automatic position sensing technologies and wireless connectivity, allowing the development of sophisticated applications – frequently stated as "*killer applications*". The present chapter aims to analyze and match the properties of heterogeneous wireless networks (e.g., mobile communications, GPS) and to set a framework for the development of Reverse Mobile Auction-based Marketplaces operating in a location sensitive context applied in freight services procurement. The application examined in this chapter is a location-sensitive, reverse, m-auction application in the freight transport market where potential suppliers (carriers) are able to place bids for Less-Than-Truckload (LTL) shipments or Truckload (TL) empty trips while on the move aiming to gain revenue through *economies of scope*. The present chapter provides a comprehensive non-technical review of required technologies for the establishment and operations of location-aware services, relevant communications technologies and a typical architecture for location sensitive auctions. This chapter contains material from our published work[6].

This chapter is structured as follows: Section 4.1 presents a series of data which encourage the study of business application in the domain of m-commerce. Section 4.2 provides an overview of the ICT infrastructure for the development and implementation of mobile applications, while Section 4.3 expands the study to the evolution of location-aware services. Section 4.4 integrates auctions with location-aware services and proposes the concept of location-aware auctions. Section 4.5 highlights the added-value implications of location-aware auctions while Section 4.6 concludes.

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[6] Marentakis (2011), Emiris and Marentakis (2008), Emiris et al., (2007a)

4.1 Motivation from the Business Environment and Technological Advances

During the 90's many companies used the Internet as dot com's to advertise their products. Later, by year 2000 many of them used the connectivity properties of Internet to form e-Marketplaces not only supporting but also promoting business transactions over it, setting the basics for the transition to what later defined as electronic economy (*e-economy*). Recent developments in mobile communications enable the transition to m-business or *m-economy* which is a new business environment which removes time and place restrictions.

The true value of m-commerce goes beyond wireless Internet; it can be realized when understanding the value of mobility in transactions between market stakeholders. M-commerce is a continuously growing research area since 2000. The most recent literature review has been published by Ngai and Gunasekaran (2007). M-commerce provides business opportunities for a number of players as noticed by Buellingen and Woerter (2004). They also state that critical success factors for m-commerce operating in the Universal Mobile Telecommunications Systems (UMTS) relate to the transmission rate, reliability, user friendliness and interface between user and engine.

Recent developments in mobile communications technology provide a scientific and business research area dealing with the transition from e-commerce to m-commerce (*m-commerce*). M-commerce in its simplest form may be considered as an enhanced form of typical e-commerce but with two additional critical properties – portability and mobility offered by wireless mobile communication devices. A simple definition of m-commerce has been proposed by Barnes (2002); "*m-commerce is any transaction with a monetary value – either direct or indirect – that is conducted over a wireless telecommunication network*". Of special interest is the development of m-commerce applications to support mobile auctions (m-auctions) and mobile advertising (m-advertising) which demolish place restrictions and allow bidders to participate while on the move using their mobile communication devices (phones or PDA's), (Varhsney, 2001), (Varshney and Vetter, 2002). The combination of these two distinct classes provides a trading negotiation tool which takes into account participants' current location to announce and execute geographically-focused auctions.

Rapid penetration of mobile communications in Europe set the basis for the evolution of innovative m-commerce applications. The integration of m-commerce and *Location-Based Services (LBS)* provides the infrastructure for geographically-focused trade of logistics services, such as the freight transport. LBS "*open a new market for developers, cellular network providers, and service providers to develop and deploy value-added services*" (Hand et al., 2006). It has been predicted that global LBS market will reach $8 billion by 2010 (Kang et al., 2007). Although LBS is recognized as a "killer application" with several research and practical implications, research articles are relatively limited, covering only 2% of the total of all research articles in M-commerce and 10% of m-commerce applications-related articles (Ngai and Gunasekaran, 2007).

Some recent studies provide evidence for the future diffusion of m-business and related applications. A recent study published from Commission of the European Communities presents a continuous growth of the mobile penetration rate in EU which is well above 100% since 2005 (Figure 4.1). One of the key drivers for the growing penetration is the lowering of communication prices for both voice and data. Given that transaction cost is perceived as the major barrier for the adoption of m-auctions, these figures are really promising.

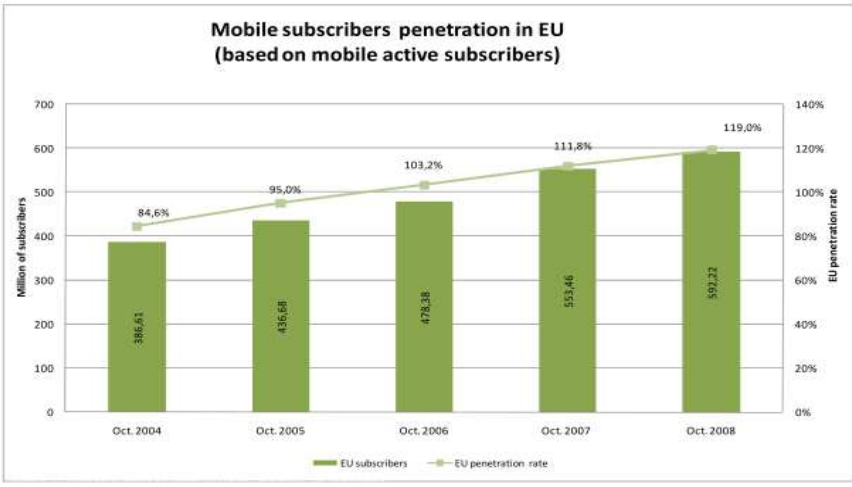

Figure 4.1: *Mobile Subscribers Penetration*

A recent study from Morgan Stanley Research (2009) related to business models in Mobile Internet, contains some very interesting and promising statements for both mobile business, auctions and location-based services in particular which are summarized as follows:

- "*Mobile Internet will be the next major computing cycle*"
- "*GPS and related location-based services proliferation are big deals*"
- "*mobile internet unlocks power of data on physical location*".
- "*push notification technology enables effortless monitoring of auction process*"

The Mobile Internet Report, Morgan Stanley Research (2009)

Despite the fact that mobile penetration dominates over Internet in the number of subscriptions, it cannot be assumed that the same type or level of demand will be present in the mobile environment for business and/or commerce applications (Ralph and Shephard, 2001); that is, it cannot be safely inferred that m-commerce will exhibit a similar behavior compared to e-commerce. It should be taken into account, however, that m-commerce (or e-commerce over wireless networks) theoretically enables business transactions between an unlimited number and unrestricted types of players without time restrictions or geographical constraints, offering on-the-move trading capabilities. It is believed that m-commerce applications and devices are less confusing than other information technology services so the learning curve is much faster (Anckar and D' Incau, 2002), while the cost of acquisition is relatively low.

M-auctions formulate an attractive application to examine under the prism of m-commerce. M-auctions and mobile advertising have been recognized amongst emerging classes of m-commerce applications (Kannan et al., 2001), (Varshney, 2001), (Sairamesh et al., 2001), (Varshney and Vetter, 2002). Compared to physical and electronic auctions, mobile auctions are considerably less-studied.

4.2 Technology

The following paragraphs provide a short technical overview (for the non-expert) of the main technological infrastructure and communication requirements for the implementation of modern mobile and location-aware services. The analysis is intentionally simple avoiding complex and sophisticated technical-terms aiming to a more business-oriented rather than ICT-oriented reading audience.

4.2.1 Wireless Communications

Wireless communications allow transmission of information over the air by means of electromagnetic waves and using wireless devices. Equipment, frequencies and data format depend mainly on the desired geographic coverage. The major characteristics of some widely used wireless technologies are illustrated in Table 4.1(Goel, 2007).

Technology	Frequency	Bitrate	Geographic Coverage	User
TErrestrial Trunked Radio (TETRA)	385-390, 395-399.9, 410-430, 450-470, 870-876, 915-921 MHz	7.2kbps	Wide	Organizations, Companies
Cellular	GSM*: 890-915, 935-960 MHz (GSM) Terrestrial UMTS**: 1900-1980, 2010-2025, 2110-2170 MHz Satellite UMTS: 1980-2010, 2170-2200 MHz	9.6kbps 144 kbps (full outdoor) 384 kbps (limited mobility outdoor in urban and suburban areas) 2048 Mbps (low-mobility outdoor in indoor and urban areas)	Indoor, urban, suburban	Organizations, Companies, Individuals
Satellite	**Geostationary Orbit (GEO):** - Inmarsat-C 1530.0-1545.0 MHz (downlink) 1626.5-1645.5 MHz (uplink) - Qualcomm 10.70-11.70, 12.50-12.75 GHz (downlink) 14.00-14.25 GHz (uplink) **Low-Earth Orbit (LEO):** 137.00-138.00 MHz (downlink) 148.00-150.05 MHz (uplink)	Downlink: 5-15 kbps Uplink: 55-165 bps Downlink: 4.8 kbps Uplink: 2.4 kbps	34% of Earth's surface with 0.25 sec. delay (global coverage via 4 satellites) Global coverage with latency	Organizations, Companies, Individuals
Dedicated Short Range Communication (DSRC)	Microwaves 5.795-5.805 GHz, 5.805-5.815 GHz		Short range vehicle to vehicle and vehicle to infrastructure	Organizations, Companies, Individuals (e.g., toll collection, collision avoidance etc.)
Broadcasting	Radio Data System (RDS) Digital Audio Broadcasting (DAB) 47-68, 174-240, 1452-1492 MHz,	1187.5 bps on FM radio broadcast 3 Mbps (2.3 Mbps for data 0.6-1.7 Mbps actually available due to redundancy)		Organizations, Companies, Individuals (e.g., Traffic Message Channel)

Note: * GSM: Global System for Mobile Communication, **UMTS: Universal Mobile Telecommunications System

Table 4.1: *Wireless Communications Technologies (Adapted from Goel, 2007)*

4.2.2 Positioning Technologies

Various technologies for positioning have been developed over the years. A descriptive overview and comparison of different communication technologies in terms of area coverage and accuracy is shown in Figure 4.2 (Vossiek et al., 2003). The figure provides also an overview of the different distance and location measurement methodologies.

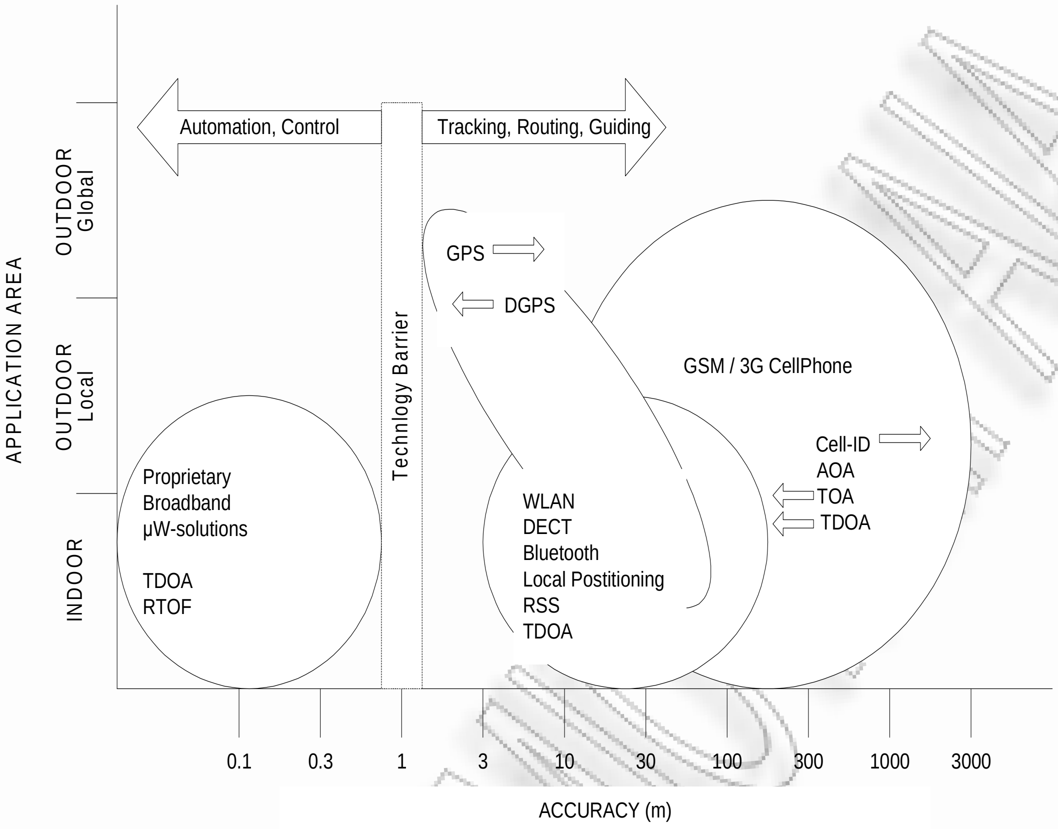

Figure 4.2: *A Comparison of Location Sensing Technologies (Vossiek et al., 2003)*

Most common positioning systems use the Global Navigation Satellite System (GNSS). These technologies are primarily focusing on detection of the spatial characteristics (geographical position and altitude, speed and direction) of an object or a human being. The evolution of positioning systems began in early 1960s by US Navy, which developed Transit, a tool to help navigate ships and submarines. In 1973, the US Air Force and Navy developed the NAVSTAR (Navigation Satellite Timing and Ranging) global positioning system and, in 1989, the GPS constellation of satellites was put into orbit for the first time. In 1993, GPS was set free for civilian use internationally. Since then, numerous companies have designed and developed devices and applications for commercial use.

Amongst others the only fully operational GNSS is the US GPS, which is used for commercial, civil and military applications. GPS is a constellation of 24 satellites, orbiting the earth at approximately 20180km every 12h on six different orbital planes, and constantly transmitting their relative positions. At any location and time at least four satellites are constantly visible above a 15° cut-off angle. All GNSS systems locate a moving object through *trilateration (triangulation)* -- a technique utilizing the exact position of three satellites, their relative distance from the moving object and a fourth satellite for time correction, fixing any problems of inconsistencies between the satellite and the moving object’s clocks.

GPS technology consists of three segments (Figure 4.3), namely:

- The *space segment* that will be further described in the next paragraph
- The *control segment*: it is responsible for constantly monitoring satellite health, signal integrity and orbital configuration from the ground. The major components are: a) *Monitor Stations*, b) The *Master Control Station (MCS)* and c) *Ground Antennas*. *Monitor Stations are* constantly monitoring and receiving information from GPS satellites and then send the orbital and clock information to the MCS. The MCS, which is located in Colorado Springs in Colorado, constantly receives GPS satellite

orbital and clock information from the monitoring stations, makes precise corrections to the data and sends back the information (ephemeris data) to the GPS satellites using ground antennas. Finally, ground antennas receive corrected orbital and clock data from the MCS and send them to GPS satellites.

- The *user segment* consists of a GPS receiver that collects and processes signals from GPS satellites that are in line of sight. User devices use this data to display location, speed, time, mapped data and other information.

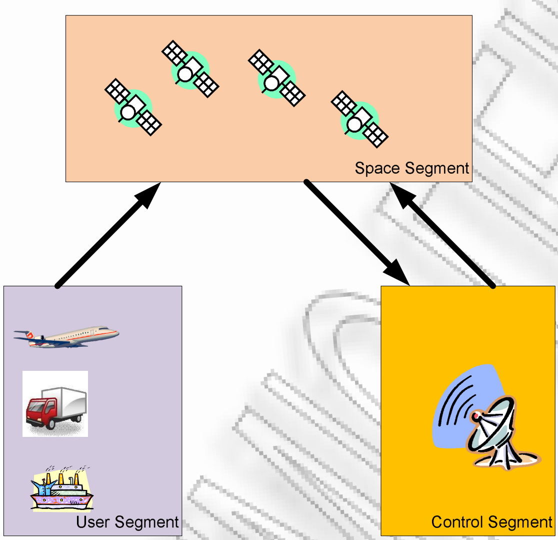

Figure 4.3: *GPS Segments (Adapted from UBLOX, 2007)*

Satellites are continuously sending signals down to earth, which are precise and timely predefined by atomic clocks. One earth-located GPS receiver receives signals from different satellites with different propagation delays, depending on the receiver's current location, and measures the time of each signal's arrival. It then calculates the difference between the measured times of arrival and the predefined time of signal departure and in this way can find the distance (range) from each satellite. Inaccuracies in the calculation of the range of satellites are commonly referred to as 'pseudo-ranges'. The computation of latitude, longitude and altitude based on pseudo-ranges requires four satellites instead of three, the fourth being responsible for time. Information about the exact satellite position and time of signal transmission is necessary for the calculation of a GPS device's position. For this reason each satellite also transmits a digital signal at 50 bps, with precise information on the satellite's orbital parameters (called ephemeris).

The precision of the calculated position is affected by many factors. The most important of them are device accuracy, satellite clock accuracy, satellite orbital inclination, atmospheric and climate influences (humidity, clouds etc.) and physical obstacles (tall buildings, tunnels, etc.). GPS technology was first developed in the 1970s for military purposes and offered limited accuracy (*selective availability* -SA) with intentional errors of ±100m for civilian applications. In early 2000, typical SA errors were 10m horizontally and 30m vertically. Recent commercial GPS utilizes complementary methods like *differential corrected GPS* (DGPS) to improve accuracy and correct any errors. The European Position System (Galileo) is expected to provide measurements that will range from 3 to 5m (Lee et al., 2008) or even centimeter level accuracy. A concise but comprehensive description of the GPS system and its applications can be found in Mintsis et al., (2004) while a brief history of the evolution of GPS, its operation and potential applications may be found in Theiss et al., (2005).

A technology called "*dead reckoning*" is used alongside GPS to overcome GPS signal loss problems, using simple devices like speedometer (for distance calculation) and gyroscope (to retrieve direction).

Other methods used for positioning purposes are cellular networks and signpost systems. Cellular networks use various positioning methodologies some of them being:

a. *Cell of Origin (COO)* (using current communication cells with accuracy ranging from 100m in urban areas to 35Km in rural areas),

b. *Propagation time* (time for a signal to travel from base station to mobile device, ideally using three base stations),

c. *Time Difference of Arrival (TDOA)* (reception of signals from three base stations and calculation of time difference between each pair of arrivals), and

d. *Angle of Arrival (AOA)* (measurement of angle of arrival of a signal from or to a base station).

Signpost systems use fixed beacons and receivers to record a vehicle's position when it passes the beacon. Detailed analysis on satellite navigation topics can be found in U-BLOX (2007).

Besides the benefits described in the previous paragraphs, combined use of GPS and mobile communication technologies (GSM, GPRS) entails a number of technological issues. These are described in brief below.

- These technologies are not always reliable (or may even be non-operative) in indoor environments, shadowed and cloudy environments or narrow streets, canyons, tunnels, ships etc. This problem has been partially solved with the development and use of indoor communication technologies, where necessary using Assisted GPS (AGPS). AGPS is different from the DGPS described above: instead of the amplification of accuracy, AGPS aims to improve the ability to detect GPS signals under conditions of low signal-to-noise ratio. Nevertheless, DGPS may be applied alongside AGPS. The implementation of such technologies in problematic areas provides higher accuracy than simple GPS. An extended analysis of AGPS technologies and issues has been provided by Richton et al., (2002).
- Another problem is that the systems may become too slow, especially when the cell communication provider is not reliable. Nowadays most GSM providers compete to offer high quality of service and high geographic (besides population) GSM coverage.
- The systems require costly and bulky devices to operate properly. However, recent advances in microelectronics have resulted in the development of lighter and cost-effective devices; moreover, modern devices are not highly energy-consuming and can provide many hours of autonomous operation.
- The technology used, and more specifically in-vehicle human-machine interface devices, must be carefully designed to meet human cognitive capabilities. The presence of a large number of in-vehicle devices places high demands on the driver's attention. Incorrect design may therefore be dangerous for the driver and public. A comprehensive model describing the relationship between different modes of information presentation (Table 4.2) and extensive information on ergonomic and design issues can be found in Garcia-Ortiz et al., (1995).
- The critical success factors for a telematics application are compatibility (openness) and scalability; Compatibility ensures that the components of the telematics application will communicate effectively with the company's ICT applications. Scalability means that the telematics application follows the growth of the company.

		Format	
		Verbal	**Spatial**
Modality	**Auditory**	Speech	Sound Localization and Pitch
	Visual	Print	Analog Pictures

Table 4.2: *Device-Driver Communication Parameters*

4.2.3 Geographic Information Systems

Geographic information systems (GIS) constitute a special class of information systems for the collection, processing and presentation of geographic data. Data collection is performed through the combined use of aerial images (rough-cut mapping) and mobile mapping (detailed mapping). The collected data are stored in a database and they are further processed by a number of special software programs.

Depending on the scope and application, related geographic information is presented in a raster model format (as an array of cells, each assigned specific attributes) and/or in a vector model format (with representation of objects as geometric shapes: point, line or area). A more realistic representation of the road network is achieved for the development of road maps with the use of an international standard named geographic data file. This is based on sets of *features* (defining real-world objects, e.g., buildings, junctions, addresses), *attributes* (defining characteristics of features, e.g., direction, one-way streets) and *relationships* (defining relationships between features, e.g., road signs, roundabouts). Major applications of GIS are in *geocoding* (representation of locations with the use of geographic coordinates and postal codes), which is used to locate addresses and calculate Euclidean distances, *routing* (calculation of the shortest, fastest or lowest-cost route between two points) using special shortest-path algorithms like Dijkstra’s algorithm, and *map matching* (determination of the address of a specific actual location) via the use of special map-matching algorithms. GIS are able to store, process and provide data related to streets, postal codes, consumer data, demographic data and geopolitical boundaries. Depending on the use of the application, different combinations of data categories are used (Garzia-Ortiz et al., 1995) (Table 4.3).

Data Reqts. / Task	Streets	Postal Codes	Consumer Data	Demographic Data	Geopolitical Boundaries
Optimal Routing	√		√		
Emergency Dispatching	√	√			
Vehicle Routing	√	√			
Vehicle Navigation	√				√
Transportation Analysis	√			√	√

Table 4.3: *Geographic Data Applications (Garzia-Ortiz et al., 1995)*

4.2.4 Telematics

The term *Telematics* describes the combination of the transmission of information over a telecommunication network and the computerized processing of this information (Goel, 2007). The rapid diffusion of Telematics was a result of the development of many communication technologies, which namely are (Giannopoulos, 2004): wireless communications (the Global System for Mobile Communication (GSM) and the Universal Mobile Telecommunications System (UMTS), positioning technologies (Global Positioning System (GPS), broadband communications, first- and second-generation internet services, dedicated short-range communications (DSRC), general packet radio services (GPRS) and other improvements concerning the speed and capacity of computers and software. The core technologies for Telematics will be further described thereafter.

In a typical application, the vehicle’s spatial and state data are collected via GPS signals and sensors, respectively. Communication between the fleet and the *fleet telematics system* (FTS) provider is over wireless or cellular networks, such as SMS messages. The evolution of 2.5G and 3G communication technologies dramatically increased the bandwidth available to fleets, allowing the transmission of high volumes of data (not solely text) and offering “*always on*” functionality. A reference *real-time fleet management systems* (RTFMS) is described by See (2007) and is depicted in Figure 4.4.

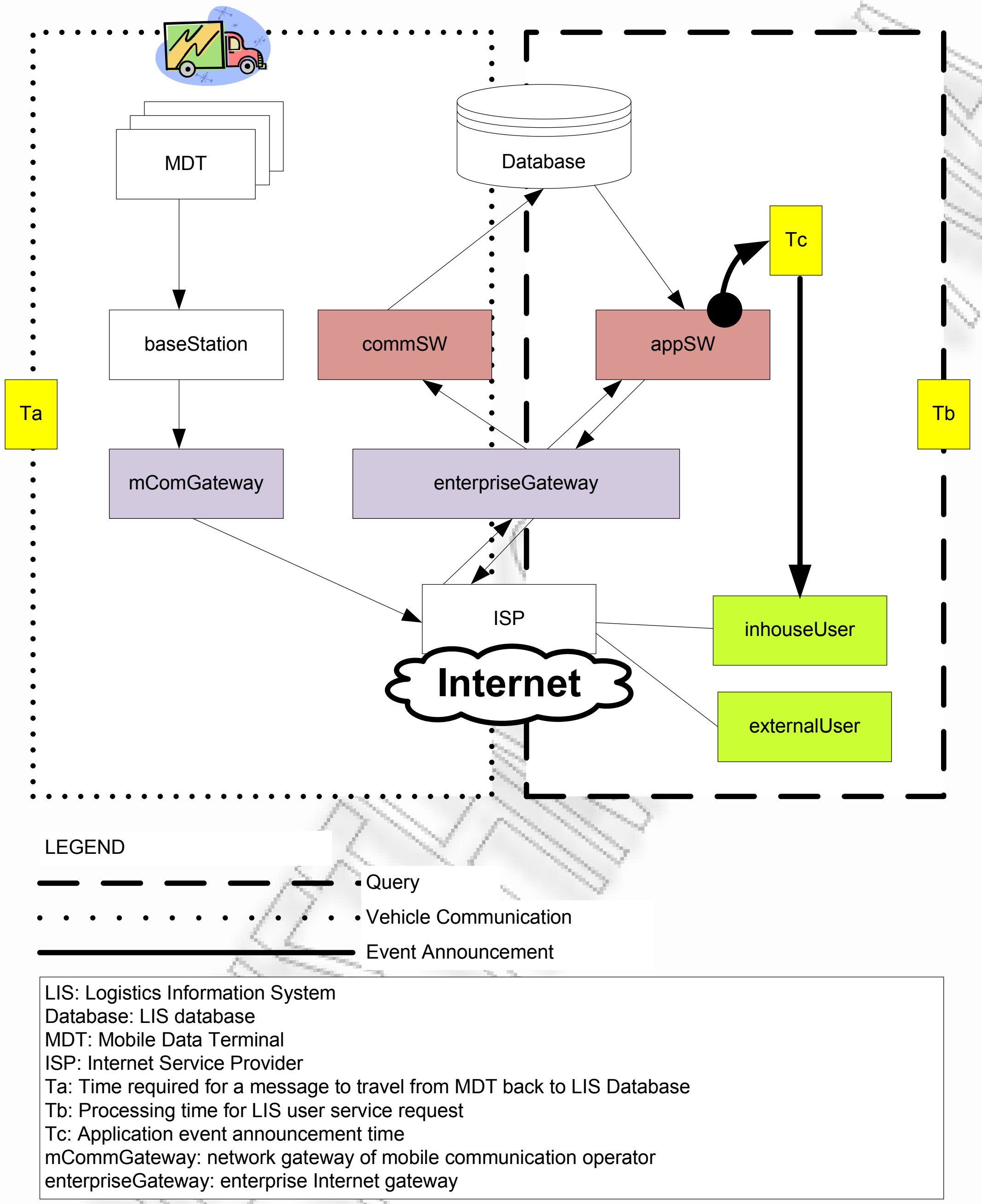

Figure 4.4: *RTFMS Architecture and Information Flow (Adapted from See, 2007)*

A typical architecture of a telematics system implementation is depicted in Figure 4.5. Any user (carrier, shipper, vehicle driver etc.) have access to a number of proper information related to trip planning and evolution or may utilize the Telematics infrastructure to provide value-adding services like Location-Based Services (LBS) as will be further described in the sequel.

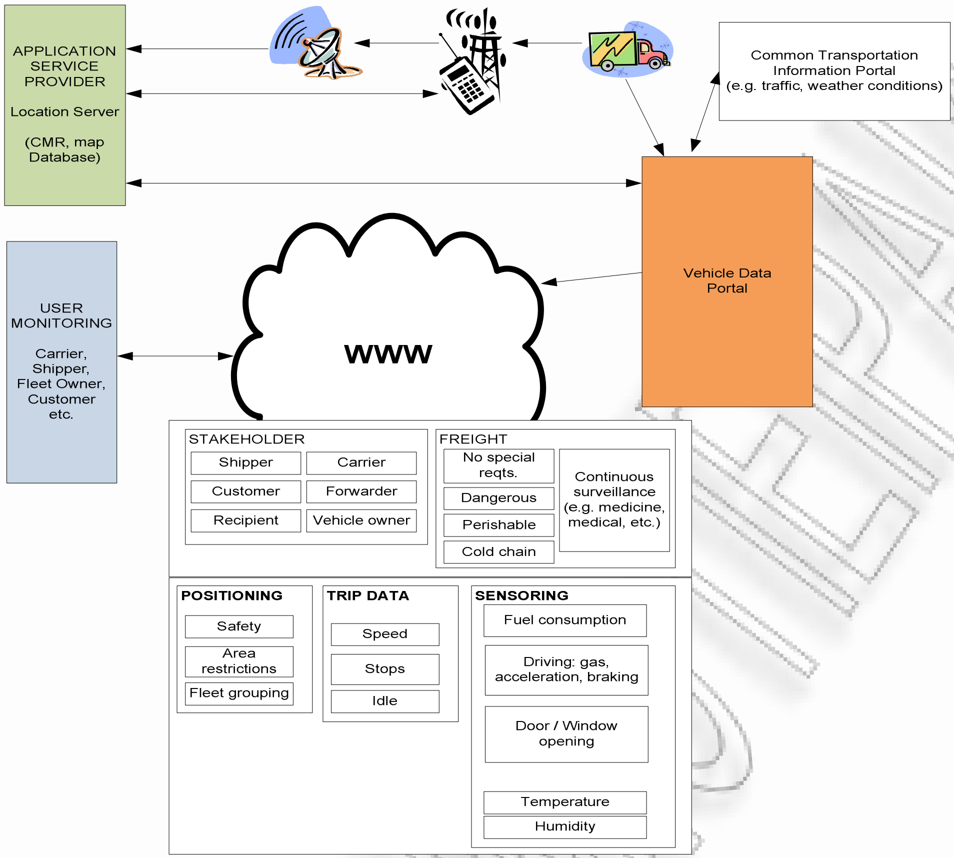

Figure 4.5: *Implementation Architecture of a Telematics System*

Current and future logistics trends focus on offering fast and accurate services to individual customers, in an efficient and economic manner, as was predicted by Crowley (1998). Moreover, practices like just-in-time, cross-docking, continuous replenishment, efficient consumer response and on-demand transportation services (like taxis, courier, ambulances, etc.) have already been widely adopted by companies aiming to reduce logistics costs and improve customer service. The evolution of e-commerce and e-business has affected the introduction and adoption of new technologies (Roy, 2001) in two ways: firstly, as a response to better supply-chain performance and. secondly, as a pressure for supply-chain improvement, better quality of service, immediate response (also called express logistics) and the need to handle large amounts of data and information. Direct transactions between consumers and companies (B2C) resulted in the elimination of physical supply chain intermediaries (e.g., wholesalers, retailers) and, as a result, the role of freight transportation and distribution operations become even more demanding.

Real-time coordination of distribution fleets and well-structured information availability is a necessity in order to support these new processes and reduce the relative complexity arising from them. Perhaps the most important and challenging application area of telematics is the freight transportation and distribution operations functions of logistics. Logistics functions benefit from telematics by combining trip planning and dispatching with seamless tracking and tracing (T&T) and proof of delivery (PoD). The benefits of telematics are more obvious when applied in third-party logistics companies (3PL) which operate large owned or leased fleets and provide shared warehousing and distribution services to numerous clients, often consolidating multiple freight loads and visiting several clients for pickup or delivery of freight. Thus, the use of telematics applications for planning and monitoring is indispensable to these companies. Depending on company size and business area, telematics applications and their special requirements may vary; frozen food distribution companies mostly require temperature monitoring while courier companies particularly require map guidance.

Telematics infrastructure applies to almost any kind of fleet, type of transported asset and business, even where there are different operational requirements. Focusing on freight transport and distribution functions for business applications, telematics applications and services are summarized in Table 4.4. A brief description of some services of special interest follows, while detailed analysis will follow later in the chapter.

Application Area	Service	Examples
Traffic and Travel Information	Pre-trip information On-trip driver information Personal Information services Route guidance and navigation	Road network, tolls, weather conditions Traffic information, maps, speed limits Telephony, SMS, e-mail, points of interest (POI) Guidance, re-routing
Vehicle Information	Vision enhancement Automatic vehicle operation Longitudinal collision avoidance Lateral collision avoidance Safety readiness Pre-crash restraint deployment	Remote unlocking Telemetry
Commercial Vehicles Information	Commercial vehicle pre-clearance Commercial vehicle administrative processes Automated roadside safety operation Commercial vehicle on-board safety monitoring Commercial vehicle fleet management	Route control Reporting Maintenance planning / Diagnostics Door opening Climate control
Emergency Management	Emergency notification and personal security Emergency vehicle management Hazardous material and incident notification	112 Malicious threads notification Stolen vehicle recovery

Table 4.4: *Telematics Applications and Services for Logistics (Adapted from Goel, 2007)*

When planning a trip, a decision maker uses telematics systems to derive information about the route, such as means of transport, points of interest, specific addresses, specific roads, tolls, distances and duration. During the trip, telematics provides information to the planner and to the driver as well. Such information can pertain to remote vehicle monitoring (e.g., variation from scheduled trip, door openings, transported goods' temperature, breakdowns, safety, weight, fuel consumption), guidance, location-based services (e.g., nearest fuel stations, repair stations etc.). Moreover, a fleet planner may use the telematics infrastructure to replan a vehicle's route dynamically, according to the current vehicle location, road traffic information and new requirements.

A wide range of information can be available to the planner, such as the location of the vehicle, the state of the transported goods, times of departure and arrival between loading and unloading points, respectively, the route evolution, length of personnel break, stops for refuelling and many others. All raw data collected during the trip are stored in a database for later processing, with the aim of providing accurate and realistic information for trip evaluation and planning purposes. Modern on-board devices and sensors have strong capabilities and are capable of providing numerous truck, driver and travel parameters (Table 4.5) (Baumgartner et al., 2008).

An extensive analysis of the use of telematics in urban real-time distribution operations has been made by Zeimpekis and Giaglis (2006) (Figure 4.6). Although they focus on Greek market, the authors' core research results can be generalized to almost any logistics market. They focus on the application of telematics to real-time routing, re-routing and monitoring of a distribution fleet, aiming to meet dynamic requirements that appear during the route execution, and describing inter-vehicle wireless communication, back-end wireless connectivity with the distribution centre and real-time decision support in response to intrinsic and exogenous stochastic problems.

Parameter	Example
General data	Date and time Position (geographical coordinates and altitude) Vehicle, driver, trailer Status (driving/rest) Change of tachograph Distance driven Fuel consumption Speed
Driving behaviour	Braking behavior Gear changing behavior Driving pedal movements Constancy of speed
Trip difficulties	Gross vehicle weight Number of stops Duration of stops Average gradient
Tech. Vehicle	Brake wear Refrigerant level Oil level Disturbances reporting Maintenance scheduling Tyre pressure
Other	Loading space temperature pattern

Table 4.5: *Available Information in On-Board Device (Baumgartner et al., 2008)*

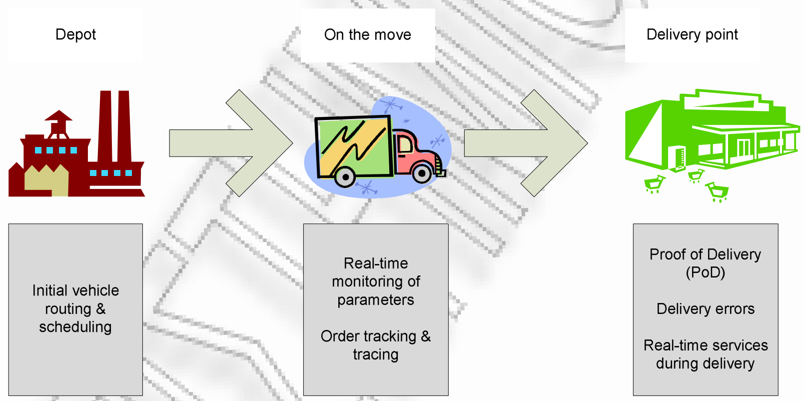

Figure 4.6: *Freight Distribution Overview (Adapted from Zeimpekis and Giaglis, 2006)*

The data interchange between fleet and fleet owner is accomplished via a *fleet telematics system* (FTS), which is usually offered by an external provider/intermediary and is supported by GPS and a cellular communications services provider. Integration between real-time FTS and information processing systems leads to the development of *real-time fleet management systems* (RTFMS).

There are three core components of these applications.

- Firstly, the *truck telematics equipment*, which includes a GPS receiver for position sensing, GSM/GPRS receiver for voice and data transmission, on-board monitor/communication device, and sensors for the door, temperature and so on, for continuous measurement. Advanced portable devices may serve as computers too, offering capabilities for data capture, barcode scanning, proof-of-delivery, reconciliation, etc. All these devices should be ruggedized terminals, i.e. they must be durable against shocks, high or low temperature and liquids. They should also be equipped with large readable screens, with high visibility and possibly with voice recognition functionality as well. Finally, they should provide connectivity options besides GSM/GPRS and GPS, such as infrared and Bluetooth.
- *Fleet owner's software*: it may consist of a) a routing software (standalone, client or web-based Decision Support System) which is integrated or interfaced with the fleet

owner's logistics software b) fleet monitoring software and c) a GIS application containing geographic data and mapping software offering identification of vehicles and points of interest (customers, retailers, distribution centers, etc.) using static or dynamic coordinates that are matched against map data.
- *FTS provider's infrastructure* (computer Hardware, Software applications and communication infrastructure).

In a typical application, the vehicle's spatial and state data are collected via GPS signals and sensors, respectively. Communication between the fleet and the FTS provider is over wireless or cellular networks, such as SMS messages. The evolution of 2.5G and 3G communication technologies dramatically increased the bandwidth available to fleets, allowed transmission of high volumes of data (not solely text), offering always-on functionality.

The telematics infrastructure may also be integrated with existing supplier and customer relationship management systems and operations support software (such as warehouse management systems), providing real-time information and value-added services during pick-up and delivery operations. These services might include billing, ex-van sales and credit control. Moreover, telematics applications may be integrated with a company's backbone Enterprise Resources Planning (ERP) system, operating as a source of real-time automatically collected data, and using them for improved financial analysis, forecasting and reporting. A more detailed analysis of value-added services and facilitation of m-commerce applications will be presented later in the chapter. Summarizing the aforementioned issues, telematics applications offer different degrees of real-time services (Transport Energy, 2003):

- Information on vehicle and driver data
- Vehicle tracking
- Trailer tracking
- Text messaging and provision of information to fleet planners and customers
- Paperless manifests and proof on delivery
- Traffic information
- On-board navigation

While it is out of the scope of this chapter, it is useful to state the environmental benefits from the application of telematics. The efficient use of a transportation fleet leads to noticeable reductions in fuel consumption and greenhouse gas emissions due to an increase in the trucks' load factors and a consequent reduction in kilometers driven. In their qualitative survey, Baumgartner *et al*. (2008) found that major telematics services like combination of automatic routing systems and GPS, semi-automated route optimization, monitoring of loading space utilization and comparison between planned and actual trips are all beneficial for the reduction of greenhouse gas emissions.

In the same context, Lee *et al*. (2008) designed a real-time GPS-based vehicle control system to alter the control of the engine, aiming to reduce fuel consumption and greenhouse gas emissions. Examining the application of GPS in commercial bus routes, Hickman (2004) states that GPS has both direct impact on air quality due to reduction in pollutant emissions and indirect impact due to changes in passengers' ridership as well.

4.3 Location-Based Services (LBS)

Recent advances and combined use of automatic position sensing and wireless connectivity resulted in the development of Location-Based Services (LBS). Such services utilize their ability of location-awareness to simplify user interactions and adapt to the specific context (Ibach et al., 2005). They add value based on knowledge of the location of a mobile device

(Tilson et al., 2004). They also provide the ability to offer locally adapted services so any partner is able to access some combination of the services market offered by the network (Loke and Zaslavsky, 2004). An integrated location management architecture which supports m-commerce applications has been proposed in (Varshney, 2003).

In the current business environment, location information is becoming an important issue for a continuously growing number of cases ranging from simple navigation services to emergency occasions and from targeted advertising to complex business transactions. LBS focus in providing location and context (situation) aware services for users while on the move based on their current and/or projected location. Application of mobile communications technology for supporting commercial transactions extends the e-commerce to location-based commerce or what Dao et al., (2002) call *l-commerce*. One of the simplest applications of LBS is *geocasting*, where one is able to send messages or communicate with mobile devices in a specific geographical area by detecting the presence of mobile devices in the geographical area of interest. A wireless communication enabled device is the only necessary equipment for a user to access LBS. Major LBS application categories include communication, fleet management, routing, safety, security and entertainment (D'Roza and Bilchev, 2003). Development of an LBS application combines a number of disciplines and technologies such as mobile communications, GPS technologies, mobile devices, trading protocols, IT technologies, etc. To be able to provide context-aware services LBS should engage additional technologies like sensors.

LBS use two major data processing architectures; mobile device operates as a client sending location data to a back-end server for processing. Recent developments in CPUs and memory of mobile communications devices (handsets, PDA's), made back-end servers obsolete (Gilbertson et al., 2006). A general approach about value and revenue generation for partners has been given by Unni and Harmon (2003). Grajski and Kirk (2003) summarize Key Performance Indicators (KPI's) and Key Implementation Requirements (KIR's). Due to the number and heterogeneity of participants in LBS, the architecture should be based in self-organization: minimize user inputs, combine multiple location information sources, switch between indoor and outdoor operation seamlessly, support cooperation between neighbor clients to determine position or increase accuracy and support integration with future technologies. A typical example of composable LBS is shown in (Ibach and Horbank, 2004). An extensive analysis of mobile data management, requirements and techniques can be found in Madria et al., (2002). Several methods have been used to locate a mobile device's location; most important of them are presented in brief by several researchers (Dao et al., 2002), (Adams et al., 2003), (Unni and Harmon, 2003), (Tayal, 2005), (Gustafsson and Gunnarsson, 2005).

A general modular LBS platform has been proposed by Xia and Bae (2007). From a communication network provider's point of view a critical question is whether existing infrastructure is capable to support communication load added by LBS (Kuhn, 2004). He states three critical steps to estimate required network capacity: (i) Service definition and decomposition into elementary service activities, (ii) Network resources per type, access points and relevant attributes like coverage, bandwidth, costs, etc., and (iii) Traffic volume requirements per service based on data volume, frequency (periodic/ on demand), continuous data streams, number of potential users, etc.

LBS have some native vulnerabilities related to heterogeneity of devices and platforms (e.g., PDA's, laptops, smartphones, etc.), processing power, memory and battery life limitations; nevertheless, advances in information technology gradually efface such limitations. LBS introduce benefits for all marketplace participants (Rao and Minakakis, 2004); additional revenue for mobile and GPS providers, relevant, timely and engaging content delivery for buyers and seller, while improving their market experience.

4.4 Mobile and Location-Aware Auctions (m- and l-auctions)

The penetration of mobile communications technology triggered the development of a new form of electronic auctions the so-called *mobile auctions*. Such auctions have special requirements related to transmission bandwidth and range, topology changes and energy requirements for the devices used (mobile phones / PDA's) (Frey et al., 2002). Such marketplaces use middleware services to discover available devices and distribute messages to them. Aiming to support auctions in ad-hoc networks they present the UbiBay prototype allowing participants to use mobile devices to run or participate in auctions. Liu et al., (2003) analyze the communication requirements for e-auctions as performance metrics and demonstrate that multicasting technology improves the effectiveness especially in open-cry auction settings.

Auctions conducted over wireless networks have special technical requirements (e.g. transmission bandwidth and range, topology changes) and energy requirements for the devices used.. Chan et al., (2001) design an auction system able to support both Internet and mobile users. Of special interest is the implementation of mobile auctions when participants are moving in limited space (e.g., 300m^2) using 433 MHz modems (Rodríguez-Hernández et al., 2002) or Bluetooth communications as proposed by Gonzáles-Castaño et al., (2005). They propose methods to overcome communication fairness and security issues. Evolution of mobile technology resulted to new forms of auctions and markets. A typical example is the development of ephemeral markets arising and closing spontaneously usually operating via peer-to-peer (P2P) networks or Mobile Ad Hoc Networks (MANETs).

Shih et al., (2005) propose a novel mobile Vickrey reverse auction system (MoRAAS) supporting bid privacy. Other mobile auction models have been provided by Tsai and Shen (2006) (Mobile Reverse Auction System – MRAS). A business decision view about m-commerce adoption is provided by Frolick and Chen (2004), while Pedersen et al., (2002) examine adoption enhancement considering users as technology users, consumers (or suppliers) and network members. An extensive analysis of benefits for participants was given by Kuo and Yu (2006). M-commerce transactions have unique operational attributes as noted in (Ahluwalia and Varshney, 2003); these include: local (in single wireless or mobile networks) or end-to-end (over multiple heterogeneous networks), real-time or non-real-time, one-way, two-way or multiple-way, symmetric (same performance for all members) or asymmetric (different performance) etc. M-commerce critical success factors have been explored by Feng et al., (2006), while Ahluwalia and Varshney (2007) stated that measurement and management of QoS is becoming more complex for m-commerce transactions over multiple heterogeneous wireless networks or multicasting supported by rapidly evolving 3G and 4G networks with unique characteristics and differences

M- and l- auctions belong to highly demanding applications in terms of ICT requirements. Essential communication requirements for the development and operation of m-auctions are Multicast, Location Management, Reliability and Roaming across multiple networks and operators. M-auctions are typical cases of group-oriented services which assume that besides real-time multicast, the system should support membership coordination, user inputs management, and application synchronization, continuous and stable connectivity for multi-stage processes, low delays (ideally real-time) and continuous connectivity (Varshney and Vetter, 2002), (Varshney, 2007), (Varshney, 2005). When communication quality from a provider is low, the user should be able to switch another network. Mobile auctions can be easily apply in conjunction with Location Based Services (LBS); Varshney (2001a; 2001b), Sairamesh et al., (2001), Varshney and Vetter (2002) and Kannan et al., (2001), Varhsney (2005) give some examples and describe the technical wireless requirements as well as communication requirements (Varshney, 2002).

Although electronic auctions have been used widely for the last 10 years, use of mobile auctions is relatively limited especially in the area of B2B trading. Some critical parameters slowing down the m-commerce adoption are: costly entry either for business or customers, lack of a globally-used standard (GSM, 3G, etc.), low bandwidth, instability of connections, device-specific applications and limited display capabilities. Such auctions have special requirements related to transmission bandwidth and range, topology changes and energy requirements for the devices used (mobile phones / PDA's). A strong shortcoming relies in the size of mobile devices. Due to recent trends mobile manufacturers make small-sized devices with proportionally small displays that limit the information that may be displayed. On the other hand wired internet does not have such limitations. Computer monitors support the display of large amount of information. Obviously transition from e-commerce to m-commerce is not very easy.

To relax such shortcomings recent technologies like voice recognition and audio feedback have been developed. Users' devices are heterogeneous in general, so a major problem for any LBS is to efficiently and equally well communicate with any of these devices and integrate them, so LBS technology should be compatible with any of the three major mobile Operation Systems (OS): PalmOS, PocketPC and Symbian OS. Communication cost is also another concern; nevertheless, mobile communication costs have dropped in the last decade. Additionally, many stakeholders have developed revenue models which are beneficial for on-the move participants. From a privacy regulation point-of-view, apart from known mobile malicious threats, it is critical for LBS to provide security mechanisms eliminating or abolish potential attacks aiming to gain access, steal or modify users' location data and identities. Finally mobile infrastructure should be "open" and scalable to cover future developments. Efficient integration between marketplace and LBS requires the presence of mobile communication technologies (GSM phones or PDA's) and location sensing equipment (GPS devices). Participants should not be required to commit to a specialized technology and information system infrastructure.

4.5 Investing on Value of Information – an Example from the Logistics Operations

Because of the rapid and globe-wide diffusion of ICT and related devices, corresponding costs were decreased very quickly making their operation affordable for almost any supply chain member. More than a decade ago, Anderson et al. (1996) performed a cost-benefit analysis of the use of transport Telematics by European Small and Medium-sized Enterprises (SMEs) and concluded that: "*…we would argue that, operationally, such technology can bring benefits to the road freight transport sector. Without question, satcom equipment is a high-cost technology. As a result, payback periods are only just considered acceptable by road freight operators. However, given that investment and exploitation costs are now some 15% lower than they were three years ago, it appears the payback periods would be more attractive*". Since then, dramatic evolution of technology and increased adoption by companies has considerably reduced the fixed and variable costs, while the range and quality of services has become even more efficient. Consequently, telematics services are currently available and affordable for almost any type of company; either an individual carrier or a large third-party logistics service provider.

In a typical logistics system a number of stakeholders can benefit from the use of telematics systems. In the following paragraphs the benefits for two core stakeholders, namely, the carrier (owner of the fleet) and the shipper (owner of the freight transported), are presented:

- Carriers: The value gained by carriers is twofold: Firstly, by analysing recorded historical data, a carrier is able to adjust route schedules, fleet size and loading, making vehicle routes more efficient and cost-effective by significantly reducing fuel and labour costs. Secondly, the centralized real-time monitoring of a carrier's fleet generates numerous benefits. In his early but well-timed research, Hamilton (1993) discovered core monetary and non-monetary benefits that reduce operational costs.

The monetary benefits included additional revenue (from capacity utilization based on actual vehicle's location), savings in dispatch labor, reduced mileage costs for drivers and reduced telephony costs). In addition, continuous monitoring and protection of transported goods against risk may reduce insurance premiums. The non-monetary benefits included improved communication with and between truck drivers, reduced driver downtime through minimization of communication calls, improved customer service, increased driver productivity and the additional income generated by using telematics as a marketing and sales tool. From a strategic business point of view telematics may act as a component for safeguarding a company's reputation.

- Shippers:, Shippers on the other hand, are able to use information from the carrier's telematics system to continuously monitor the state and location of the goods, and to estimate, accurately and with acceptable confidence, the spatial and temporal characteristics of the freight, such as loading, unloading, waiting and transit times, temperature, etc. As a result, information provided by telematics systems may add value to shippers by reducing operational costs through better and more accurate planning.

The penetration of telematics systems however, is not yet high and varies globally. Apart of differences in economies, the most important reason is that potential industrial users are not able to determine the infrastructure and the combination of stand-alone systems and applications they need. When a number of IT providers realized this weakness, they began to invest in such technologies on a large scale, aiming to offer telematics services as outsourcers. In their extensive research Zeimpekis and Giaglis (2006) characterized the most important factors that discourage companies from the adoption of telematics systems: investment costs, unclear returns on investment, attitudes to change management, running costs, integration and interfacing with existing information systems, staff training, labor acceptance, lack of confidence in standards and difficulties in selection of telematics service suppliers.

The acquisition and operation cost of telematics services should obviously be balanced against potential benefits arising from the use of information. As real-time monitoring entails high communication costs, an effective way to reduce operation costs but retain an operationally effective information service level is to transmit telematics information on a *per request* or *per alarm/event* basis. In the first case, data are transmitted when a user in a control station submits a request, while in the second, data are transmitted whenever a measured value diverges from a predefined value (e.g., travel area, goods temperature). The depth of use depends strongly on the size of the company and varies according to product and fleet type. For example, companies that distribute chilled or frozen agrifood products focus mainly on vehicle tracking and cold-chain operation surveillance. On the other hand, international forwarders focus on guidance tools that help drivers to reach customers' addresses.

The Less-Than-Truckload (LTL) freight business is a typical example of perishable good - sensitive to time and location; the available capacity of a truck has no value when it bypasses a loading point (e.g., logistics center); that is, the location of the truck is a critical issue for the value of the available (unused) capacity of the truck. Moreover a trucker's desire to gain revenue from this capacity increases while approaching the distribution center. It can be easily presumed that a moving carrier is expected to bid more aggressively in a freight auction for a shipment contract as he approaches the loading point. The fact of different carriers' valuations according to their distance from loading point, leads to low vulnerability because it is hard for bidders to collude due to temporality of valuation. Finally, a shipper knowing carriers' location is able to make rough estimations about their valuations. Integration of LBS to the freight procurement mobile auction offers many other benefits summarized in Table 4.6.

Participant / role	Benefits
Auctioneer / Marketplace owner	Lower communication costs Magnification of subscriber base Lower transaction costs
Carrier	Revenue management / capacity utilization Co-operation opportunities New markets – especially for individuals Low participation costs LTL enhancement Subcontracting between carriers
Shipper / Logistics Center	Reduced freight rates (less than market price) Growth of potential supplier base Response to ad-hoc needs High procurement speed Better control on supply chain flows
Value-adding service providers (insurance, law, banking, collecting, etc.)	Market growth Business opportunities Advertising
Communication infrastructure providers	New source of revenue New service development Roaming
Other participants (IT, consulting, etc.)	Growth of business

Table 4.6: *Benefits for Marketplace Participants*

4.6 Conclusion

The integration between telematics and other information and communication technologies creates the potential for the development of a variety of important services. As a conclusion, this chapter provides a short description of three emerging applications for fleet planning and operations, which combine telematics services and other technologies to improve efficiency and safety. Finally, it describes a value-added application that incorporates telematics into a mobile marketplace to allow dynamic yield management and effective pricing of freight transport services.

.1 Vehicle Routing and Monitoring

In the past, Eibl *et al*. (1994) described the need for vehicle routing and scheduling software for the cost-effective management of truck fleets. They also described the application of such software in the brewing industry, which faced a number of geographical and time constraints. Their study analyzed an interesting software acquisition process ("make" or "buy"), that is still applicable in today's companies. Tarantilis and Kiranoudis (2001) underlined the importance of the time between loading and delivery of food products and developed a specialized routing algorithm aiming to optimize distribution schedules for milk products.

One rather challenging issue for such applications is the integration with telematics services, in order to provide real-time information and controlling opportunities during the evolution of the planned routes. In this context Giaglis *et al*. (2004) proposed an architecture for a real-time mobile decision support system, while Zeimpekis *et al*. (2007) proposed a detailed design framework for a vehicle management system that supports intelligent re-routing.

.2 Safety

Recently, Jedermann *et al*. (2009) proposed an application of RFID technology to capture temperature conditions in truck compartments (instead of transported items) during the transportation of chilled products. An obvious shortcoming of this methodology is that the temperature report is not real time; it is developed and analyzed only after the arrival of the truck in a facility. Integration of the proposed architecture and telematics may potentially provide additional value through the timely provision of such reports while the products are still on-the-move.

.3 Value-Adding Applications

In addition to fleet monitoring and reporting, telematics and wireless networks can be combined to provide integrated value-added applications. Zeimpekis *et al*. (2003) proposed a taxonomy framework of positioning technologies, based on the criterion of location accuracy, for various B2B and B2C applications. Auctioning over wireless networks constitutes an attractive emerging class of m-commerce application. It is a procurement negotiation tool and involves the announcement and execution of geographically focused auctions. Various combinations of heterogeneous communication services like internet, mobile and GPS can be applied to form value-badded applications, which are usually called location-based services (LBS). Emiris *et al*. (2007) demonstrated the coupling of LBS and m-commerce in auction environments to create an m-auction environment for use in logistics-related services. In particular, they examined the case of auctions where several bidders compete to win a freight contract by offering a lower price. They designed an LBS system that was used in conjunction with an appropriate database to pre-select potential bidders who fulfilled a set of criteria, such as appropriate equipment and proximity to the pick-up point. An m-commerce environment was used as the information exchange platform between the auctioneer and potential bidders.

Emiris and Marentakis (2009) also examined a location-sensitive, reverse, m-auction application in the freight transport market. Here, potential suppliers (carriers) were able to place bids for less-than-truckload shipments while on the move, aiming to gain from economies of scale. Given that participation via internet or mobile device is inexpensive and depends only on wireless communication, the telematics-based marketplace is accessible to carriers of almost any size, with numerous benefits:

- cost-effective accessibility to small carriers;
- reduction of empty miles (deadheading) and better capacity utilization;
- generation of collaboration or subcontracting opportunities, especially for individual carriers, to offer adjacent long-haul services independently of their license, or to increase their capacity to undertake large shipments.

Chapter 5

Expansion of ACE: Implementation Strategy

This chapter further expands the decision-making schemes presented in Chapter 3, conceptually defined as Level-1 and Level-2 of the ACE, by taking into account the decisions related to the implementation of an auction. It is reminded that Levels 1 and 2 focus on the design and development of the auction mechanism which constitutes the “heart” of the marketplace; nevertheless, of equal importance is the issue of implementation of the mechanism in a marketplace.

This chapter therefore deals with the presentation of these critical decisions that are related to the implementation of the auction in several operational contexts and proposes a methodology which serves different stakeholders assuming that ACE Levels 1 and 2 have already been used to configure the auction mechanism. The proposed methodology is conceptually defined as “*progressive design*” and serves as a decision-making environment which complements ACE with a third level. This chapter contains material from our published work[7].

The term "implementation" for ACE Level-3, is employed herein to denote the issues related to the environment and the intrinsic attributes of the marketplace where an auction is implemented. Here the environment is perceived to be physical (p-), electronic (e-), mobile (m-) or location-sensitive (l-) and largely defines and affects the application for which the auction is designed for and developed. Levels 1 and 2 of the ACE are perceived as "internal" and are related to the design of the core auction mechanism and its further development with the injection of enhancement parameters. On the other hand, Level-3 is perceived as "external" and is related to the specific attributes of the marketplace where the auction applies, the stakeholders' intentions and the available resources for the implementation.

This Chapter is structured as follows. Section 5.1 examines the implementation issues for advanced auctions and Section 5.2 establishes the 3rd level of ACE. Section 5.3 presents an example of how ACE-Level-3 applies for the development of location-aware auctions which is the core concept in the present thesis. Section 5.4 presents a secondary application of ACE-Level-3 for the transition of an auction setting from one instance to another. Section 5.5 proposes the use of connected graphs with ACE-Level-3 to visualize priorities for decision-making in the design phase, and Section 5.6 concludes.

[7] Marentakis and Emiris (2010c), Emiris and Marentakis (2010b)

5.1 Implementation Issues

The success of an auction relates to the efficient design of the auction mechanism and may be strengthened with the use of additional attributes which inject special properties. This design is based on elements and characteristics which are endogenous to the auction mechanism; yet, this is only a first step towards the development of the auction. In the real world, the success and often the viability of the auction is affected heavily by the implementation context. The implementation may become more complex subject to the technological infrastructure engaged in advanced auctions where several stakeholders are needed to coordinate and cooperate in the design process. As a result, there is a clear need for a more profound analysis on the auction implementation issues focusing deeply on special technical parameters. The basic question that arises may thus be expressed as: “which are the parameters and attributes that alter the implementation properties and how”. To answer this question we will (i) spot the evolutionary characteristics, (ii) evaluate their impact, and, (iii) identify their interdependencies. The resulting Level-3 of the ACE provides answers to these questions and serves as a reliable support for a decision-maker, as it deals with the implementation of the auction mechanism configured through the use of ACE Level-1 and Level-2.

5.1.1 Auction Implementation Contexts

The methodology proposed herein originates from the fact that physical auctions (*p-auctions*) are foundational and electronic (e-), mobile (m-) and location-aware (l-) evolve from physical auctions. The e-auctions thus largely contain the attributes of p-auctions, m-auctions contain most of the attributes of e-auctions and, finally, l-auctions contain several attributes of m-auctions.

The distinct characteristic for each of these auction forms is the gradually increasing use of ICT (Figure 5.1). While auction mechanisms may be quite similar at their core, they differ significantly in the operational *context* over which the auction is implemented.

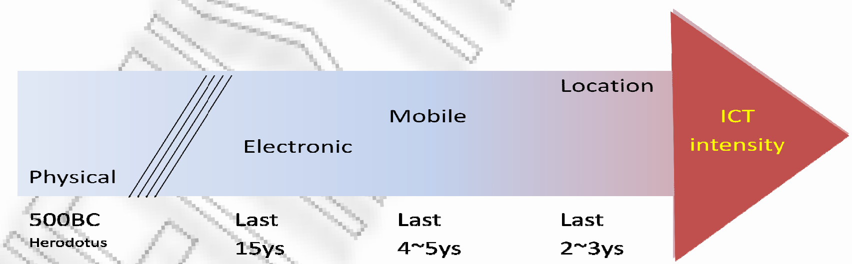

Figure 5.1: *Evolution of Auctions*

Based on the above, a set of four distinct contexts is acknowledged in the ACE Level-3, namely: (i) the physical (p-) context, (ii) the electronic (e-) context, (iii) the mobile (m-) context, and ultimately, (iv) the location-aware (l-) context.

5.1.2 Auction Implementation Perspectives

Decision-making for the design of an auction mechanism is a task for auction designers supported mostly by economists and operational researchers. ACE Levels 1 and 2 may efficiently help this process. On the other hand, the implementation of an auction expands further the range of decision makers and stakeholders by incorporating considerations concerning the operational environment. Figure 5.2 presents a typical auction flow and the core decision-makers in any type of auctions, enriched by the ICT provider who corresponds to ICT-engineer’s decisions related to services and infrastructure.

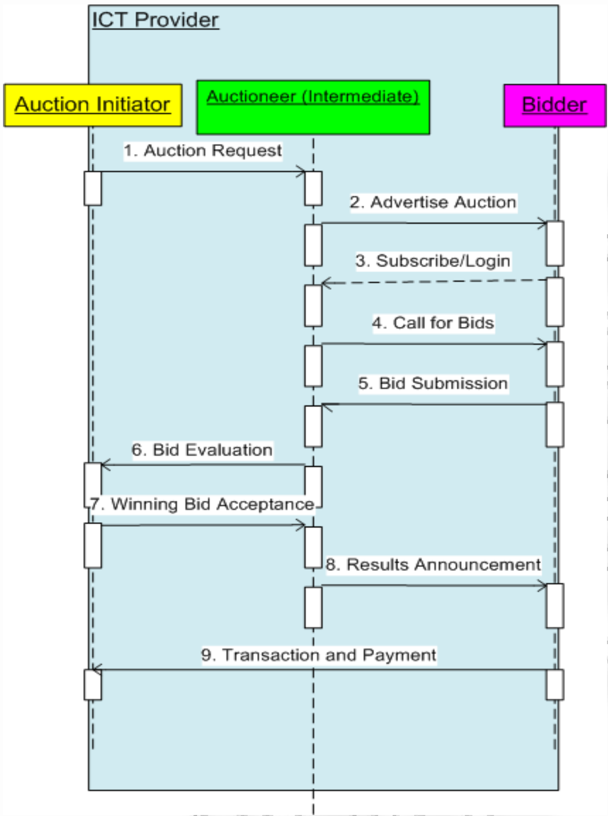

Figure 5.2: *Decision Makers and Auction Flow*

As depicted in this figure, the AUCTION INITIATOR (either buyer or seller), sends an *auction request* to the AUCTIONEER containing the major information (e.g., item, price data, valuation data etc.) required for the design of the auction mechanism. Then, the AUCTIONEER *advertises the auction* to several BIDDERS (usually through web-sites or through mobile messaging), and interested BIDDERS *login* (if they are already registered) or *subscribe/register* the auction platform. Using the auction platform the AUCTIONEER *requests bids* from BIDDERS who then *submit* their bid(s). The AUCTIONEER then *evaluates* submitted bids and informs the AUCTION INITIATOR who confirms the *acceptance* of the winning bid informing the AUCTIONEER appropriately. The latter *informs* the set of participating BIDDERS about the results and then the *financial transactions* take place between winning BIDDER and AUCTION INITIATOR. The whole process is *supported* by the infrastructure designed and provided by an ICT PROVIDER.

Evidently, the implementation of an auction requires the strong cooperation between these decision-makers whose decisions sometimes may conflict. In certain cases one decision may have positive or negative effect on other decisions and often the decision-making process must be prioritized.

Based on the above, the core set of decision-makers identified by ACE Level-3 consists of 4 stakeholders each of them representing a different *perspective* (*Decision Group*):

- The *market maker (or auctioneer*): He is responsible for hosting the auction process. In most cases he is an intermediate entity (e.g., an agent or broker) although (rarely) he may be the auction initiator. The auctioneer gains revenue by receiving commissions from participants (usually auction initiator).
- The *auction designer*: He is responsible for the design of the auction mechanism. In most business cases he is an entity belonging to the market-maker's decision-making team. He is

examined separately since his decisions relate more to the engineering of the auction mechanism while market-maker is focusing mainly on marketing issues.

- The *user*: The user segment includes several stakeholders most important of which being the auction initiator and the set of bidders. Nevertheless, other stakeholders offering supportive and value-adding services in the auction process are taken into account as well.
- The *ICT engineer*: The ICT engineer is perceived the entity responsible for the definition and design of the proper ICT infrastructure for a specific ICT-enabled auction. His role gets more important along with the ICT-intensity in advanced auctions (e-, m- and l- by order of intensity).

5.1.3 Decision Classification and Structure

Decisions related to each of the *perspectives* described above are classified in several distinct *functions* reflecting the corresponding *decision areas* as shown in Table 5.1:

PERSPECTIVE	DECISION AREA (FUNCTION)
MARKET	MARKET DESIGN
	BUSINESS
	TIME-SPACE
AUCTION	ITEM
	AUCTION DESIGN
	ROBUSTNESS
USER	USER SERVICES
	USER COSTS
ICT	TECHNOLOGY
	EFFICIENCY

Table 5.1: *Auction Design Decision Areas*

Although some of these functions spread over more than one perspective, the proposed classification scheme has in its center the functional owner of the corresponding decision area. For each of the decision areas described above, an extended set of decision elements and parameters is defined and evaluated, representing corresponding customizing options. Each of them is evaluated with the use of numerical or linguistic ranges of values indicating the importance, the degree of benefit and/or the technical sophistication. The evaluation is based mainly on research findings and –to maintain practicality and applicability- experts' opinions, and it is evolutionary; both parameters and their values may change dynamically when a new parameter is inserted or when its importance changes.

The proposed decision areas correspond to different stakeholders' functional decisions. A stakeholder is perceived herein as the operational owner of the function and the basic decision-maker. In particular:

- A market-maker's main intention is the advertising of the auction to as many markets as possible and the linkage to many commercial web sites; furthermore he cares about the integration of the market setting within an extended market design. The market maker should also care about the temporal and spatial attributes of the auction including location sensitive auction services.
- An auction designer's main intention is to configure a proper, efficient and robust auction mechanism given the specific properties and attributes of the auction item.
- A user's main intention is to take advantage of the market's services to trade efficiently, fairly and economically.

5.2 An ICT-engineer's main intention is to identify and combine efficiently appropriate ICT technologies in order to set the infrastructure for the efficient and successful implementation of the particular needs of the auction studied.

5.2 The ACE Level-3

ACE Level-3 is a development and expansion of ACE which encompasses in one single scheme the design of mechanisms, the parameters and the implementation decisions for the design of auctions (resulting from Levels 1 and 2), and the selection and adjustment of implementation enhancing parameters. More specifically, the ACE Level-3 deals with the contextual implementation of auctions in both traditional and modern ICT-supported contexts.

The ACE Level-3 applies to the gradual development and implementation of auctions in an integrated way:

- It describes and evaluates the auction organizational decision parameters for each of the four distinct contextual settings (p-, e-, m-, l-)
- It presents the options for each of these decision parameters through an evolutionary pattern
- It assigns organizational decisions (*Decision Groups*) to specific decision areas (*Functions*)
- It uses evaluation indices and/or ranges which reflect the importance, the benefit and the degree of sophistication for each auction option in each of the contexts.

In summary, Level-3 identifies and evaluates decision parameters and classifies them using evolutionary patterns for specific contexts and perspectives. Ultimately, the Ecosystem serves as a generic and applicable auction customizing scheme for the development of advanced auction settings aiming to:

- Customize auction mechanisms
- Identify the decision elements
- Organize key decision elements in multi-dimensional auctions
- Identify and clarify the interdependencies of decision elements
- Support different stakeholders and perspectives

The 3 levels of ACE are strongly integrated and can be used in a sequential manner by first defining the auction mechanism, enhancing it and finally implementing it (Figure 5.3).

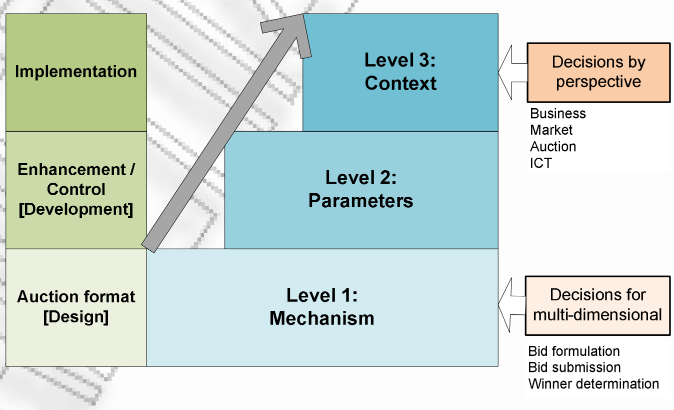

Figure 5.3: *Auction Development: ACE Sequence*

Overall, the design process is based on a decision-making process which consists of the following steps each of them corresponding to a set of discrete decisions:

(1) The auction designer uses the ACE Level-1 to design the core auction mechanism. Depending on the specific properties and quantities of the trading item(s), he can use

the proposed set of plug-ins to further expand the core mechanism with multi-dimensional characteristics.

(2) The designer then uses the ACE Level-2 to further develop the core mechanism by selecting additional parameters to enhance attributes like robustness, control, competitiveness, etc.

(3) Finally, the designer uses the ACE Level-3 to establish, evaluate and prioritize the implementation actions for each stakeholder's perspective.

The next paragraphs present a detailed overview of the ACE Level-3. Importantly, the analysis is focusing on the current state and it can easily be adapted, modified or extended along with the progress of research and technology. The analysis is presented in *Perspective* and *Decision Area (Function)* levels, presenting the *Decisions (Parameters)* and their *Options* and *Values* for the 4 distinct *Contexts (p-, e-, m-, l-)*. Finally, the Customizing Options and assigned Values are defined based on findings from the literature and on experts' opinions.

5.2.1 Market-maker Perspective

The market-maker perspective consists of three major decision areas corresponding to: (i) the market design function, (ii) the business organization function, and, (iii) the time-space function of the auction marketplace. Each of them is further analyzed in the sequel.

.1 Market Design

The decision parameters related to the market design function are tabulated in Table 5.2 below.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)					
		Level 3(P)		Level 3(E)		Level 3(M) / Level 3(L)	
MARKET DESIGN	Operating time	Fixed, restricted, periodic	0-1	24x7			4-5
	Geographic requirements	None	5	Coverage, language, currency,law, tax			4-4
	Marketplace	None	0	e-tail connected stores	4-5	Mobile portals	2-4
	Collaboration need	Limited	1	Group buying, communities, cross-bidding	4-5	Ad-hoc	1-3
	Security services	None	0	Escrow	4-5	Escrow	2-4
	Insurance services	Pemium, terms, claim handling					0-5
	Publicity	Old-fashion	1-3	Links, search engines, meta-auction sites	3-5	"Push" (announcement)	4-5
	Participants	Restricted	1	Theoreticaly unlimited	5	Restricted	1-3
	Collaboration support	Not (always) supported	0-1	Supported	4-5	Difficult	3-4
	Communities	Not (always) supported	0-1	Supported	4-5	Difficult	3-4
	Intermediaries	Auctioneer	0-3	None or auctioneer			3-4
	Integrity	Low	0-2	High	3-5	Very high	4-5
	Scope	Focused	0-2	Focused/Generic	4-5	Generic (less than e-)	3-4
	Physical presence (participants)	Required	2-3	Not required			4-5
	Accessibility	Physical location	0-1	Everywhere	2-4	Everywhere + wireless	2-5

Table 5.2: *Market Design Decision Parameters*

(1) *Operating time*: this may be fixed, restricted or periodic for physical auctions offering low customization flexibility. The same option for modern ICT-enhanced auctions offers high flexibility since an advanced auction may operate anytime, so it is ranked higher.

(2) *Geographical requirements*: Physical auctions are mostly local, while advanced auctions have several localization requirements due to their global coverage.

(3) *Marketplaces*: Physical auctions are hard to advertise in several physical marketplaces. E-auctions offer several offerings for integration and expansion to e-marketplaces while m- and l-auctions offer comparatively less offerings.

(4) *Collaboration*: E-auctions may easily facilitate development of communities between different market players while m- and l- auctions offer only ad-hoc and on-demand collaboration (relatively highly). Collaboration in p-auctions is hard to obtain and comparatively limited.

(5) *Security services*: Both e-, m- and l- auctions require intense use of security services mainly due to anonymity of participants while such services in p-auctions are of low importance.

(6) *Insurance service* is a parameter that must be taken into account in any type of auction. Their importance relates mainly to the auctioned item instead of the context, so its weight ranges between 0 (no need) to 5 (absolutely needed).

(7) *Publicity*: E-auctions can be implemented through a wide and advanced range of advertising channels (e.g., search engines, links to web-sites and portals etc.). M-auctions may also benefit from them (yet, with several limitations); their advertisement is limited to “push” marketing techniques which are in general less effective than techniques used in e-auctions.

(8) *Participants*: E-auctions offer the access to theoretically unlimited number of participants, while participation in m- and l- auctions is comparatively lower mainly due to higher communication costs. Obviously p-auctions offer limited participation - usually invited bidders. In p-auctions the presence of an intermediate (physical) auctioneer is mandatory, while in advanced auction the presence of an auctioneer is not always necessary (for example P2P auction settings).

(9) *Integration*: Wireless (m- and l-) auctions require sophisticated integration between different technologies. E-auctions are less demanding, while integrity in p-auctions is of low (or even no) importance.

(10) *Scope*: Usually p-auctions are much focused on specific scopes; each auction deals with a specific item or category (e.g., art, collectibles, government procurement etc.) while e-auctions’ scope is quite generic. Parts of e-auction items range can be easily extend to m- and l-auctions as well.

(11) *Physical presence*: P-auctions require the physical presence of the participants which obviously is not the case for advanced auctions.

(12) *Accessibility*: P-auctions are not easily accessible; usually they are accessible by residents of a city and to a less extend in country-wide basis. On the other hand e-auctions are offered from almost anywhere while m- and l- auctions are even better since they abolish wired Internet requirements (yet, with restrictions related to wireless networks coverage).

.2 Business

The business function relates to several decisions as described in Table 5.3. A brief discussion on each of the parameters follows:

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
BUSINESS	Distribution channel expansion	physical markets	0-1	e-markets	4-5	m-markets			4-5
	New procurement process	procurement	1-2	e-procurement	4-5	m-procurement			4-5
	Range of items	physical	3	physical + digital	5	restrictions due to description			2-4
	Market penetration	mostly local	0-1	global	3-4	global, no location restrictions			3-5
	Other stakeholders (VA-service providers)	insurance	0-3	insurance, banks, advertising sites					1-5
	Other stakeholders (infrastructure)	auction site	2	IT, telecoms, logistics					4-5
	Scope	C2C, B2C, B2B, (or G)							3-5
	Geograpical coverage	Local	0-1	Global	4-5	Local/Global	3-5	Local/Global	2-5
	Entities	Mediated, participants	2-3	Users, devices, agents, platforms					4-5

Table 5.3: *Business Decision Parameters*

(1) *Expansion of distribution channels* and *new procurement processes*: While physical auctions support only physical markets, e-auctions and m-auctions support the development of *new procurement processes* (for the upstream supply chain) also defined as e- and m-procurement respectively.

(2) *Range of items*: For both procurement and distribution processes, p-auctions support the trading of –mostly- physical items while electronic auctions may support trading a wide range of both physical and digital (informative) items – especially with the use of visualization and multimedia tools. M- and l-auctions are less supportive since they are restricted by bandwidth and device capabilities.

(3) *Market penetration*: Obviously, e-auctions offer great opportunities to penetrate into new markets while m- and l-auctions expand this capability to markets without restrictions of location and appliances.

(4) *Other stakeholders*: One of the biggest deals of advanced auctions (and e- and m-commerce in general) is the reduction of the number of trading intermediaries (disintermediation). Advanced auctions open great business opportunities for several stakeholders offering *value-adding services* (e.g., insurance, escrow, e- and m- banking etc.) and *infrastructure services* (e.g., networks, logistics services etc.) as well.

(5) *Scope*: In general, all contexts offer all forms of S2S transactions (where "S" denotes a stakeholder which may either be a Consumer, Business, or Government).

(6) *Geographical coverage*: P-auctions have comparatively low geographical coverage (local) while e-auctions have the most extended coverage. Coverage for m- and l-auctions may prove limited in certain cases due to technical shortcomings (e.g., mobile coverage) or intentionally (which is requested in l-auctions).

(7) *Entities*: Advanced auctions involve several entities (users, devices, agents etc.) while participating entities in p-auctions are static and limited to the mediating auctioneer and the participant.

.3 Time-space

The time-space function incorporates several decisions relating mainly to the temporal and spatial attributes of the marketplace. A representation and evaluation of these decisions is presented in Table 5.4. A brief description on these decision parameters follows:

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
TIME-SPACE	Timing (real-time)	Required	0-3	No restrictions					4-5
	Synchronous activity	Required	0-2	No restrictions					4-5
	Time-zone	Restrictions	0-1	No restrictions					5
	Speed	Restrictions	0-1	No restrictions	4-5	Network dependent			3-4
	Multi-bidding	Restrictions (sealed-bid, agents)	0	Applicable	5	Network dependent			3-4
	Geographic coverage	Local	0-1	Global	5	Network dependent			3-4
	Location-awareness (item)	Not applicable	0-1	Restrictions	2-3	Allowed	3-4	Ideal	5
	Location-awareness (participant)	Not applicable	0-1	Restrictions	2-3	Allowed	3-4	Ideal	5

Table 5.4: *Time-Space Decision Parameters*

5.2.1 *Timing* and *Synchronous activity*: P-auctions are executed in real-time and require the synchronous activity of participants.

5.2.2 *Time-zone*: Advanced auctions have global geographic coverage; they do not have geographic restrictions due to different time-zones.

5.2.3 *Speed*: The duration and the execution speed of physical auctions are comparatively high – especially for open-cry auctions. On the other hand, speed of transaction is not a problem in e-auctions while m- auctions may show some restrictions due to data network used for the transmission of transaction data.

5.2.4 *Multi-bidding*: E-, m-, and l- auction marketplaces support the execution of multiple simultaneous auctions and allow bidders to participate and place bids in a theoretically unlimited number of independent auctions (even for similar items). Multi-bidding in p-auctions is applicable only in sealed-bid auctions or by engaging several agents for different open-cry auctions.

5.2.5 *Location-awareness*. Identification and tracking of location of the item or the participant (or both of them) is a rather modern application which is ideally supported by l-auctions; m-, e- and auctions show several limitations, while p-auctions cannot support this feature.

5.2.2 Auction-Designer Perspective

The auction-designer perspective consists of three basic decision areas related to: (i) the auctioned items(s), (ii) the design of the auction mechanism, and, (iii) the robustness of the designed mechanism. Each of these is further analyzed in brief in the next paragraphs.

.1 Item

Item-related functions require three basic parameters presented in Table 5.5.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
ITEM	Items with high information content	Hard to support	0-2	Supported	4-5	Difficulties			2-3
	Description of complex items	Easy	4-5	Depends	3-4	Relatively hard			0-1
	Physical presence (items)	Yes (in most cases)	4-5	No					1

Table 5.5: *Item-Related Decision Parameters*

A brief description of these parameters follows:

(1) *Items with high information content*: P-auctions can hardly support items with high information content, for example, digital goods. This shortcoming can be realized when

several items with high information content are traded simultaneously, and the interested bidder wishes to acquire specifications, to retrieve information (e.g., evaluations, ratings, etc.) and compare between them to estimate his valuation. Such requirements can be facilitated in electronic environments, since Internet offers easy and costless access to vast amounts of related information. Such information can also be retrieved through mobile internet; yet, the information is not always adequate due to mobile device limitations.

(2) *Description of complex items*: In most cases, p-auctions and e-auctions as well, allow for the extended description of items regardless of their design or technical complexity. P-auctions also facilitate optical inspection of items. E-auctions may be equally supportive since they can facilitate linkage to informative web-sites. Finally, m-auctions show several shortcomings due to message costs and device restrictions. E-, and particularly, m-auctions are less capable of describing complex physical items. Comparing e- and m- auctions, e-auctions offer more capabilities to transmit visual content about the item.

(3) *Physical presence*: P-auctions are the most appropriate when participants want to physically inspect the auctioned item in order to estimate their valuations. On the other hand, advanced auctions in general can hardly support such items (e.g., collectibles, jewelry, masterpieces, etc.)

.2 Auction Design

Auction design functions deal with parameters related to the engineering of the auction mechanism. A representation and evaluation of these is presented in Table 5.6 followed by a brief description.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)					
		Level 3(P)		Level 3(E)		Level 3(M)	Level 3(L)
AUCTION DESIGN	Complex (contemporary) mechanisms	Difficult to execute	1-3	Easy to execute	4-5	Difficult	1-3
	Auction parameters	Practical difficulties	2-3	Supported	4-5	Less supported	2-3
	Advanced bidding charact. and language	Difficult to execute	0-1	Supported	4-5	Less supported	2-3

Table 5.6: *Auction-Design Decision Parameters*

(1) *Complex mechanisms*: E-auctions are ideal for the implementation of complex auction mechanism (e.g., multidimensional mechanisms). They also offer advanced computational and decision-making capabilities through strong integration with sophisticated IT applications (e.g., decision-making, optimization, etc.). On the other hand, p-auctions are comparatively slow and less IT-sophisticated. Thus, they cannot easily support complex mechanisms. M- and l-auctions are not equally supportive mainly due to interface limitations.

(2) *Mechanism parameters*: Mechanism-enhancing parameters like those contained in ACE Level-2, are ideally supported by e-auctions; moreover, modern commercial IT tools support the quick design and customization of complex mechanisms enriched with several parameters. Currently, many auction web sites allow the auction initiator to customize the auction mechanism according to his specific needs. On the other hand p-auction mechanisms are in most cases predefined by the auctioneer and not modifiable. Same as before, m- and l-auctions are less supportive due to device technical limitations.

(3) *Advanced bidding characteristics and languages*: As already stated, e-auctions are supportive for advanced and complex bidding languages like those required for multi-dimensional auctions. Moreover, they can ideally facilitate intelligent agent applications which automate the bidding process on bidders' behalf. Finally, p-auctions are less supportive especially when open-cry mechanisms are engaged.

.3 Robustness

Decisions related to the robustness of the auction mechanism aim to prevent market manipulation and are of great importance for the successful implementation of the auction. The core decisions are presented in Table 5.7 followed by a brief analysis for each of them.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)						
		Level 3(P)		Level 3(E)		Level 3(M)	Level 3(L)	
ROBUSTNESS	Collusion	Easy	2-3	Difficult				3-5
	Contact btw. Participants	Easy	2-3	Controlled	4-5	Controlled - IT support		2-4
	False name	Hard	5	Easy				0-4
	Security	High	5	High	4	Lower		2-4
	Privacy	Low	0-1	High	3-5	Mid-high		2-5
	Misleading item data	Low	5	High				2-3
	Legal support	High	5	Medium (low experience, global coverage)				0-3
	Prequalification	Allowed	5	Allowed				2-4
	Item inspection	Allowed	5	Photos, descript	3-4	Photo, description		1-3
	Participants' rating	Allowed	5	Feedback mechanism, data, roles (who whom), when, range (numeric, %)	3-4	Like e- but with less options		2-3
	Censorship	Allowed	5	Country-dependent, hard to control				2-4
	Fraud detection	Relatively easy	5	Auto detection rules (shill, multiple ID, feedback extortion)				2-4
	Authentication	Easy	5	Process, interaction-based				1-3
	Cryptography	Not applicable	5	Algorithm selection/design				2-4

Table 5.7: *Mechanism Robustness Decision Parameters*

(1) *Collusion*: Collusive phenomena between participants may occur in any instance; nevertheless, advanced auctions are more robust against collusion since the number of participants is large compared to traditional auctions.

(2) *Contact between participants*: Advanced auctions allow the controlled contact between participants (e.g., for the formation of coalitions) while in p-auctions this contact is easy to be realized but it is uncontrollable, since face-to-face contacts usually exist.

(3) *False-name*: P-auctions are more robust against false-name participation while advanced auctions are not.

(4) *Security*: It is higher in p-auctions, while m- and l- auctions need more attention.

(5) *Privacy*: It is low in p-auctions is low due to face-to-face contact. E- and m- auctions may support privacy more easily.

(6) *Misleading item data* and *inspection*: In p-auctions participants are usually able to physically inspect the auctioned item, so the danger from provision of *misleading item data* is very low. E- and m- auctions are more vulnerable since the interested bidder is informed from digital material (images, videos).

(7) *Legal framework*: It is not always adequately supportive in advanced auctions since these auctions begun the last two decades and their evolution was very rapid; p-auctions have been used for centuries and are more controllable.

(8) *Prequalification*: P-auctions support prequalification of participants more effectively than advanced auctions because of the prerequisite for physical presence.

(9) *Rating indices*: Many auction marketplaces apply evaluation ratings for participants. Rating in p-auctions is more realistic than advanced auctions mainly because it is personalized.

(10) *Censorship*: Special attention regarding censorship is required in advanced auctions due to different legal frameworks in country-level range.

(11) *Fraud behavior* and *authentication*: Physical presence of participants is very supportive for inspection of fraud behavior and for authentication of participants’ identities.

(12) C*ryptography*: Advanced auctions may benefit (and in some cases it is compulsory) from a *cryptographic* methodology which reduces fraud and safeguard privacy.

5.2.3 User Perspective

The user perspective consists of two basic decision areas related to: (i) user services and, (ii) usage costs, briefly discussed in the sequel.

.1 User Services

Any auction implementation should provide several mainly informative and logistical services. A representation and evaluation of related decisions is presented in Table 5.8.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES) Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
USER SERVICES	Personalization	Not allowed	0-1	Allowed, degree	4-5	Less allowed			3-4
	Bidders' information	Present bidders ID	1-3	Controlled	4-5	Not easy			0-2
	Training	Not easy / costly	0-1	Easy	4-5	Not easy			2-3
	Interactivity	Physical	4-5	Supported	2-5	Not easy			2-3
	Process complexity	Low	4-5	Low-Medium	2-4	Medium			2-5
	Historical data	Difficulties	0-2	Easy	4-5	Medium difficulty			3-4
	Content	Physical only	0-3	Supported	4-5	Device/network restrictions			0-2
	Ease of use	Easy	4-5	Some skills	3-5	More skills			2-4
	Location services	None					0	Guide, follow, what's near, emergency, tracking	4-5
	Automation	Not supported	0	Proxy Agents			4-5	LBS agents	4-5
	Automatic intelligence	Not supported	0	Bidding, info collection, intelligence, bundling					3-5
	Payment/collections	Varies	4	Money transfer, credit card	4-5	Auto billing (mobile comm. provide			5
	Registration reqts./extend	User data	5	User data	4-5	Depends on: Device (screen, autonomy, keyboard) and network Control methods e.g. triggering			0-3
	Navigation	Physical	5	GUI, personalization	4-5				
	Bidding process	Clear	5	Workflow, message sequence	3-4				
	Observability	Presence	5	Time, current bidding data	3-4				
	Alerting	Not necessary	5	When, event, type of info	3-4				
	Search	Not applicable (push)	5	Simple, custom, categories, hierarchies, catalog	3-4				
	Attractiveness	Oriented	5	General (images, photos, simplicity)	3-4				
	Communication	Presence	5	Online, mail, phone	3-4				
	Friendliness	Presence	5	Training, FaQ, online help, language	3-4				
	Accuracy level	Presence	5	Data integrity, validity	3-4				
	Bidding process info.	Presence	5	Range, brdwatchinsg, public, registered	3-4				
	Spatial information	Not applicable	5	Not applicable	3-4	Depends on (see above)	0-3	Location, speed, direction, pojections	5

Table 5.8: *User Services Decision Parameters*

The decisions and related parameters are briefly discussed below:

(1) *Personalization*: E-auctions (and to a lesser extent m-auctions) offer several options for personalization of the auction process and relative information, while p-auctions are more strict.

(2) *Bidders' information*: It is more easily controlled in advanced auctions while in p-auctions (mostly open-cry) each participant can easily observe his rivals.

(3) *Training*: E-auctions may easily facilitate training methods for potential participants (both initiators and bidders) by offering simulation instances. This is hard to be implemented in the rest of the contexts.

(4) *Interactivity*: P-auctions are absolutely interactive; in e- and m- auctions application of multimedia tools may support to some extent the interactivity.

(5) *Process complexity*: By nature p-auctions are less complex; m-auctions should be designed to be simple while e-auctions may facilitate complex process whenever needed. One of the valuation criteria for bid formulation relates to historical data of previous auctions for same items.

(6) *Historical data* and informative *content*: E- and to less extend m- auctions may easily collect and offer raw or structured historical data and informative content to interested participants - even from several auctions from different auction sites. Obviously informative content for p-auctions is not critical due to the physical presence of the item and the participant.

(7) *Ease of use*: The skills required for the participation and easiness are ranked in increasing order as p > e > m > l.

(8) *Location services*: It is obvious that l-auctions are intentionally used when the awareness of the participants' and/or the actual/projected location of the item is crucial for the valuation, participation and auction outcome.

(9) *Automation* and *intelligence*: Advanced auctions may easily facilitate the use of automated agents to support the bidding and participation process in general which may also be intelligent enough to offer decision-supportive services.

(10) *Payment / collections*: P-auctions support almost all types of payments transactions between participants, while advanced auctions support mostly credit and debit card. Interestingly m-auctions may be supported by automatic billing by the mobile network services provider.

(11) *Usability*-related decisions: A series of decisions related to the *usability* offered is of special importance during the implementation. These decisions are: requirements for *registration*, easiness of *navigation*, the *bidding process*, the *observability* of the auction process, the *alerting* services during the auction, the *search* tools provided, the elements that enhance the *attractiveness* of the auction, the facilitation of *communication* between participants, the *friendliness* of the instance in general, the *accuracy* of the information provided and the *information* related to the bidding process. In general p-auctions are ideal to support this set of requirements. Several ICT tools have been developed to realize, enhance and support these requirements for e-auctions. Similar tools are currently developed for m-auctions. Their major characteristic is that they are provided on-demand (and not continuously) due to bandwidth, device and cost limitations.

(12) *Spatial Information*: These informative services of the item or the participant (e.g., speed, direction, projection etc.) can easily be facilitated in real-time by l-auctions. Of course these services can be published and integrated within e-auction contexts which are strongly integrated with LBS architectures.

.2 User Costs

The implementation of the auction involves four basic decisions in the function of cost definition. A representation and evaluation of these decisions is presented in Table 5.9 followed by a brief analysis.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
USER COSTS	Transaction costs	Zero	5	Zero	5	Network	2-3	LBS	2-3
	Search costs	High (travel etc.)	0-2	Zero	5	Network	2-3	LBS	2-3
	Participation costs	High (travel etc.)	0-2	Revenue model or zero	4-5	Network	2-3	LBS	2-3
	Listing costs	Yes	0-2	Revenue model or zero	4-5	Yes	2-3	LBS	2-3

Table 5.9: *User Costs Decision Parameters*

(1) *Transaction costs*: In most cases, transaction costs in the auctions are zero. M- and l-auctions may incur transaction costs (unless the participant use a permanent connection).

(2) *Search Costs* and *Participation Costs*: Advanced auctions minimize (or even set to zero) search costs and participation costs since the participant is able to search over the Web for specific auctions and items. Such costs are very high in p-auction contexts since they require travel costs, etc.

(3) *Listing Costs*: E-auctions minimize listing costs while such costs in m-, l- and p-auctions are relatively high.

5.2.4 ICT Perspective

The fourth perspective is that of ICT-infrastructure designer and consists of two basic decision areas related to: (i) the selection of technology, and, (ii) the efficiency of the design.

.1 Technology

Decisions related to the function of the establishment of the technology architecture are relevant mostly to advanced e-,m- and l-auctions. Yet, some technology-related decisions are also important for traditional auctions which are supported by Information Systems (Table 5.10).

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
TECHNOLOGY	H/W infrastructure	Not required	0-1	Servers, applications	3-4	+ mobile comm.	4-5	+ GPS/Cell	5
	S/W infrastructure	Not required	0-1	Apps, DB, ASP	3-4	+ mobile comm.	4-5	+ GPS/Cell	5
	Database	Not required	0-1	Data structure, location					5
	Bidding entities	Human	0-1	Human, proxy					5
	Hosting	Not required	0	Own, leased, shared, common, ASP					5
	Network	Not required	0	Internet	3-4	Heterogeneity, 2.5G, 3G	4-5	GPS, Cell	5
	Protocol compatibility	Not required	0	JAVA, SQL, HTML, XML, Browser	3-4	GPRS, WAP	4-5	GPS, Open GIS	5
	Privacy	Presence	0-1	Cryptography protocols	3-4	Cryptography protocols			4-5
	Workload	Physical restrictions	2-3	Max bids, frequency, duration, arrival rates, bidders#	3-4	+bandwidth, data volume, transmission rate			5
	Time	Physical restrictions	2-3	Criticality level, real-time, nicast, multicast	3-4	+time-outs, response time, transmission delay			5
	Fault tolerance	Human	2-3	DoS, delay	3-4	+Packet loss handling (due to			5
	Architecture	Not applicable	0	Topology, 3-tier client-server, distributed, P2P	3-4	Ad-hoc, multi-hop, fixed topology (local)			5
	Transaction data	Not applicable	0	Page view, bidding, internal auction			3-4	+Location	5
	Integration reqts.	Not applicable	0	Other IS	3-4	+Mobile	4-5	+LBS	5
	Coverage	Local	0	WWW - global	4-5	Range, roaming, providers			3-4
	Reliability	Not relevant to IT	0	Internet	4-5	Continous connectivity, network, real-time	3-4	+LBS	3-4
	Fairness	Not relevant to IT	0	multicast, all-or-none	4-5	+response time			5
	Message types	Not relevant to IT	0	transaction, forms, mail	3-5	SMS, WiFi			5
	Geospatial/location reqts	Not applicable	0	Not applicable	0	Roaming	3	Satellite, Cell, WiFi, BT	5
	Location senstivity	Not applicable	0	Not applicable	0	Low	2	Accuracy, speed, direction, projection	5
	Site maintenance	Not applicable	0	Continous update					5
	Info. Reusability	Not applicable		Required					5

Table 5.10: *Technology-Related Decision Parameters*

The decisions and related parameters are briefly discussed below:

(1) *Hardware*, *Software* and *Network* infrastructure: In general, the infrastructure becomes more sophisticated when moving from e- to m- and then to l-auctions.

(2) *Database* and *hosting*: Requirements for database systems and hosting of information systems are of equal importance and sophistication in all advanced auctions.

(3) *Bidding entities*: All advanced auctions allow the participation of several bidding entities - both human and artificial agents.

(4) *Protocol compatibility*: Each of the e-, m- and l- auctions engages various communication and interfacing protocols on an additive, complementary and evolutionary form.

(5) *Privacy*: M- and l- auctions are more demanding for existence of cryptographic protocols which safeguard privacy of marketplace participants.

(6) *Workload* and *time*: Large marketplaces need to offer enough "capacity" expressed in terms of workload and time-related parameters; e-auctions need study of duration, arrival times etc., while m- and l-auctions additionally require extended study and estimates of bandwidth consumption, transmission rate, delays etc.

(7) *Fault tolerance*: Normally workload and time metrics are set in approximately values, so fault tolerance should be accurately defined in terms of Quality of Service, delays, packet loss etc.

(8) *Architecture*: The ICT architecture in l- auctions is highly sophisticated (lesser in m- and lesser in e- auctions).

(9) *Transaction data*: The type of transaction data is common for all advanced auctions; yet, l-auctions additionally handle data related to location.

(10) *Integration requirements*: they become more intense along with the sophistication of each context: e-auctions require integration between several information systems, m-auctions additionally require integration with mobile services and l-auctions additionally require integration with LBS.

(11) *Coverage* and *message types*: E-auctions offer extended (even global coverage) while m- and l-auctions show some limitations due to mobile communication providers and roaming.

(12) *Reliability* and *fairness*: M- and l-auctions offer comparatively lower reliability; thus they often need enhancement in order to be *fair* for all participants.

(13) *Communication* in e-auctions is attained with the use of several types of messages (forms, mail etc.) while m- and l-auctions may use additional types of messages (e.g., SMS).

(14) *Geographical* and *location requirements*, *location-sensitivity*: L-auctions have particular geographical (roaming, aGPS etc) and location-sensitivity requirements (accuracy, speed etc.) in order to be successful.

(15) *Site maintenance* and *information reusability*: All advanced auctions require continuous maintenance of the web-site and database in order to be able to reuse past information.

.2 Efficiency

Decisions related to the function of efficiency are also important for the ICT-engineer. These parameters and their values are depicted in Table 5.11 followed by a brief description.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
EFFICIENCY	Equity	Controlled	0-1	Filtering	3-4	Filtering			5
	Allocative efficiency	Mechanism dependent	2	+IT dependent	3-4	+IT dependent	4-5	+IT dependent	5
	Perfect competition	Bidder# limitations	2	Theoretically unlimited #bidders					3-5
	Entry barriers	Cost	0-1	Theortically none	4-5	Cell-coverage	4	LBS coverage	3-4
	Publicity	Focused	2-3	WWW-easy	4-5	WWW-push			5
	Competition	Rivalry btw. Particpants	2-3	Highly relevant to IT, duration, spatial					5
	Fairness	Mechanism dependent	2-3	Highly relevant to IT, duration, spatial					5
	Workload sensitivity	Bidder#, auctioneer experience	2-3	Highly relevant to IT, duration, spatial					5
	Arrival rate sensitivity	Not applicable (fixed time)	0-1	Highly relevant to IT, duration, spatial					5
	Anonymity	ID's	0-1	Supported					5
	Observability	Physical	5	Controlled	3-4	Controlled - IT restrictions			2-3

Table 5.11: *Efficiency-Related Decision Parameters*

(1) *Equity*: All advanced auctions provide filtering options in order to safeguard equity between participants.

(2) *Allocative efficiency*: The efficiency of the auction mechanism is affected by the ICT in a high degree in advanced auctions.

(3) *Perfect competition*: it is better supported in advanced auctions since they may incorporate theoretically unlimited number of participants.

(4) *Entry barriers*: E-auctions and relevant technology are quite mature, yet there are minimal (even none) entry barriers. Nevertheless, there are several entry barriers for m- and l-auctions related to technology for example mobile network coverage, LBS coverage, etc.

(5) *Publicity*: P-auctions are usually advertised to focus audience. E-auctions use the WWW while m- and l-auctions use WWW in a “push” format.

(6) *Competition* and *fairness*: In p-auctions, generation and enhancement of competition along with the level of fairness depends strongly on the auctioneer and the mechanism attributes. On the other had in advanced auctions, these parameters depends strongly on the IT infrastructure. Moreover, the magnification of the participants’ base offered in advanced auctions enhances the degree of competition and reduces the possibility of occurrence of collusive phenomena.

(7) *Workload sensitivity*: workload in advanced auctions relates to participants’ experience (which is typical for p-auctions) and also to other parameters like IT, duration and spatial state.

(8) *Arrival rate*: This is a controllable parameter which in advanced auctions may also be affected by ICT and spatial state.

(9) *Anonymity* and *observability*: As stated earlier, advanced auctions may better control anonymity and allow controlled observability for interested and potential participants.

5.3 Example of Use (Comparative Evaluation)

This section presents an example of use of ACE Level-3; the example is focusing on the development of a novel, location-aware auction for freight services which at the core operates on the basis of a simple Dutch auction mechanism with minimal additional parameters. This mechanism is also used in Chapter 7 of the thesis for the design of an experimental marketplace. In the present example the parameters and their values (or value ranges) have been selected among works cited in the literature review of Chapters 2 and 4. In this example we employ an integer ranking scale which ranges from 0 to 5 where 0 correspond to lowest grade while 5 represents the highest grade.

The market designer should take decisions related to the organization of the marketplace; a freight transportation market should operate continuously (even on weekends for long-haul transportation) and should be customized to country's currency, language, tax, etc. Since the auction is location-aware it should be advertised over mobile networks through a "push" strategy. For the same reason it does not require the physical presence of participants; on the contrary, it is able to search and identify participating carriers even on-the-move. The customizing options and some indicative values are presented in Table 5.12.

The market designer, moreover, aims to expand the business; thus, he aims to establish an m-marketplace supporting the simultaneous execution of e- and m-procurement processes. M-auctions show limitations for the description of complex items and services. The described auctioned service, therefore, should be kept as simple as possible (e.g., no additional evaluation attributes, no complex bidding) thus, based on a simple auction mechanism. L-auctions require high integration between different ICT technologies in order to cover efficiently the required geographical area and to support different types of participating entities, for example, devices, mobile agents, etc; furthermore, several service providers (related to freight business) can join the marketplace offering B2B services. Customizing options for the business-related functions are presented and valuated in Table 5.13.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES) Level 3(P)		Level 3(E)		Level 3(M) / Level 3(L)	
MARKET DESIGN	Operating time	Fixed, restricted, periodic	0-1	24x7			4-5
	Geographic requirements	None	5	Coverage, language, currency,law, tax			4-4
	Marketplace	None	0	e-tail connected stores	4-5	Mobile portals	2-4
	Collaboration need	Limited	1	Group buying, communities, cross-bidding	4-5	Ad-hoc	1-3
	Security services	None	0	Escrow	4-5	Escrow	2-4
	Insurance services	Pemium, terms, claim handling					0-5
	Publicity	Old-fashion	1-3	Links, search engines, meta-auction sites	3-5	"Push" (announcement)	4-5
	Participants	Restricted	1	Theoreticaly unlimited	5	Restricted	1-3
	Collaboration support	Not (always) supported	0-1	Supported	4-5	Difficult	3-4
	Communities	Not (always) supported	0-1	Supported	4-5	Difficult	3-4
	Intermediaries	Auctioneer	0-3	None or auctioneer			3-4
	Integrity	Low	0-2	High	3-5	Very high	4-5
	Scope	Focused	0-2	Focused / Generic	4-5	Generic (less than e-)	3-4
	Physical presence (participants)	Required	2-3	Not required			4-5
	Accessibility	Physical location	0-1	Everywhere	2-4	Everywhere + wireless	2-5

Table 5.12: *Customizing for Market Design*

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
BUSINESS	Distribution channel expansion	physical markets	0-1	e-markets	4-5	m-markets			4-5
	New procurement process	procurement	1-2	e-procurement	4-5	m-procurement			4-5
	Range of items	physical	3	physical + digital	5	restrictions due to description			2-4
	Market penetration	mostly local	0-1	global	3-4	global, no location restrictions			3-5
	Other stakeholders (VA-service providers)	insurance	0-3	insurance, banks, advertising sites					1-5
	Other stakeholders (infrastructure)	auction site	2	IT, telecoms, logistics					4-5
	Scope	C2C, B2C, B2B, (or G)							3-5
	Geograpical coverage	Local	0-1	Global	4-5	Local/Global	3-5	Local/Global	2-5
	Entities	Mediated, participants	2-3	Users, devices, agents, platforms					4-5

Table 5.13: *Customizing for Business Offerings*

The innovative characteristic of the auction is that it offers location-aware services related to the current or projected spatial characteristics of participants. Special care should be given to the geographical coverage and speed of the transactions, while important decisions should be taken about the timing of the auction process (e.g., real-time bidding and evaluation or periodic evaluation). The details of the customizing options are shown in Table 5.14.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
TIME-SPACE	Timing (real-time)	Required	0-3	No restrictions					4-5
	Synchronous activity	Required	0-2	No restrictions					4-5
	Time-zone	Restrictions	0-1	No restrictions					5
	Speed	Restrictions	0-1	No restrictions	4-5	Network dependent			3-4
	Multi-bidding	Restrictions (sealed-bid, agents)	0	Applicable	5	Network dependent			3-4
	Geographic coverage	Local	0-1	Global	5	Network dependent			3-4
	Location-awareness (item)	Not applicable	0-1	Restrictions	2-3	Allowed	3-4	Ideal	5
	Location-awareness (participant)	Not applicable	0-1	Restrictions	2-3	Allowed	3-4	Ideal	5

Table 5.14: *Customizing Time-Space Parameters*

As mentioned above, l-auctions (and m-auctions, in general) cannot easily support complex auction mechanisms, parameters and bidding languages as shown in Table 5.15. To overcome this, the auction designer should develop a quite simple auction mechanism with low complexity.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
AUCTION DESIGN	Complex (contemporary) mechanisms	Difficult to execute	1-3	Easy to execute	4-5	Difficult			1-3
	Auction parameters	Practical difficulties	2-3	Supported	4-5	Less supported			2-3
	Advanced bidding charact. and language	Difficult to execute	0-1	Supported	4-5	Less supported			2-3

Table 5.15: *Customizing Auction-Design Options*

Since the auction is carried-out over mobile networks, it should be quite robust. Although it can hardly permit collusion between bidders, it is very sensitive to other threats like false-name bidding, low security, and safeguard of privacy. To overcome such problems, focused decisions and actions related to prequalification, authentication should be followed and safe communication protocols should be adopted. An overview of such decisions is presented in Table 5.16.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES) Level 3(P)		Level 3(E)		Level 3(M) / Level 3(L)	
ROBUSTNESS	Collusion	Easy	2-3	Difficult			3-5
	Contact btw. Participants	Easy	2-3	Controlled	4-5	Controlled - IT support	2-4
	False name	Hard	5	Easy			0-4
	Security	High	5	High	4	Lower	2-4
	Privacy	Low	0-1	High	3-5	Mid-high	2-5
	Misleading item data	Low	5	High			2-3
	Legal support	High	5	Medium (low experience, global coverage)			0-3
	Prequalification	Allowed	5	Allowed			2-4
	Item inspection	Allowed	5	Photos, descripti	3-4	Photo, description	1-3
	Participants' rating	Allowed	5	Feedback mechanism, data, roles (who-whom), when, range (numeric, %)	3-4	Like e- but with less options	2-3
	Censorship	Allowed	5	Country-dependent, hard to control			2-4
	Fraud detection	Relatively easy	5	Auto detection rules (shill, multiple ID, feedback extortion)			2-4
	Authentication	Easy	5	Process, interaction-based			1-3
	Cryptography	Not applicable	5	Algorithm selection/design			2-4

Table 5.16: *Customizing for Auction Robustness*

The freight l-auction entails advanced core-service properties related to required location-awareness. The trade-off here lies on limitations on supportive services (e.g., personalization, interactivity, content, usability, interfacing, etc.) which are highly-dependent to network capacity and device specifications. Finally, mobile networks may support advanced payment collection methods. The decision elements and an indicative evaluation of the decision criteria are shown in Table 5.17.

The main cost factor for the users is the cost related to LBS services (including communication networks costs). The decision-maker has to decide on the revenue model to be adopted – for example to subsidize subscribers' connectivity costs, etc. The importance of the cost elements is shown in Table 5.18.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES) Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
USER SERVICES	Personalization	Not allowed	0-1	Allowed, degree	4-5	Less allowed			3-4
	Bidders' information	Present bidders ID	1-3	Controlled	4-5	Not easy			0-2
	Training	Not easy / costly	0-1	Easy	4-5	Not easy			2-3
	Interactivity	Physical	4-5	Supported	2-5	Not easy			2-3
	Process complexity	Low	4-5	Low-Medium	2-4	Medium			2-5
	Historical data	Difficulties	0-2	Easy	4-5	Medium difficulty			3-4
	Content	Physical only	0-3	Supported	4-5	Device/network restrictions			0-2
	Ease of use	Easy	4-5	Some skills	3-5	More skills			2-4
	Location services	None					0	Guide, follow, what's near, emergency, tracking	4-5
	Automation	Not supported	0	Proxy Agents			4-5	LBS agents	4-5
	Automatic intelligence	Not supported	0	Bidding, info collection, intelligence, bundling					3-5
	Payment/collections	Varies	4	Money transfer, credit card	4-5	Auto billing (mobile comm. provide			5
	Registration reqts./extend	User data	5	User data	4-5				
	Navigation	Physical	5	GUI, personalization	4-5				
	Bidding process	Clear	5	Workflow, message sequence	3-4				
	Observability	Presence	5	Time, current bidding data	3-4				
	Alerting	Not necessary	5	When, event, type of info	3-4				
	Search	Not applicable (push)	5	Simple, custom, categories, hierarchies, catalog	3-4	Depends on: Device (screen, autonomy, keyboard) and network Control methods e.g. triggering			0-3
	Attractiveness	Oriented	5	General (images, photos, simplicity)	3-4				
	Communication	Presence	5	Online, mail, phone	3-4				
	Friendliness	Presence	5	Training, FaQ, online help, language	3-4				
	Accuracy level	Presence	5	Data integrity, validity	3-4				
	Bidding process info.	Presence	5	Range, brdwatchinsg, public, registered	3-4				
	Spatial information	Not applicable	5	Not applicable	3-4	Depends on (see above)	0-3	Location, speed, direction, pojections	5

Table 5.17: *Customizing for User Services Requirements*

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES) Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
USER COSTS	Transaction costs	Zero	5	Zero	5	Network	2-3	LBS	2-3
	Search costs	High (travel etc.)	0-2	Zero	5	Network	2-3	LBS	2-3
	Participation costs	High (travel etc.)	0-2	Revenue model or zero	4-5	Network	2-3	LBS	2-3
	Listing costs	Yes	0-2	Revenue model or zero	4-5	Yes	2-3	LBS	2-3

Table 5.18: *Customizing for Required Level of User Costs*

By default, l-auctions require highly sophisticated ICT infrastructure for H/W, S/W and database. This infrastructure should operate on the basis of well-defined and secure communication protocols supporting different technologies for both human and proxy bidders. Decisions related to bandwidth, speed, time-outs, etc., should safeguard high QoS level with low fault tolerances in order to secure the fairness of the auction process. Finally, LBS should be safeguarded through the selection of proper providers and roaming services. The evaluation of relevant criteria is presented in Table 5.19.

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
	H/W infrastructure	Not required	0-1	Servers, applications	3-4	+ mobile comm.	4-5	+ GPS/Cell	5
	S/W infrastructure	Not required	0-1	Apps, DB, ASP	3-4	+ mobile comm.	4-5	+ GPS/Cell	5
	Database	Not required	0-1	Data structure, location					5
	Bidding entities	Human	0-1	Human, proxy					5
	Hosting	Not required	0	Own, leased, shared, common, ASP					5
	Network	Not required	0	Internet	3-4	Heterogeneity, 2.5G, 3G	4-5	GPS, Cell	5
	Protocol compatibility	Not required	0	JAVA, SQL, HTML, XML, Browser	3-4	GPRS, WAP	4-5	GPS, Open GIS	5
	Privacy	Presence	0-1	Cryptography protocols	3-4	Cryptography protocols			4-5
	Workload	Physical restrictions	2-3	Max bids, frequency, duration, arrival rates, bidders#	3-4	+bandwidth, data volume, transmission rate			5
	Time	Physical restrictions	2-3	Criticality level, real-time, nicast, multicast	3-4	+time-outs, response time, transmission delay			5
TECHNOLOGY	Fault tolerance	Human	2-3	DoS, delay	3-4	+Packet loss handling (due to interference, landscape etc.)			5
	Architecture	Not applicable	0	Topology, 3-tier client-server, distributed, P2P	3-4	Ad-hoc, multi-hop, fixed topology (local)			5
	Transaction data	Not applicable	0	Page view, bidding, internal auction			3-4	+Location	5
	Integration reqts.	Not applicable	0	Other IS	3-4	+Mobile	4-5	+LBS	5
	Coverage	Local	0	WWW - global	4-5	Range, roaming, providers			3-4
	Reliability	Not relevant to IT	0	Internet	4-5	Continous connectivity, network, real-time	3-4	+LBS	3-4
	Fairness	Not relevant to IT	0	multicast, all-or-none	4-5	+response time			5
	Message types	Not relevant to IT	0	transaction, forms, mail	3-5	SMS, WiFi			5
	Geospatial/location reqts	Not applicable	0	Not applicable	0	Roaming	3	Satellite, Cell, WiFi, BT	5
	Location senstivity	Not applicable	0	Not applicable	0	Low	2	Accuracy, speed, direction, projection	5
	Site maintenance	Not applicable	0	Continous update					5
	Info. Reusability	Not applicable		Required					5

Table 5.19: *Customizing According to Technology*

The efficiency of the designed ICT infrastructure has several views; it must support allocative efficiency and enhance competition. In any case, the ICT infrastructure must support fair and secure trade. The ICT-designer should have in mind that these are the major success factors for the l-auction. The evaluation of relevant parameters is given in Table 5.20.

Finally, the freight service is a relatively simple trading item with comparatively low information content without requirements for physical presence (Table 5.21).

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
EFFICIENCY	Equity	Controlled	0-1	Filtering	3-4	Filtering			5
	Allocative efficiency	Mechanism dependent	2	+IT dependent	3-4	+IT dependent	4-5	+IT dependent	5
	Perfect competition	Bidder# limitations	2	Theoretically unlimited #bidders					3-5
	Entry barriers	Cost	0-1	Theortically none	4-5	Cell-coverage	4	LBS coverage	3-4
	Publicity	Focused	2-3	WWW-easy	4-5	WWW-push			5
	Competition	Rivalry btw. Particpants	2-3	Highly relevant to IT, duration, spatial					5
	Fairness	Mechanism dependent	2-3	Highly relevant to IT, duration, spatial					5
	Workload sensitivity	Bidder#, auctioneer experience	2-3	Highly relevant to IT, duration, spatial					5
	Arrival rate sensitivity	Not applicable (fixed time)	0-1	Highly relevant to IT, duration, spatial					5
	Anonymity	ID's	0-1	Supported					5
	Observability	Physical	5	Controlled	3-4	Controlled - IT restrictions			2-3

Table 5.20: *Customizing to Obtain Efficiency*

DECISION AREA (FUNCTION)	DECISION (PARAMETER)	CUSTOMIZING OPTIONS (VALUES)							
		Level 3(P)		Level 3(E)		Level 3(M)		Level 3(L)	
ITEM	Items with high information content	Hard to support	0-2	Supported	4-5	Difficulties			2-3
	Description of complex items	Easy	4-5	Depends	3-4	Relatively hard			0-1
	Physical presence (items)	Yes (in most cases)	4-5	No					1

Table 5.21: *Customizing According to Item's Characteristics*

5.4 Decision Prioritization

A preliminary analysis of the average valuation indices defines priorities for decision-making in the decision-area level. It is shown, for example, that decisions related to user services are most important in e-auctions while decisions related to market-making are of almost equal importance. ICT-related decisions are also (but less) important while decisions related to the auction mechanism are of less importance.

In our foundational study we have based our analysis on plain averages of the values assigned to each option as presented in the previous section and grouped by perspective. Since a real implementation goes beyond the scope of our research, we adopted simple averages. This approach results in smooth unbiased indices which are perceived sufficient for this preliminary approach. In the future, it is our intention to deal with the estimation and assignment of realistic or subjective weights to each of the parameters based on the application, the instance the business or the available infrastructure; the overall score for each perspective would then result as a weighted average.

Successful e-auctions are mostly user-centric; equally well, successful e-auctions are highly advertised and linked to several other marketplaces, web-sites, portals and retailing houses. ICT is quite mature and able to support even highly sophisticated auctions, while several commercial tools and applications are available to support the development and operation of e-auctions. Finally the auction mechanism is ranked 4th since ICT-auctions are able to support almost any auction format. These results are presented in Figure 5.4 and are particularly useful for the modification or enhancement of auctions in a given context.

GROUP PRIORITIES								
P		E		M		L		Priority
AUCTION	3,107	USER	4,250	ICT	4,477	ICT	4,693	1
USER	2,729	MARKET	4,181	MARKET	3,822	MARKET	3,908	2
ICT	1,239	ICT	4,034	USER	2,333	USER	2,500	3
MARKET	1,234	AUCTION	3,512	AUCTION	2,127	AUCTION	2,127	4

Figure 5.4: *Results of Decision Priority*

A more profound analysis of functions and parameters levels provides useful results for different perspectives: for each decision group and context, the set of decision parameters is indexed using average value levels in order to prioritize decisions parameters (Figure 5.5).

If, for example, an ICT-engineer has to make decisions in the e-context, then he has to first identify the efficiency parameters and then ICT-related decision parameters. This priority is relaxed in the m-context since efficiency and ICT have almost identical indices. Finally, in the l- context, he has to give priority to the ICT-related decisions. This difference results from the fact that in the m-context the ICT infrastructure is very sophisticated and not less mature compared to e-contexts. These results are very useful in the case of the expansion or evolution of one auction-marketplace from a given context to a more advanced one – especially for the project manager.

	DECISION AREA PRIORITIES							
GROUP	P		E		M		L	
MARKET	BUSINESS	1,778	BUSINESS	4,222	BUSINESS	4,000	TIME-SPACE	4,313
	MARKET	1,300	TIME-SPACE	4,188	TIME-SPACE	4,000	BUSINESS	3,944
	TIME-SPACE	0,625	MARKET	4,133	MARKET	3,467	MARKET	3,467
AUCTION	ROBUSTNESS	4,321	AUCTION	4,500	ROBUSTNESS	2,714	ROBUSTNESS	2,714
	ITEM	3,333	ROBUSTNESS	3,036	AUCTION	2,333	AUCTION	2,333
	AUCTION	1,667	ITEM	3,000	ITEM	1,333	ITEM	1,333
USER	USER SERVICES	3,458	USER COSTS	4,750	USER COSTS	2,500	USER SERVICES	2,500
	USER COSTS	2,000	USER SERVICES	3,750	USER SERVICES	2,167	USER COSTS	2,500
ICT	EFFICIENCY	1,909	EFFICIENCY	4,409	EFFICIENCY	4,545	ICT	4,841
	ICT	0,568	ICT	3,659	ICT	4,409	EFFICIENCY	4,545

Figure 5.5: *Decision Priorities in Decision Area Level*

5.5 Conclusion

In this chapter we broke new ground on the primarily technical decision items that characterize e-,m- and l –auctions and we further examined the design of auction contexts from several functional perspectives, which culminated in the expansion of ACE to a 3rd Level. We presented, in particular, an innovative and structured methodology for the implementation of auctions in contemporary contexts which can also serve as the basis for the evolution from one context to another. More specifically, we classified the wide range of decision elements into decision groups, and examined the importance and the interrelationships from several stakeholders' perspectives. Importantly, we identified and classified technical decision elements which are of special and great importance in the currently emerging e-, m-, and l- auction settings. We also provided evidence for the importance and applicability of innovative LBS-based auctions and corroborated our findings with an illustrative paradigm. Our results can leverage advanced research in relevant areas, such as, in the decision analysis and the design of decision support systems.

Chapter 6

Applications

By nature, e-, m-, and l-auctions apply in business environments where technology, mobility and location awareness are of high importance, serving pricing and trading purposes. This chapter integrates advanced auctions with LBS into a whole, aiming to develop m- and l-auctions and examines several use cases in the services domain. More specifically, it proposes applications in two heterogeneous service areas, namely, B2C trading of tourism services and B2B trading of freight transportation services, and describes how l-auctions may complement Revenue Management practices. The common denominators in these service areas are the mobility and the location-awareness of the participants. The chapter first presents in brief issues related to technical infrastructure for both e- and m-marketplaces. Then, it focuses on how l-auctions may apply to locate and filter potential auction participants so as to enhance the efficiency of the auction setting. In the freight transportation area, it presents several use cases and examines the viability of l-auctions. Finally, it proposes a macro-temporal use of l-auctions in the practice of Revenue Management. This chapter contains material from our published work[8].

This chapter is structured as follows: Section 6.1 provides a brief analysis of the technical infrastructure underlying the architectural and communication difference between electronic and mobile contexts. Section 6.2 describes the application of l-auctions in the tourism services domain. Section 6.3 presents the application of l-auction in the freight transportation service market with support in several use cases while Section 6.4 presents macroscopically how l-auctions may complement RM. Section 6.5 summarizes and concludes.

[8] Emiris and Marentakis (2010b), Marentakis and Emiris (2010a), Petridis et al., (2010), Marentakis and Emiris (2009), Emiris and Marentakis (2009), Anagnostou et al., (2009), Emiris and Marentakis (2008), Marentakis and Emiris (2008), Emiris et al., (2007a), Marentakis et al., (2007).

6.1 Overview of Markets and Literature Review

6.1.1 Electronic Marketplaces – a Brief Note

An electronic marketplace (from now on, e-Marketplace) is an institution that allows the participating market members to exchange information about prices and offerings. An e-Marketplace generates value by lowering transaction costs, improving marketing functions, optimizing prices, strengthening customer relationships, increasing IT effectiveness and facilitating the back-office work. Stockdale and Standing (2004) summarize the benefits from the participation in e-Marketplaces in: magnification of markets range, potential for partnerships, administration and communication flexibility, convenience (24/7), information diffusion, customer service improvement, information update, lower transaction costs, differentiation and customization of products and services and alleviation of barriers for small companies to join supply chains of large companies. An e-Marketplace is the basis for forming virtual markets via the development of virtual enterprises, that is, temporary organizations of companies that come together to share costs and skills and address temporal business opportunities that they could not undertake individually via a process of creation, operation, evolution and dissolution (Gou et al., 2003).

Prior to enter an e-Marketplace, a participant has to select the right one for his needs. Numerous approaches to sustainability, adoption and success factors of e-Marketplaces have been proposed by Brunn et al., (2002), Daniel et al., (2004), Albrecht et al., (2005), Fu et al., (2006), Hadaya (2006) and Wang et al., (2006), while Ratnasingam (2007) identifies four types of risks pertinent to this selection, which are economic, technological, implementation-related and relational.

Due to these characteristics, e-Marketplaces are able to support current and future commercial trends like differential, dynamic pricing, especially in the area of Supply Chain Management, by facilitating e-auctions (Bichler et al., 2002d). E-marketplaces operate as private, public or consortia-based markets in horizontal or vertical structure. Companies collaborate, share demand, resources and information with each other over them. Rudberg et al., (2002) described how an e-marketplace can support collaborative supply chain planning focusing in the transportation sector. In the rapidly changing business environment, Supply Chain Management (SCM) has shifted from engineering and improvement processes to the coordination of the activities of dynamic supply chain networks. This transformation has been described as the “fourth SCM evolutionary type” (Folinas et al., 2004). Park and Suresh (2005) investigated the effects of e-Marketplace development and adoption to supply chains, by comparing the traditional supply chain of physical goods to the supply chain of auction-based, e-Marketplaces. They found that e-Marketplaces perform better on average, mainly due to aggregation capabilities.

E-Marketplace developments may vary between countries because their success depends on a set of factors analyzed by Javalgi and Ramsey (2001). These factors are: IT maturity (hardware, software, and communications), social and culture infrastructure (language, education level, beliefs), commercial infrastructure (transport and energy capabilities, banking and financing institutions) and government and legal infrastructure (customer protections, security, taxation, liability). Being an important success factor related to transaction quality, workload of e-Marketplaces is a composition of sessions each of them corresponding to a specific sequence of functions by a single participant during a single entrance to the marketplace. On the other hand, the reliability of electronic transactions depends heavily on the capacity of the infrastructure and the workload generated by the intended transactions (Menasce and Akula, 2003). The problem of workload control gets even more complex for business transactions executed over mobile networks as new constraints related to network bandwidth and device characteristics are present. An e-Marketplace is the basis for the formation of virtual markets via the development of virtual enterprises – being temporary organizations of companies that come together to share costs and skills and to address temporal business opportunities that they could not undertake individually, via a process of creation, operation, evolution and dissolution (Gou et al., 2003).

6.1.2 Trading of Service Capacity

Several e-marketplaces are currently operating using auctions in order to trade re-usable items like finite available service capacity and resources. Wellman et al. (2001) claim that an auction mechanism which entails some minimum properties (e.g., disclosure of participants' private information, minimum communication costs, timely completion, solutions to not waste resources being Pareto optimal), may prove more efficient than typical scheduling and allocation methods (e.g., "first-come first-served", "shorter-job-first", "priority-first") for capacity-related services (such as, distributed computing, factory shifts, room allocations, etc.). Results are supported using examples for single and combinatorial services. Jap (2002) supports that eRAs are an efficient means to allocate spare capacity by suppliers.

Several types and applications of auction based e-marketplaces have been studied in the literature. Nilsson (1999) examined the case of allocation rights to use railway infrastructure capacity by trains according to a specified timetable. They experimentally found that the auction mechanism they proposed yields results close to economically efficient. Later, Affuso (2003) described the pros and cons of the application of auctions to allocate railway capacity concluding that feasibility of the use of auctions is not always clear. Maldoom (2003) analyzed the complex nature of airport slots as a bundle of rights for runway, stands and terminals requiring international coordination (connecting flights) with substitutes (flights frequency) by taking into account market power attributes claiming that a complex combinatorial auction may be appropriate for such allocations. Wang and Schulzrinne (2004) focused on pricing and allocation of Quality of Service (QoS) enhanced networks and compare between two price formation mechanisms, an auction-based and a *tatonnement-based* method (being the dynamic update of price until the aggregate demand meets supply). Bhargava and Sundaresan (2004) analyzed a case of allocation of on-demand service capacity and examined various *contingent auction* mechanisms ranging from advance commit (*advance reservation*) to pure no-commit (*pay-as-you-go*), evaluating how different levels of commitment affect price, revenue and resource utilization.

Later, Pettersen, Strandenes and Wolfstetter (2005) proposed an efficient auction mechanism based on Clark-Groves-Vickrey format for the ship loading/unloading scheduling problem which is more efficient than typical "first-come first-serve" methods but is not suitable when interdependencies between other port's schedules exist (likewise airport slots). Hajiaghayi et al. (2005) examined mechanisms for the same problem when future arrival rate is not known in advance (likewise scheduling and pricing in WiFi spots or computing resources). Teo (2005) evaluated the use of a reverse auction for utility computing services (link between sellers and customers, allowing customers to execute applications over the network) finding positive results in general.

Sometimes auctions may not be appropriate when used for the allocation of complicated network services or investing on them, mainly due to complexity. Stem and Turvey (2003) analyzed practical problems arising when auctions are used to allocate utility networks resources (like electricity, gas, airport and rail resources). In the same way, Newbery (2003) claimed that auctions are not appropriate in the case of investment of future capacity when the regulatory framework restricts the revenue of the future use. Sentance (2003) concluded that auctions are not proper for slot allocation or capacity expansion.

The adoption of e-auctions for application in the supply chain domain is vast. Bichler et al., (2002a) underlined the need for flexible pricing in supply chains in the context of B2B electronic transactions. They described major flexible pricing mechanisms (auctions, Requests-For-Proposal, negotiations on price and quality) and major prerequisities (strong integration, real-time functional data flow). Settoon and Wyld, (2003) perceived E-procurement as a bundle of business activities; the bundle consists of advertisement of tenders, electronic submission, electronic ordering, Internet sourcing via third parties, electronic mail between buyers and sellers, electronic mail in contract management, research into supplier markets and integration of procurement within the financial and inventory systems. A common problem in Supply Chain formation is the development and assurance of relations between buyer and supplier. The problem becomes more complex for building ad hoc temporal relations. Yasin et al., (2004) provides a deep analysis on quality issues in supply chain B2B transactions and proposed a model which guarantees and improves quality of auction-based business process in a supply chain.

Supply chains have some special attributes; importantly, suppliers are not autonomous; their performance and relative costs depend heavily on other suppliers positioned in early stages of the supply chain. In some cases a buyer requires the existence of dependencies between two or more suppliers in order to develop a network of suppliers. Various auction formats apply in supply chains; Walsh et al. (2000) presented a one-shot combinatorial auction protocol for supply chain formation of complementary goods. Sun and Sadeh (2004) examined the case of a manufacturer procuring product components from a set of suppliers offering same components submitting multi-attribute bids consisting of price and delivery dates. They propose techniques supporting the manufacturer to optimally select suppliers.

Kim and Segev (2003) proposed a bidding mechanism allowing bidders (suppliers) to express cost dependencies with other potential winning suppliers after the completion of the process. The bidding mechanism is based on a multi-attribute sealed-bid auction format where each supplier submits conditional bids (up to the number of supplier networks he may potentially participate) where the price depends on the suppliers network that will win the auction. The proposed mechanism "*Multi-Component Contingent Auction – MCCA*" has many advantages for both participants: it displaces the supplier compatibility problem to suppliers and their bids are binding only a part of a specific set of bids.

6.1.3 Technical Requirements for e-auctions

In their relatively early article, Kumar and Feldman (1998) presented an e-auction application and studied issues concerning mechanisms, security requirements, transactions before, during and after the auction, and proposed a generic auction development architecture which may be integrated in ERP systems. This generic data flow architecture, as depicted in Figure 6.1, supports all standard functions which in brief are: Registration, Setup, Publicity, Bidding, Bid Evaluation and Closing and Settlement. The architecture of the platform utilizes several components, the most important of which are database tables and web pages. Each of them serves specific purposes; internal data base tables store permanent customizing or transaction data for all auctions carried out. Structures (tables appended by blank arrows) contain temporal transaction data generated during each transaction session which are deleted after the end of the auction. Each database table is utilized in specific stages of the auction process to store or retrieve data via web pages or forms by participants.

For example, a seller uses a *define* or *update* form to determine in a formal manner the product wishing to sell or to change it – of course before the auction starts – storing this information in the *Product* table. A potential buyer is able to retrieve proper information concerning the auction item interested in, using a *search* form providing access to the same *Product* table. Otherwise registered buyers may be automatically notified about the item set in auction via an alert message form. A number of structures are used to temporally store transaction data. For example, a *short list structure* is temporally filled with a selected set of auctions via the successive use of search and select forms with specific selection criteria. The contents of the structure are deleted each time a buyer executes the search or select forms or immediately after the log-off or session termination.

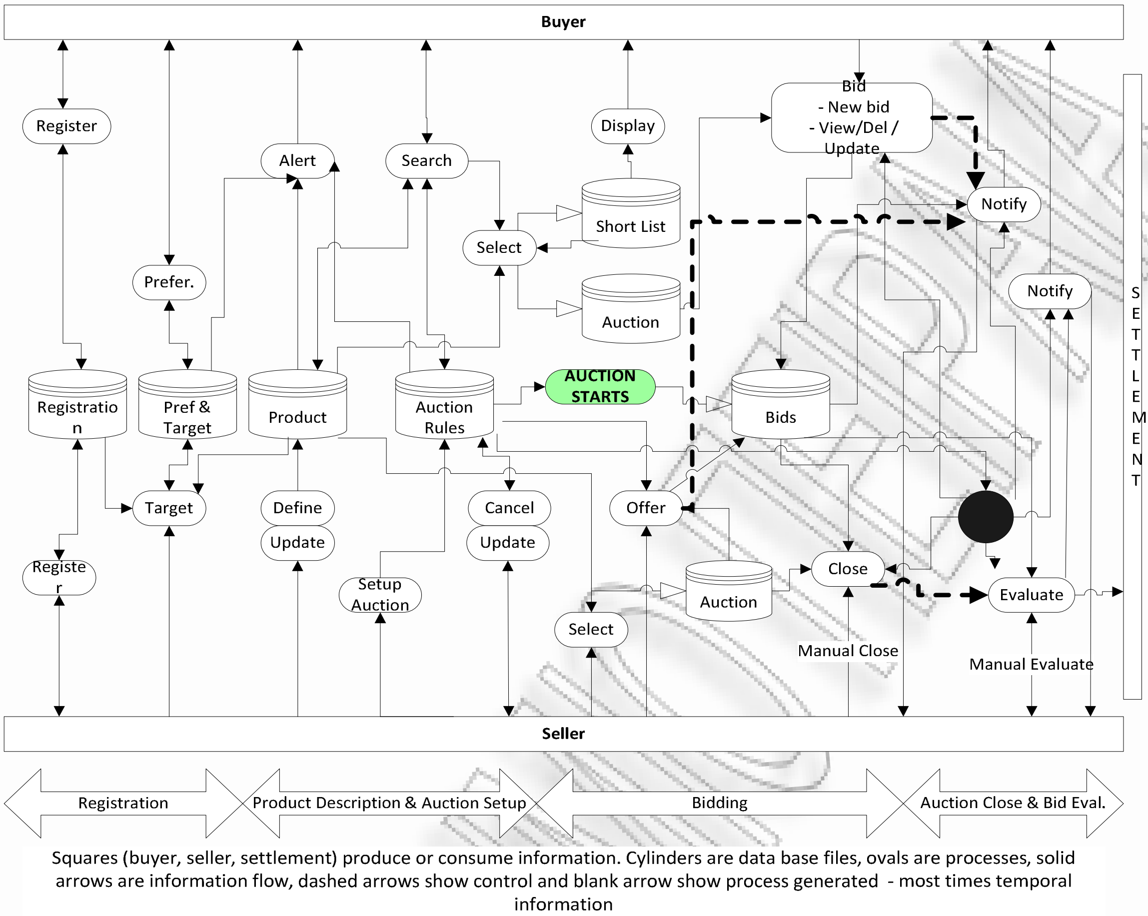

Figure 6.1: *A Generic e-auction Process Data Flow Architecture (Kumar and Feldman, 1998)*

The application operates as a Web site with a solid page structure (Figure 6.2). In the following sections, this architecture will be properly modified and extended to support the case of freight transport service procurement in a mobile context.

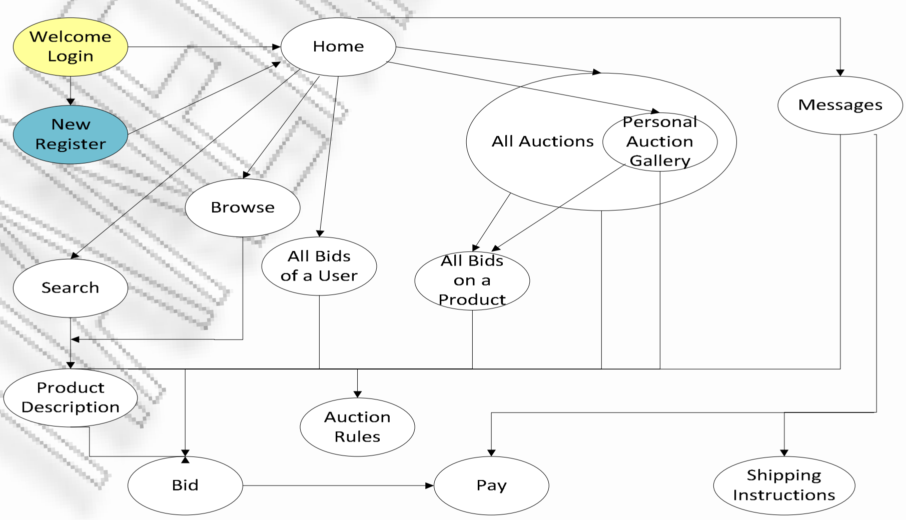

Figure 6.2: *e-auction Web Site Structure (Kumar and Feldman, 1998)*

6.1.4 Technical Requirements for m- and l-auctions

A mobile auction is a typical case of a group-oriented, real-time mobile service exhibiting special requirements for lower delays and continued connectivity (Varshney, 2005). The communication performance parameters for e-auctions are presented in Liu et al., (2003) (Table 6.1), and obviously apply in m-auctions too.

Quality of Service to online auction users	Communication Performance Metrics of Online Auctions
Fast response	Respose time
No site failures	Traffic reliability
Predictable response	Predictability
24 X 7 services	Availability
Low transaction fee	Costs
Secure	Security
Fairness	Information sharing

Table 6.1: *QoS and Performance Metrics in e-auctions*

In addition to the above, the critical networking requirements for m-auctions are (Varshney and Vetter, 2002):

- Multicast Support for atomic all-or-none transactions
- Location Management
- Network Reliability and continued connectivity
- Support for Roaming Across Multiple Networks

For mobile auctions, in particular, specific multicast requirements are shown in Table 6.2 (Varshney, 2002). Regarding LBS for mobile auctions, requirements are shown in Table 6.3 (Varshney, 2001).

M-commerce applications	Description	Type of communication and number of entities	Multicast requirements and response time	Other multicast requirements and issues
Mobile Auction, Interactive Games, Financial Services	Allow users to buy or sell certain items (or play multiparty games) using multicast support of wireless infrastructure	Real-time multicast with active participation by multiple users	Security and reliability of wireless multicast are major requirements. Very low delay required (few hundrend ms to a second). Removal from group due to intermittent connectivity or brief disconnectivity significantly affects possible result	Duration of multicast session can be long and involve multiple players in different networks

Table 6.2: *Multicast Requirements for m-auctions*

Both marketplaces can be designed in accordance to the standardized layered framework proposed by Kannan et al., (2001) which allow participants to develop and run m-commerce applications, as depicted in Figure 6.3. Of special importance is the fact that mobile applications should take into consideration the general capabilities of user infrastructure instead of individual devices.

Following the presented general description of modern auctions, we drill the applications domain with three distinct cases in structurally different sectors. Specifically, in Section 6.2, we explore the trading of capacity in Tourism Services, in Section 6.3, we investigate trading of unused capacity in the freight business, and in Section 6.4, we demonstrate the complementarity of l-auctions and revenue management approaches in serving freight tasks.

Applications	Location Precision (network level)	Response time	Wireless coverage	Devices / entities involved (type of communication)
Mobile Financial Application	Meters (sub-cell)	Seconds	Local	Few (unicast)
Mobile Advertising	Hundreds of meters (cell)	Minutes	Local	Several (multicast)
Mobile Inventory Management / Product Location and Search	Meters (sub-cell)	Seconds	Local, possibly nation-wide	Several (multicast)
Proactive Service Management	Kilometers (multiple-cell)	Hours	Local	Few (unicast)
Wirelss re-engineering	Hundreds of meters (cell)	Minutes	Nationwide	Few (unicast)
Mobile auction / reverse auction	Hundreds of meters (cell)	Seconds	Local, possibly nation-wide	Several (Real-time multicast with active user participation)
mobile Entertainment Services	Hundreds of meters (cell)	Minutes	Local	Several (Real-time multicast)
mobile Distance Education	Hundreds of meters (cell)	Minutes	Local, possibly nation-wide	Several (Real-time multicast)

Table 6.3: *LBS Requirements for m-auctions*

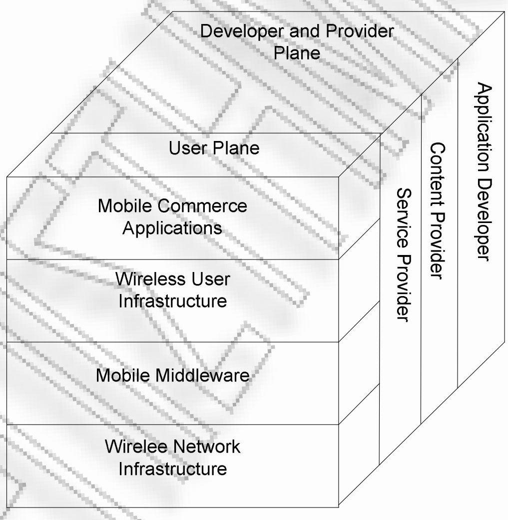

Figure 6.3: *The m-commerce Framework*

6.2 Application 1: Trading Spare Capacity in Tourism Services

6.2.1 Service and Market Characteristics

In the competitive tourism marketplace, the success or even the survival of a company depends heavily on its operational efficiency. Due to the perishability of the components of tourism services, one of the most important factors that affect the efficiency and profitability of companies offering tourism services, is the utilization of the available capacity of the revenue enablers, such as rooms, tickets, restaurant tables, cars for rental, etc. The management of these available resources is a complex task and aims to balance capacity demand and availability by generating their maximum surplus.

Revenue management related methods (such as, price modification as a function of the time that the service is offered) may serve as a tool to positively influence the demand and the capacity utilization; however, the reliability of these methods is dependent on the amount, adequacy and validity of data, as well as, on the selection of the proper forecasting method. Intense overbooking, for instance, does not guarantee that the service is enjoyed by all interested customers and may lead to their dissatisfaction (Kandampully, 2000); on the other hand, a more conservative overbooking may result to sub-optimal utilization of resources. As a result, methods adopting “last-minute offer” approaches are employed to remedy this deficiency and increase utilization even in the last day or minute of service offering. The effectiveness of the latter methods can further be enhanced if temporal and spatial attributes of the service and/or the customer are taken into account. The communications infrastructure and related tools thus play a vital role in conveying this information and enabling the interaction between the interested parties in near-real time.

The evolution of Information and Communication Technologies (ICT), for example, Internet, mobile communication, GPS, etc., has provided the toolset and platforms where innovative tourism business models (including auctions), marketplaces and commercial channels may be developed and operated. In this context, appropriate data may be retrieved, processed and used to manage capacity, revenue and dynamic pricing; moreover, customer participation is not restricted by time or position of access to the system, while booking and price-formation processes are time and place sensitive. As a result, the ICT support the adoption of electronic and mobile auctions as a model for setting dynamically the price of a service and several tourism service providers use auctions through intermediate marketplaces which can be travel-dedicated (e,g, www.priceline.com or www.skyauction.com offering flights, hotel and car rental), generic (e.g., www.ebay.com), specialized in one service category (e.g., www.generousadventures.com, www.allcruiseauction.com, www.roomauction.com) or focusing in specific customer group (www.luxurylink.com). The recent advances in wireless communication systems, networks and devices, further boosted the development of electronic and mobile marketplaces for auctions and permitted the participation of potential buyers and sellers while on the move.

6.2.2 Price Formation in Tourism Services

The price formation problem is of great importance in the tourism services marketplace. It is difficult for classical economic methods to support price formation in this context, since a tourism marketplace cannot be characterized strictly as competitive, monopolistic or monopsonistic; furthermore, the tourism marketplace cannot be modeled as a retail market either, since the object of each transaction is intangible and of time-limited availability and capacity unlike in physical products. The objective of a tourism company is thus to apply service promotion and provision strategies adapted not only to customers’ demand but also to their broader preferences. As a result, price formation is not influenced exclusively by demand and/or offer but from additional factors as well.

Ellerbrock et al., (1984) were among the first to claim that among the basic economic market structures (perfect competition, pure monopoly, oligopoly and monopolistic competition) the latter represents better the hospitality industry (many sellers, slightly differentiated products, similar costs, competition through advertising, no entry barriers, dual demand curves – perceived and realistic). He also presented an empirical model for price formation of tourism services. A few years later, van Dijk and van der Stelt-Scheele (1993) noted that, although components of tourism services seem identical at a first glance, actually they are highly differentiated in terms of quality attributes, while each commercial transaction has many dimensions beyond price, such as, proximity, accessibility, variety, etc. They also commented on models in the economic literature (demand/supply factors or both, market structure, service differentiation and capacity issues) and concluded that only few econometric models can analyze the behavior of providers and customers, because of inefficiencies related to product differentiation, informal labor, variability in size of the companies and inadequate data related to labor costs. It has thus been realized that an inherent characteristic of price formation of tourism services is that it shows fluctuations or entails subjective attributes and a good practice to profit of this is to engage customers in the process. During the recent years, many companies adopted this strategy and Klein and Loebbecke (2003) and Park and Rothkopf (2005) were based in this principle to present applications for the reservation of air tickets and hotel rooms, where they attempted to:

- Retrieve service characteristics from the customer
- Learn and/or negotiate price
- Identify specific and personalized combinations of services and attributes

Pellinen (2003), in his empirical research, reviewed costing and accounting information (Yield Management, segment profit analysis, cost-based pricing) and stated that the use of cost-based pricing methods is limited. He identified three categories of tourism companies based on pricing strategies, namely, the *imitator*, the *strong calculator* and the *customer enticer* and also concluded that prices depend on a number of factors beyond cost. A year later, Danziger et al., (2004) discriminated over two major pricing categories, namely, the cost-driven approach (cost plus target profit) and the externally-driven approach (like value-based pricing) where prices are set based on the customers' perceptions on value. They tested the validity of their findings by examining how the value of a hotel's assets (location, stars rating, corporate affiliation, number of rooms and list price) may affect pricing decisions by hotel owners.

Sanchez and Satir (2005) approached the provision of hotel services as a revenue (or yield) management system aiming to sell the right inventory unit to the right customer at the right time for the right price and identified market segmentation, timing (demand and supply management) and pricing, as the three pillars of yield management. Mattila and Choi (2005) empirically analyzed customer's perceived fairness as an outcome of yield management system finding that provision of information about pricing methodology to customers, enhance the perceived fairness. Later, Desinano et al., (2006) focused on the control of computerized hotel yield management systems based on four vectors, namely, the definition of room inventory, the allocation of room inventory, the length of stay and the group booking. They supported that capacity fluctuations resulting from cancellations, non-shows or early check-outs can be controlled using yield management techniques like overbooking and proposed a practical overview of yield management reports and relevant evaluation indices.

In general, any pricing strategy aims to: (i) acquire of a fraction of traveler's surplus value near his *Willingness to Pay* (*WTP*) and, (ii) gain advantage against competitors in terms of sales volume and capacity utilization. Interestingly, Klein and Loebbecke (2003) claimed that perfect competition or monopolistic market models are hard to be seen in real travel and tourism markets so the classical pricing task may prove inappropriate. They state that currently companies try to apply techniques to capture customers' surplus by setting the price close to each customer's WTP while maintaining competitive advantage. To achieve this, the companies focus on four types of differential pricing (or price discrimination): (i) customer characteristics (personalized and group pricing), (ii) sales volume, (iii) product characteristics (versioning and bundling), and (iv) dynamic or flexible pricing (forward and reverse auctions and private markets). An interesting aspect of this work apart of presenting actual applications of forward and reverse auctions, is that it identifies the active role that the consumer has on price formation.

Being a service with non-standard subjective value, the process of pricing and allocation of tourism services may be efficiently supported in an auction-based marketplace. An additional advantage of the use of auctions in the tourism services sector is that they permit near-optimal allocation of excess capacity while improving efficiency and price visibility. Further to that, auctions may be viewed as an unbiased and transparent means for a customer to express his/her WTP, as a function of his/her subjective valuation for the service offered in combination with other, non-offered, non-evident criteria. Sellers and buyers thus interact in an implicit and indirect negotiation shaped by different criteria for each party, which criteria are never directly revealed to each other.

Simon and Butscher (2001) focused on the concept of *price customization* according to which every customer is charged the individual WTP based on his own private valuation of the product / service. They claim that auctions are the best strategy since the customers pay exactly the maximum amount they aim to spend; when the customers' population is efficiently large, auctions ideally extract the customers' prospective WTP.

6.2.3 Auction-based Pricing of Tourism Services

Over the last two decades, the rapid growth of ICT technologies boosted the diffusion and adoption rate of electronically-conducted auctions (*e-auctions*) and increased the number of potential participants (buyers, sellers, and auctioneers) globally. Internet auctions in essence improved the role of the buyer and made him a critical element in price formation. The e-market thus became more buyer centric, and the business relationship between seller(s) and buyer(s) became "many to many" in contrast to "one to many" in a traditional marketplace. Kasavana and Singh, (2002) stressed the fact that the price sensitivity in electronic markets is not solely product-related but is also customer- and transaction-related through the development and operation dynamic-pricing models. In their study, they provide an extended analysis of the beneficial characteristics of electronically-conducted auctions in the tourism sector and their impact on the utilization of free capacity and revenue management practices, and they illustrate complementary properties on disintermediation, increase in flow of information, formation of e-marketplaces and support of dynamic transactions.

Multi-attribute auctions are suitable for the tourism context, and they can also be conducted electronically. A simple tourism product, for example, may have a number of characteristics having interrelated negotiable values (temporal, spatial, quality, etc.) which strongly affect the buyer's perceived value; thus, the interested buyer may have different valuations for an air-ticket depending on the day (or even the time) of the departure and the length of travel or number of intermediate stops. The selection of the appropriate fare is thus the result of a decision which takes into account monetary trade-off between these attributes and the corresponding price. Obviously, the provider does not know the different valuations for each combination of the attributes of the service or it may be costly to collect such information. This auction model is thus ideal to make a customer express by himself the different levels of his WTP only for the attributes of interest. Bichler, (2001) presents an Internet application of this type of auctions in the tourism industry called *BidTaker*.

A more advanced use of auctions in the tourism domain appears when customers (bidders) wish to acquire combinations of homogeneous or heterogeneous services or products. A buyer, for example, may wish to not only select accommodation, but also air ticket(s), guided tours, events, etc. These combinations are called *bundles;* importantly the value of each bundle is greater than the sum of its individual components' separate value. Auctions that efficiently address this market need are called *combinatorial auctions* and are mostly conducted electronically

6.2.4 Contemporary Auctions for Tourism Services

A more recent, attractive and suitable price-setting method –that benefits of the technological advances- is the one that capitalizes on traditional auction theory and auction models, yet it utilizes the Internet or the mobile phone networks as the means to execute the price determination process and to exchange information between seller(s) and buyer(s). Tourism services are well-fit to the auction model, as it helps achieve better and fairer estimates of the value of tourism services subject to the customers' intentions to pay and the offer-demand rules. From a provider's perspective, the value of a tourism offering varies as a function of time; it may increase in times where the expectations to sell are high, or it may fall as non-booked or unsold resources remain in the offering and the time expires. From a buyer's perspective, on the other hand, the valuation of the service may result from consideration of multiple subjective, heterogeneous and combinatorial criteria, which may only partially be addressed by the provider at a reasonable cost. Auctions thus become an efficient frame to make potential customers reveal their valuations of a tourism service subject to temporal and spatial attributes (such as, time of request, time and place of service provision, other supplementary services, etc.).

In the last decade, the evolution of 3G and 4G mobile networks and devices, the reduction of relevant acquisition and usage costs, the strengthening of security, and basically, the abolishment of location restrictions and broad reach, set the infrastructure for the next step in modern business (Buellingen and Woerter, 2004), (Frolick and Chen, 2004), (Kuo and Yu, 2006) which is the shift from wired Internet e-business to business over wireless networks, the so-called *mobile* or *wireless* business. Analyzing the m-commerce market structure, Kauber (2004) identified four types of stakeholders namely, *operators*, *content providers*, *service providers* and *billing agencies* where the three first of them are usually operated by a single company.

Auctions over mobile networks (*m-auctions*) constitute an attractive application in m-commerce enabling potential individual or corporate buyers and sellers to participate without temporal and spatial restrictions. The m-auctions present similar benefits to the e-auctions but they do not require the presence of a personal computer with wired Internet connection and allow on-the move participation through the use of mobile phones or personal digital assistant (PDA) devices. Ahas and Mark (2005) underlined the rapid development of 3G wireless technology and the evolution in the characteristics and operational attributes of the mobile devices. The latter, currently, combines the functionality of a mobile phone, Internet and lately with strong computing capabilities.

In the area of tourism services, in particular, the evolution m-auctions may prove beneficial for hospitality business stakeholders due to importance of geographical closeness and relevant information. The valuation of a car for rent, for example, is different for two customers that are on the move and request this service through their mobile phone, the one being very close to the pick-up site and the other planning to travel to the city where the pick-up site is located in. Recent advances in location sensing technologies enable the instant and targeted advertisement of auction products and services in the mobile equipment of specific groups identified by their location attributes.

6.2.5 Technical Considerations for Service Support

The wide diffusion of Internet and the penetration of mobile communications support the development and operation of effective markets as well as innovative and revenue-generating services; the tourism sector is no exception. Recent improvements in the 'visualization' of tourism services and the security of transactions enabled the rapid adoption and continuous growth of the market. The uninterrupted and global operation of the Internet and the supporting tools that were developed (such as, intelligent evaluation tools, ratings, "virtual" guides, interactivity, audio and visual content, transaction verification, etc.) leveraged this adoption rate (Park and Gretzel, 2007). The even more recent mobile applications bridged the gap between accessibility and mobility and removed the barrier of the need for a wired Internet connection.

The set of ICT-supported functions (from simple advertising and promotion of tourism services to the conduction of complete commercial transactions) form the so called *eTourism* business model. Within this model, several new business opportunities arose and innovative services were offered, which led to lower costs, broader potential customer base, horizontally or vertically expanded business networks, and generation of economies of scope and scale (Palmer and McCole, (2000), (Ndou and Passiante, 2005), (Hakolahti and Kokkonen, 2006), (Berger et al., 2007). The eTourism business model also offers *price transparency* for all participants, the ability to engage *differential pricing* methods based on a number of parameters like demand, available capacity, customer type, service attributes, etc., (Klein and Loebbecke, 2003) and supports the application of yield management techniques (e.g. room reservations) (Sanchez and Satir, 2005), (Desinano et al., 2006). Schubert and Hampe (2005) discussed mobile business models and the corresponding creation of value for the participants and summarized respective expectations depending on the role of each participant.

An additional advantage resulting from the growth of the Internet is that tourism service providers of any sort are now able to provide dynamic combinations of services apart of the single services they always offered (Alvarez et al., 2007). This ability enhances the expected “experience” (where the term “experience” is employed to describe a package consisting of heterogeneous components such as flights, accommodation, meals, amusement etc.) by allowing tourists to get multimedia resources, to make bookings and create component packages by themselves, before and during their trip. The formation of a successful package depends on the combination of the appropriate services according to customers’ primary and secondary needs with a focus on the quality and price attributes (Kandampully, 2000). On the other hand, customers are now able to transparently get informed on offers, services, packages, etc., to experiment with pricing and to take the initiative to formulate their self-preferences subject to prices. The ICT infrastructure thus served not only as a marketing tool but also leveraged the creation of marketplaces and collaboration between providers and buyers of tourism services over electronic and mobile networks and helped extend the perceived customers' value from monetary price to other service-related components like single point of access, timely and accurate information, quality of products, uniqueness of services, personalization and integration (Hakolahti and Kokkonen; 2006).

Given the projected evolution of technology and rapid reduction of acquisition and usage costs, one may doubtless realize the rapid development of m-commerce. This is strongly supported by key figures presented in a recent study from Morgan Stanley Research. These figures and corresponding estimates until 2014 are presented in Figure 6.4.

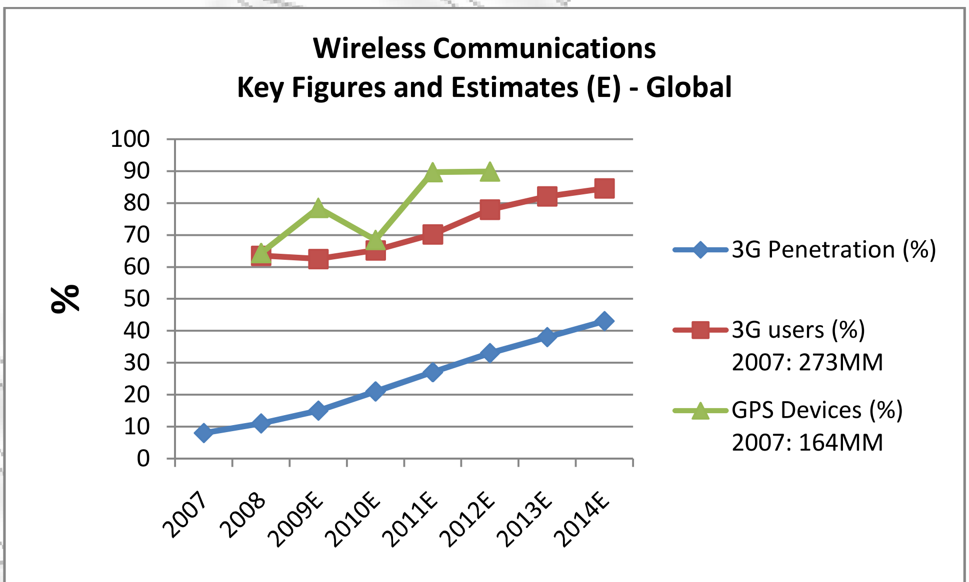

Figure 6.4: *Wireless Communications: Global Key Figures and Estimates (Data Based on Morgan Stanley Research, 2009)*

An early study from TowerGroup predicted 118M, 145M and 22M users to purchase low-cost content over mobile networks in Western Europe, Asia-Pacific region and North America, respectively (Cellular, 2002). A study by the Yankee Group predicted 1,87 billion mobile users globally by the end of 2007 following an annual growth rate 8,7% between 2002 and 2007 (Infosyncworld, 2004). Currently, CTIA (2009) reports more than 270M subscribers during the first six months of 2009 only in the U.S., while InformationWeek (2009) states that according to ABI's research reports mobile users are expected to spend $1,6B via mobile commerce during 2009. Currently, many software developing houses work on and offer specialized applications supporting the monitoring and participation in e- and m-auctions. Typical examples are the *Mobile Auction Manager* for BlackBerry RIM and the *eBay iPhone App* (with the self-explaining motto: "*Manage Auction from your Pocket*".

Ndou and Passiante (2005) examined the value gained by service providers, which is an outcome of increased flexibility, cost and time reductions due to integration, timely launch and provision of service, response to differentiated requests, access to new marketplaces, services and technologies, development of new forms of collaboration and networks, etc. Such a network may be viewed as a *virtual organization* (Palmer and McCole, 2000) operating on the basis of collaborating tourism service providers of heterogeneous but complementary services. Buhalis and Zoge (2007) studied the impact of Internet in competition between service providers and travelers bargaining power and found that overall it increases rivalry between competitors, bargaining power of suppliers and buyers (consumers) in hotel and airlines services. Yu (2005) dealt with a marketplace model that supports the submission and evaluation of travelers' offers with multiple attributes beyond price, and proposed a decision support architecture. Ngai and Gunasekaran (2007) provide an extended literature review and a relevant classification scheme on mobile commerce distinguishing between theory, research, wireless network structure, mobile middleware, wireless user infrastructure and applications.

The suitability of m-commerce for the tourism domain has been defended by several researchers. Buhalis and Licata (2002) conducted a survey on the expansion of mobile commerce applications for the distribution of tourism products. They concluded that mobile commerce is a great opportunity for *location-dependent distribution* supporting last-minute offers for travellers "on the move" over new types of marketplaces operated by *mobile eMediaries.* Additionally, Buhalis and Law (2008) conducted a literature review on eTourism articles over the last 20 years. Interestingly they claim that mobile and wireless technologies are of the most important research areas in tourism management. Oh et al., (2009) analyzed and validated *Technology Acceptance Model (TAM)* for m-commerce applications in the tourism sector and found that user's intentions rely more on performance expectancy and less on effort expectancy. Park and Gretzel (2007) collected all the critical success factors for tourism web sites from the literature proposing a single model. Current research focuses on the smoothing of –mostly- technological problems and shortcomings like equality of access, systems integration and interfacing (O' Connor, 2008).

6.2.6 LBS in Tourism

The technology deployed in m-commerce combined with networks, satellite communications, automatic position sensing and wireless connectivity resulted in the development of geographically-sensitive content. These services combined with Geographical Information Systems (GIS), provided the opportunity to precisely locate the user of a mobile device (*location awareness*), setting the basis for the development and provision of *location-based services* (LBS) which added value to users and revenue to providers (Adams et al., 2003). LBS are based on the geographic relevance of information (Choi and Tekinay, 2003), (Ibach et al., 2005) and offered upon user request or through an automatic triggering function (D'Roza and Bilchev, 2003). The position of the mobile device is determined with the use of either satellite positioning systems (Global Positioning System – GPS) or cellular communications technology (e.g., triangulation) to serve a wide range of location-sensitive businesses such as transportation, sightseeing, navigation, supply chain management etc. (Xia and Bae, 2007).

LBS add value based on knowledge of the actual location of the user of a mobile device (Tilson et al., 2004) having the ability to offer locally adapted services so any user is able to access some combination of the services market offered by the network (*location-based commerce or l-commerce)* (Loke and Zaslavnsky, 2004). Many researchers were based on these studies to examine relevant aspects in many areas of relevance. Varshney and Vetter (2001) analyze potential classes of applications and networking requirements. Kannan et al., (2001) examine potential applications of mobile commerce (referred also as *wireless commerce)*, that may also be location-aware, claiming that booking and ticketing for travel, hotels and events belong to important B2C applications. Varshney and Vetter (2002) classify applications and address organizational (definition, architecture, implementation) and technical requirements (networking, multicasting, reliability etc.). The combination of these distinct classes provides a trading tool able to announce and carry out geographically focused auctions based on travellers' current location. An integrated location management architecture supporting m-commerce applications has been proposed by Varshney (2003).

Hand et al., (2006) enumerated the potential informational applications of LBS in tourism (advertising, advising, traffic information, buying, navigation etc.) and proposed a detailed architecture of an LBS application underlying the need for privacy and security of payment transaction. Tourism services forms an ideal landscape for the application of LBS mainly because all tourism products contain a "where" component. Dickinger and Zins, (2008) examined the application of informative LBS for river cruise operations. Earlier, Rashid et al., (2005) presented a brief technical overview of LBS and a Bluetooth-based application for tourist guided tour.

LBS may support commercial transactions whenever a physical proximity between supplier and buyer is required, for example recommendation of nearby restaurants and price negotiation (Tewari et al., 2002). Such transactions may be carried out through trading mechanisms like *mobile-auctions* (Tsai and Shen, 2006) with the use of mobile devices (smart phones, PDA's etc.). Further to the fact that *mobile internet computing* will be the "*next major computing cycle*", it is predicted that by the year 2014 the number of 3rd Generation subscribers and the corresponding penetration will be more than doubled (subscribers: from 1,055B in 2010 to 2,776B in 2014; penetration: from 21% in 2010 to 43% in 2014) while LBS and real-time awareness "*unlocks power of data on Physical Location*" (Morgan Stanley Research, 2009).

A growing number of survey articles focusing on empirical evaluation of the application of LBS and m-auctions in the tourism industry, reflect a real potential for the research of such technologies. Tang (2006) examined C2C auctions and summarized major challenges for the adoption of mobile auctions; he concluded that m-auctions are still not-mature enough and perform better by complementing instead of replacing e-auctions. Yu and Chang (2008) examined the user-perceived usefulness for a range of B2C mobile services through a combined used of literature findings, interviews and surveys, showing that auctions are of medium importance for all stakeholders. Mallat et al., (2009) examined user acceptance of mobile ticketing services and spotted two core benefits for users (performance, spatially and temporally improved service access) while recommending that service providers should focus on the benefits of mobility complementary to traditional and electronic commerce models for certain cases (e.g., urgent ticketing). Most recently, Reuver and Haaker (2009) underlined the differences of added value between simple mobile and context-aware business models.

6.2.7 L-auctions for Hospitality Services: Model and Architecture

This section deals with the systemic design and development of an architecture suitable for the execution of LBS-supported m-auctions in the hospitality business and discusses the distinct roles of the participants and the ICT-related technical requirements. Although the example case refers to the lodging industry (considered as central in tourism services and able to integrate several other applications), the proposed model can be slightly modified to apply effectively in numerous capacity-specified tourism industry applications, for example car-rental, guided tours, concert/opera tickets, special events, etc. The proposed prototype is described using the *Unified Modeling Language (UML)* notation, which offers a set of tools for the analysis, design and implementation of complex ICT development projects. This notation has been adopted because it allows better communication between business modeling and application development, using elements to model actors, business processes, activities, logical components, etc., and represent static (using objects, attributes, operations and relationships) and dynamic (using sequence, activity and state machine diagrams) views. A use case and a sequence diagram are employed to illustrate the functionality provided by the actors of the system and the way they interact between them and with the system identifying the system boundary and the interfaces.

.1 *Motivation*

The development of the model for application in the tourism domain was motivated by the following factors: (i) the need for differential pricing based on temporal and location attributes of tourism services and potential customers; (ii) the realization that auctions are ideal market-making mechanisms to extract customers' WTP; (iii) the broad penetration of m-commerce and its associated ability to reach a large base of potential customers as supported by relevant studies; (iv) the advances in ICT that enabled the recognition of users' location and created the ability to offer spatially-differentiated services.

The proposed model aims to reflect the following key functionalities of a mobile marketplace:

- Price formation for tourism services through an auction process to obtain higher capacity utilization.
- On-the move advertising of offers and bidding by travellers using ordinary mobile devices.
- Geographically focused differentiated auctions where the area depends on the location of service traded and the actual position of subscribed travellers.

.2 *Model Development*

An auction-based m-marketplace in the tourism context may prove beneficial for tourism service providers that want to minimize capacity underutilization. The proposed auction-based pricing mechanism is time-efficient, enables geographically-related interested tourists express their WTP, and may be used irrespectively of other revenue management techniques (overbooking, "phantom" bookings, etc.) which may be perceived as unfair or are inefficient for last-moment booking. In the modeled m-marketplace, a service supplier (seller) advertises and offers a service unit to interested, on-the-move, potential travelers (buyers) through a forward, first-price sealed-bid (FPSB) mobile auction process; the buyers compete to buy the service by offering the highest price. This mechanism has a fixed predefined duration and is very simple. It requires the interchange of 3 *receive* and 3 *send* messages (including two *send* messages (AcceptInvitation) and (AcceptfromWinner_Debit) used to safeguard the overall process). A typical expected duration of 30 to 60 minutes is not considered prohibitive or repelling subject to the expected benefit.

A hotel manager, for instance, knows that a hotel room is reserved for the next two days and he expects that it will not be occupied afterwards, which will lead to undesirable loss of revenue. The global coverage properties of the Internet may be of minor importance or may prove inefficient in this case, mostly due to short timeframe (even intra-day) between a potential auction process and the resource availability time; this would lead the service to remain unsold. The problem may be alleviated through an m-auction in a country-wide context; travelers located in the same country may show more interest to participate in the auction, while far located travelers may show low or no interest. Other tourism services (e.g., car rental, tickets, events, etc.) may be treated similarly.

The mobile communications infrastructure may also serve for a range of complementary services such as, informational services, route finding, etc., and support a range of finance-related operations like mobile payments and currency conversion; they can also be used to penalize untrustworthy users, for example charge them for non-shows. Obviously, it is more probable to find potential travelers currently located in the city the service is offered (or travelling within a specific radius from it) wishing to participate actively in the auction process, even creating a sense of “after-the-last-minute” travelers (Figure 6.5).

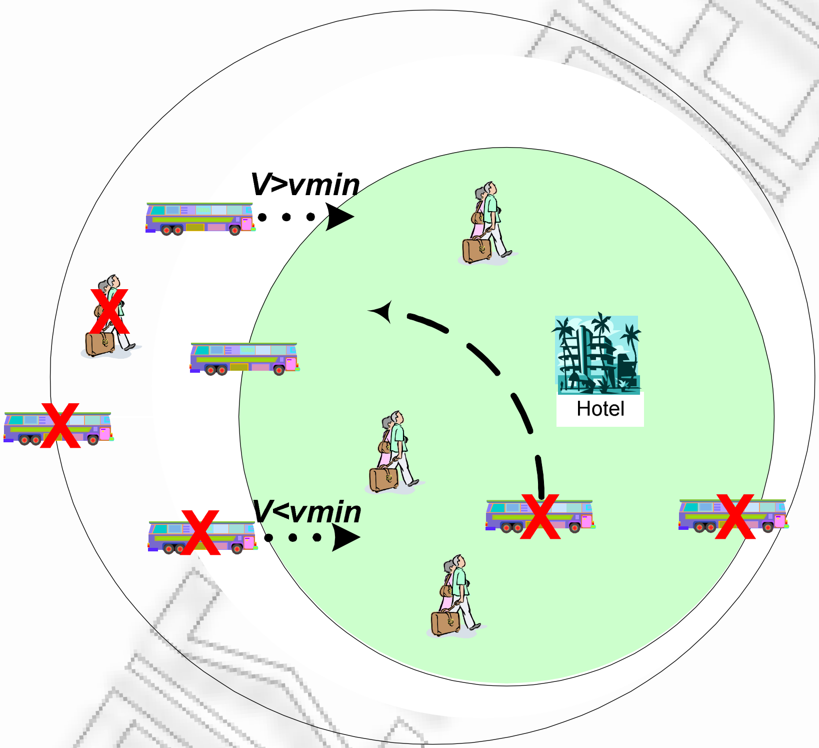

Figure 6.5: *LBS-Assisted Screening of Bidders*

The described marketplace therefore, focuses on a targeted group, thus increasing the probability of service provision and, at the same time, decreasing the communication load and costs. This can be accomplished through the integration of the “find-me” ability of LBS in the m-auction context, using cell phone triangulation or Global Position System (GPS) technologies to locate subscribed travelers. Detailed and technical analysis on various positioning technologies can be found in Dao et al., (2002), Choi and Tekinay (2003), D’Roza and Bilchev (2003), Unni and Harmon (2003), Gustaffson and Gunnarsson (2005) and Kang et al., (2007).

In the hotel example described herein the hotel manager (seller) submits a request to an auction organizer infomediary’s (auctioneer) Internet site, to carry-out the m-auction for the room (Phase 1). The auctioneer sends a request (Phase 2) containing subscribed potential bidders (buyers) to an LBS-provider asking him to filter and select eligible bidders located within a specific city/geographic area (Phases 3,4) and then advertise and conduct the whole auction process via a cell phone network (Phase 5). The proposed architecture and the corresponding steps are depicted in Figure 6.6.

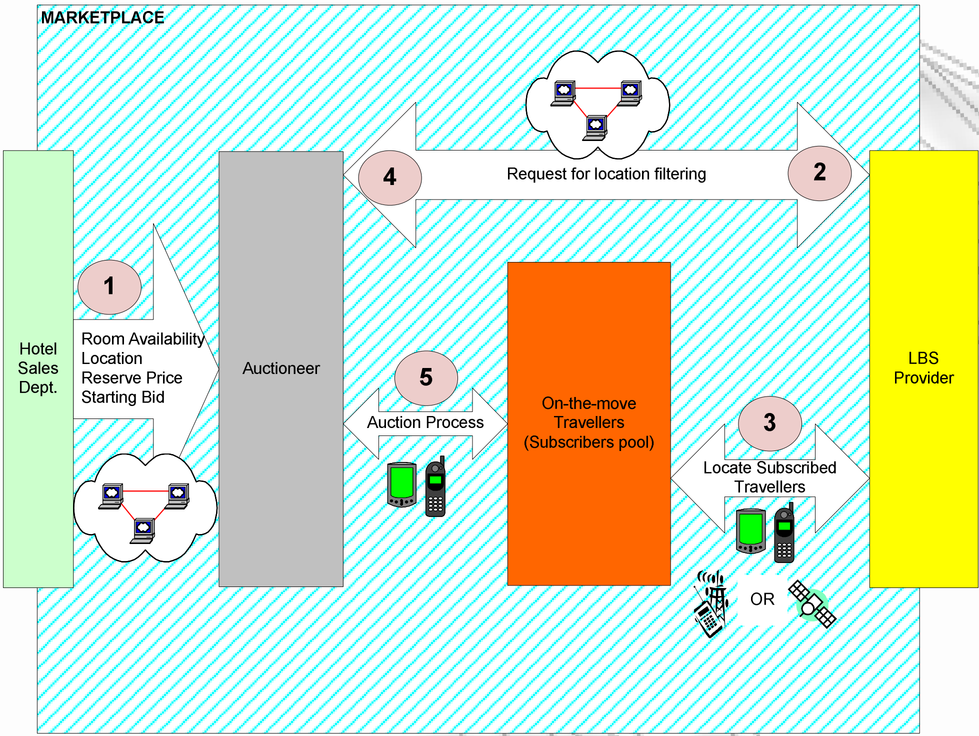

Figure 6.6: *LBS-Assisted m-auction Marketplace Architecture*

The described auction is based on a one-shot first-price sealed-bid auction mechanism where each traveller submits a single monetary bid invisible to other bidders in a restricted timeframe. At the end of the auction process the auctioneer compares monetary bids and awards the auction item to the bidder with the highest monetary bid in a price equal to the bid amount. The auction mechanism may be customizable to some extent by the seller by defining parameters like reserve price and its visibility (minimum selling price visible to bidders or not – if no bid is greater than this reserve price the service remains unsold) and starting bid (minimum acceptable bid).

A detailed workflow analysis of the process under the prism of the temporal evolution of the transaction is presented in Figure 6.7 as a sequence diagram using the Unified Modeling Language (UML). This abstract model considers 5 types of entities, namely, the seller, the buyer (bidder), the auction organizer (auctioneer), the LBS provider and the IS and database infrastructure. Initially, the hotel owner uses the Internet to send an auction request to the auctioneer defining the room, the location, the start and reserve price and the search area (Step 1). The auctioneer then checks whether the seller is subscribed; if not, he requests a new subscription (Steps 2-5). Subsequently, the auctioneer searches his database for subscribed travelers (Steps 6 and 7). The set of subscribed travelers is filtered according to their current location and the auctioneer sends a request to the LBS provider containing the list of subscribed travelers and the geographic area under investigation (Step 8); the LBS provider then retrieves travelers' positions within desired areas with the use of cell triangulation or GPS (Steps 9 and 10). This short list is sent back to the auctioneer over the Internet to filter the list of subscribers (Step 11) and initiate the auction process sending SMS invitations to travelers and receiving SMS replies confirming participation and bid amount (Steps 12-15). Once the bids are collected (typically in a predefined time window) the auctioneer evaluates the bids according to the first-price sealed-bid (FPSB) auction protocol (Steps 16-18), announces the winning bid and the winner to all participants (Step 19), requests accept and debit data from the winner (Step 20) and informs accordingly the seller (Step 21) and the LBS provider about winner's data (Step 22). In the last phase of the process, the LBS provider may offer guidance service to the winner of the auction (Step 23). The transaction data are used to update the auctioneer's database of the marketplace (Step 24).

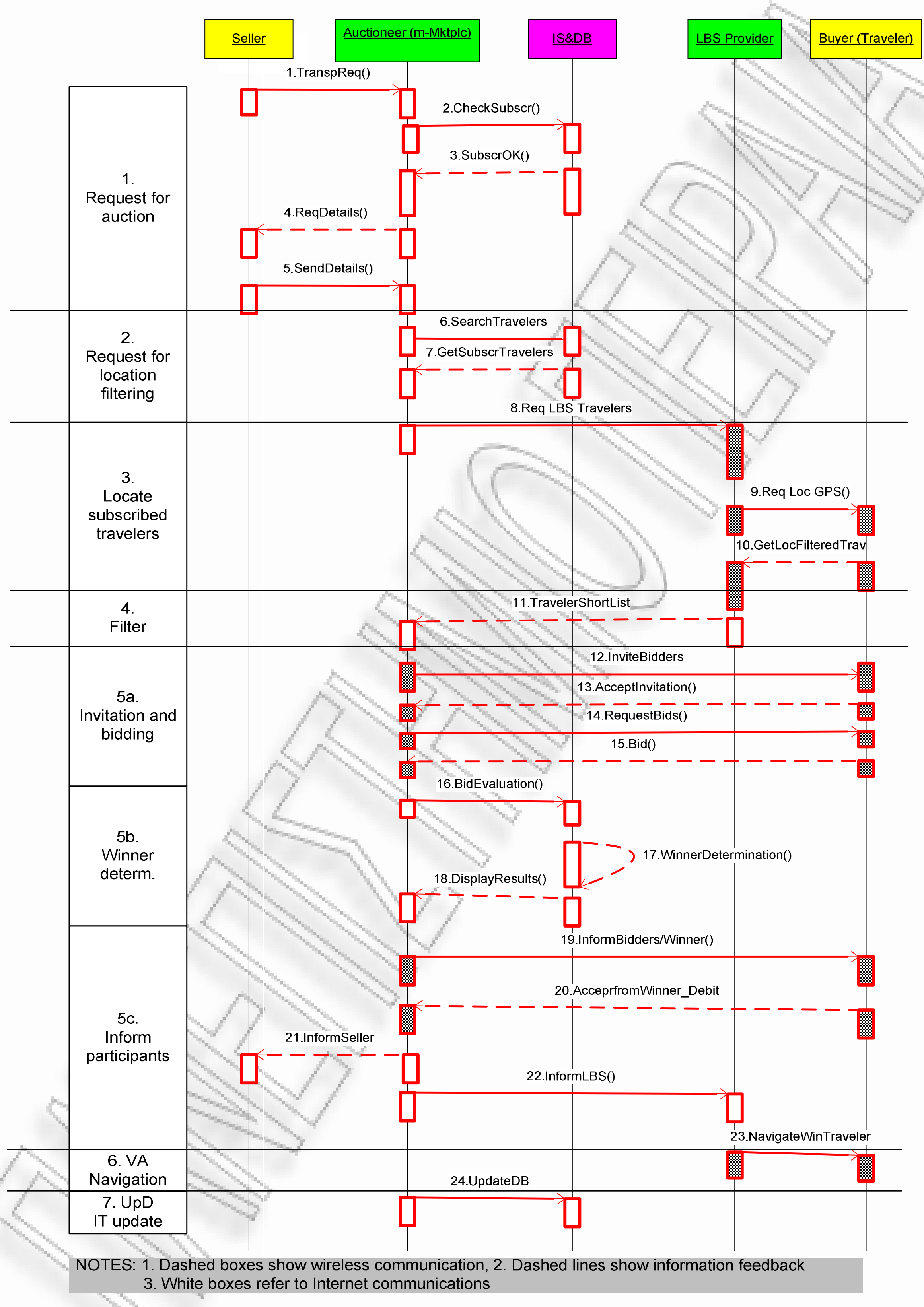

Figure 6.7: *LBS-Assisted m-auction UML Workflow*

.3 *Technical Requirements and Limitations*

From a managerial point of view, the anticipated adoption rate of this new technological business model is of high importance (Pura, 2005). Several research efforts have focused on critical parameters affecting the expected adoption rate of mobile commerce applications as a function of the perceived value. Results from surveys showed that technical parameters (e.g., device display, audability, portability, ease of use, etc.) and price transparency are affecting the adoption rate (Ihlstrom-Eriksson and Akesson, 2007; Eriksson and Strandvik, 2004). The special case of mobile hotel reservation application was examined by Wang and Wang (2010) who concluded that perceptions on information and system quality are critical in using this technology; secondarily, technological effort and fees may also affect the attractiveness of the solution. Finally, Kim et al., (2008) showed that the adoption rate depends on travelers profiles; for example, the adoption rate is higher for frequent travelers.

The adoption and success rate of the marketplace proposed herein, follows the general findings outlined above and depends on some critical technical and performance-related issues, such as fairness and reliability. An m-auction is a typical case of a group-oriented, real-time mobile service with special requirements for lower delays and continued connectivity (Varhsney, 2005). The communication performance parameters for e-auctions are presented in Liu et al., (2003) and apply in m-auctions too while the critical networking requirements for m-auctions are presented in Varhsney and Vetter, (2002). For mobile auctions, in particular, specific multicast requirements are summarized in Varhsney, (2002) while requirements of LBS for mobile auctions have been presented by Varshney, (2001) and Varshney (2003). A summary of the technical requirements is depicted in Figure 6.8.

Requirements and metrics for e-auctions

- Fast response (time)
- No site failures (reliability)
- Predictable response (predictability)
- 24X7 services (availability) – continued connectivity
- Low transaction fees (costs)
- Secure (security)
- Fairness (information sharing)

Networking requirements for m-auctions

- Multicast support for individual all-or-none transactions
- Location management
- Roaming across multiple networks

Multicast requirements for m-auctions

- Real-time multicast
- Active participation by multiple users
- Very low delay (few hundred of ms to a sec.)
- No intermissions / no disconnections

LBS requirements for m-auctions

- High location precision (hundreds of meters – cell)
- High response time (seconds) and priority (# queries, frequency, duration)
- High wireless coverage (local & nation-wide)

Figure 6.8: *Technical Requirements for the Proposed Model*

6.3 Application 2: Trading Unused Capacity in Freight Transportation Business

Freight transport refers to the physical movement of goods from point to point within a specific time and cost. The transportation business is diversified and fragmented over large geographical areas. A large section of economy depends on the transportation of goods and the freight transport industry. The latter is extremely differentiated in terms of size (individual carriers, small and large international companies) operating in a very competitive market. New practices and marketplace platforms have been developed to match loads and capacity in a cost-effective manner. A transportation marketplace attempts to match loads allowing shippers and carriers to post, search and negotiate their shipping and capacity utilization requirements via short-term contracts. The aim of these markets is to lower search and transaction costs, increase convenience, and provide carriers and shippers access to larger markets. (Figliozzi et al., 2002) summarized the unique characteristics of freight business:

- The trading entity is the service capacity which by nature is perishable and non-storable
- One freight service contract contains terms relative to penalties for delay which often are higher than the cost of transportation per se
- Demand and supply are geographically dispersed and uncertain over time and space
- Group effects are present (e.g., geographic closeness of destination points)
- Network effects (e.g., continuity of trips) are present
- Economies of scope (complementarity, substitution)

Reverse auctioning is an emerging negotiation mechanism for the freight transportation business area (conceptually defined as E-transportation) because it offers agility, optimal capacity allocation practices, flexibility and real-time negotiation (Nair, 2005). Tse and Soufani, (2003) claim that one of the major benefits of freight auctions is that they enlarge the freight business market in a way that enables small and medium sized players to participate with low access cost. Small carriers benefit by obtaining access to large markets; furthermore, they can participate as subcontractors or through collaboration with other small participants. On the other hand a freight marketplace gives small shippers the opportunity to collaborate by consolidating freight, supporting the creation of TL shipments. Common questions for bidders (carriers) are: participating or not, how to valuate the service, how to bundle various services and which bidding strategy to follow.

The freight auction marketplace is also a source of revenue for many other stakeholders beyond basic trading partners which indicatively are: Application Service Providers – ASP's (e.g., software development and hosting), purchasing consolidators (e.g., aggregation of buying power), Infomediaries (e.g., information providers, GPS), e-fulfillment companies (e.g., handlers of LTL and e-commerce package transport), and others.

6.3.1 Trading Freight Transportation Services

.1 Freight Transportation Auctions

Reverse B2B auctions have been widely used for the procurement of freight transportation services offering. Anandalingam et al., (2005) summarized their major benefits, namely: savings to the buyer, ability to constrain non-price related attributes, alleviation of carriers' logistical problems through bundle bidding and complementarities. Nair (2005) examined how electronic environment changed the way transactions are carried out for different participants and provided a condensed view of the properties of e-auctions in the freight sector, the major of which are: cost reduction for LTL freight (approximately 20%), time savings, agility, optimal capacity allocation practices, flexibility and allowance for real-time negotiation. He also claimed that freight auctions may be non-binding; the auction initiator may get the results and review other issues like quality, reliability and shipping times before awarding the contract. Buyers consist of manufacturers, distributors, retailers, service organizations, 3PLs, freight forwarders and brokers while sellers include common carriers or common fleets.

In the freight business, a Logistics Center (LC) is usually the market maker responsible to organize and coordinate the auction process and does not own any transportation equipment; it is only participating in forward and reverse auctions in order to sell service packages and acquire transportation services, respectively. The LC can thus be perceived as a *service composition agent* as described in the *FreightMixer* paradigm proposed in Preist et al., (2003) being the *matchmaker*, the *negotiator* and the contractual *provider* of the service.

Gomber et al., (1998) compared between basic auction types for decentralized marketplaces for electronic procurement of freight transportation services finding that the Vickrey auction is a common basis. Preist et al., (2003) designed a service composition intermediate agent (*FreightMixer)* acting as a broker: its role is to hire trucks (service components) as buyer and then to provide freight services as a seller using acquired service components. Yunsong and Lim (2003) introduced a set of new business decision variables set by shippers in the freight RA and proposed relevant solution heuristics. These variables are: the maximum number of shippers, the shippers' coverage, synergies between shipper and carrier, the carrier performance and cost penalties. Song and Regan (2003a) dealt with the optimal formation of bids evaluating their proposed method through simulation. Later, they focused on how shippers define procurement constraints from business rules and they proposed a Lagrangean relaxation algorithm to find optimal solutions (Song et al., 2004b).

Advanced combinatorial e-auctions first applied in the freight transport business by Sears Logistics Services (SLS) (Ledyard et al., 2000) to gain economies of scope. SLS saved $25 million (13% cost reduction) per year maintaining suppliers' satisfaction using a *combined-value* auction format to increase load consolidation, reduce empty mile lanes and create combined-value lanes. Preist et al., (2002) described a marketplace as a virtual company creator and examined relevant algorithms used for negotiation and execution of trade.

.2 Multi-dimensional Freight Auctions

Full Truckload (TL) freight transport business may benefit from *Economies of Scope* related to temporal and spatial proximity between neighbor transportation lanes and two-directional movements of freight. Carriers' main concern is to minimize trucks' idle time and improve utilization of available transportation resources (truck capacity and drivers' working hours). Spatial proximity can be attained through the acquisition of specific *bundles* of lanes. Carriers' cost depends more on his overall network traffic - including reverse and combined lanes – (economies of scope) and less on the load volume (economies of scale). Carriers, therefore, aim to operate balanced networks in order to handle follow-on loads and position their resources at appropriate locations. Combinatorial auction mechanisms can serve this efficiently, allowing freight owners to reduce operation costs and help carriers offer lanes balanced to their networks for specific time periods.

Moreover, multi-attribute auctions support bidding and evaluation of different criteria related to service level or capabilities beyond price including quality attributes like on-time performance, familiarity with shipper's operations, resources suitability and availability, complementary non-transportation services (e.g., payments collection), pick-up performance and other facilities (billing accuracy, reporting, EDI, tracking systems, etc.). The value of the attributes may vary by lane for the same carrier. To evaluate carriers' bids the shipper has to weight these attributes based on service level requirements.

The bid evaluation process is a rather complex process especially when the number of the negotiable attributes and the number of submitted bids is large. Several techniques have been proposed for the reduction of complexity. A rather simple method used by shippers is to define a minimum attribute value threshold in order to evaluate just a set of "serious" carriers at the expense of competition reduction. A better way to manage high data volume without bidder rejection is to modify price bids as a function of quality (or other) attributes. In order to do this, a shipper has to define how much each fraction of the attribute is worth compared to rivals' (benchmark) values and calculate price/attribute value trade-off. Prior to applying this methodology the shipper has to determine the monetary value of attributes using utility theory. Bid evaluation may occasionally be further constrained by business rules applicable on single/group of lanes, defined as *system constraints*. Examples of these constraints are: the minimum and maximum number of carriers for each departure site, the minimum and maximum load per carrier, the capacity of known carriers, system-wide constrains, the minimum number of winning carriers, the minimum number of "small" winning carriers, etc.

As stated above, freight services are characterized by a number of parameters beyond price, related to quality aspects of the service, such as, carrier's experience, loading/unloading time, equipment, fleet surveillance, etc., which are employed in an auction environment to shape the monetary bid through *multi-attribute (or multi-criteria)* auctions that complement a combinatorial auction mechanism (Sheffi, 2004), (Lavendelis and Grundspekins, 2006).

Figliozzi et al., (2002) presented a framework to study carriers' strategies in sequential freight auctions. The auction setting and relevant information flows of a typical auction process in a freight marketplace have been presented by (Figliozzi et al., 2003a; 2003b). They also provided an introductory analysis on the operation of freight marketplaces based on sequential auctions, and examine carriers' decision elements and behaviour. Mes and van der Hijden, (2007) examined carriers' and shippers' strategies in sequential freight auctions taking into account future opportunities and the effects of delays and breaks on the schedule. Finally, Ergun et al., (2007) developed bidding algorithms for carriers participating in simultaneous multiple lane freight auctions.

Gomber et al., 1998) examined decentralized Multi-Agent systems using a special combinatorial mechanism (*matrix auction)* which allow bidders to set multiple bids – different for each lane or for different combinations of transport lanes. In their study on combinatorial auctions for freight services procurement, Song and Regan (2002) examined how carriers may benefit from a combinatorial auction format. Later, Song and Regan, (2003b) designed a combinatorial mechanism supporting collaboration between carriers. Caplice and Sheffi (2003) provided a business-focused analysis on the application of auctions with conditional bids in the procurement of TruckLoad (TL) transportation services. They explained carriers' economics dynamics and described how optimization techniques can be used to deal with combinatorial and contingent bids based on shippers' requirements. Elmaghraby and Keskinsocak (2003a) described a real-world case study of the Home Depot retailing company which applied combinatorial auctions to procure transportation services and analyze issues related to design, implementation and participation.

Sheffi, (2004) presented a comprehensive overview on special auction types and a brief analysis from carriers' and shippers' perspective. Although simple auction mechanisms are not always efficient, in certain cases carriers and shippers prefer them instead of combinatorial (Song et al., 2004a). Many software providers have developed tools to cope with complex bid evaluation mechanisms, like *Transport Bid Collaboration (i2), Optibid (Manhattan Associated)*, etc. The complexity of bid evaluation problem increases when additional restrictions are introduced. Some indicative restrictions are: minimum/maximum number of winners, bidder preference, multiple bids for multiple items, full coverage, and minimum winning lanes for a winner, performance metrics, etc. They also dealt with simple reverse auctions where the shipper (auctioneer) asks for specific mutually exclusive packages of lanes and carriers submit a bid for a single package, thus reducing the bid formation complexity. They also proposed a mathematical model and heuristics for bid analysis problem applying business constraints set by shippers, adopting them from Caplice and Sheffi (2003).

Later, Song and Regan (2005) proposed an approximation method for carriers to construct optimal bids in combinatorial procurement auctions. Kwon et al., (2005) proposed a multi-round combinatorial auction mechanism where bidders (carriers) draw price information from each round integrating shippers' winner determination problem and carriers' bid formation problem. A brief overview of various simple and complex auction formats used in e-Marketplaces has been given by Anandalingam et al., (2005). Krajewska and Kopfer (2006) applied combinatorial auctions for the formation of collaboration schemes between freight forwarders aiming to subcontract transport orders. A more complex case where carriers and shippers bid simultaneously in a double auction for freight capacity trading has been presented by Garrido (2007).

Recently, Gujo and Schwind (2008) considered ComEx, an electronic exchange operating on the basis of combinatorial auctions where allocation of transport orders to carriers depends on geographically-related (and area overlapping) LC's and their cost relationships. They focused on bid formation, preference elicitation, bid valuation and pricing problems under the prism of collaborative planning through combinatorial auctions. The proposed mechanism operates on the basis of a clustering process where each LC calculates outsourcing candidates and develops combinatorial bids subject to distances and required time-windows. In the same context, one year later Schwind et al., (2009), introduced a distance-based cost estimation strategy, an iterative mechanism and a *convex hull mechanism* aiming to reduce computational complexity of the combinatorial auction.

.3 Bidding Strategies

Several studies focused on the formulation of bidding strategies by bidding carriers. Common questions for bidders (carriers) are: participating or not, how to valuate the service, how to bundle various services and which bidding strategy to follow.

Figliozzi et al., (2002) presented a framework to study carriers' strategies in sequential freight auctions. Hoen et al., (2004) proposed a multi-agent software architecture model for freight transportation auctions. An et al., (2005) analyzed bidders' decision for the efficient selection of bundles, with application on transportation auctions. Based on *adaptive learning* methods, Raychaudhuri and Veeramani (2006) proposed an optimal bid formation methodology based on estimates on best rival's cost in each round for single and combinatorial auctions. Tan et al., (2005) developed an auction model for a dynamic freight transport market and they evaluate its effects in terms of expected price, number of bidders (carriers) and backorders.

Krajewska and Kopfer (2006) applied combinatorial auctions for the formation of collaboration schemes between freight forwarders aiming to subcontract transport orders, and Mes and van der Hijden, (2007) examined carriers' and shippers' strategies in sequential freight auctions taking into account future opportunities and the effects of delays and breaks on the schedule. Finally, Ergun et al., (2007) developed bidding algorithms for carriers participating in simultaneous multiple lane freight auctions. Ergun et al., (2007) examined carriers' bid formation in simultaneous reverse auctions for procurement of freight transportation services taking into account lanes synergies and competitor's bidding strategies. They formulate a stochastic bid optimization problem and propose an iterative coordinate search algorithm. Mes and ven der Heijden (2007) studied the interactions between carriers and shippers in a reverse sequential auction for freight transportation services with time-windows and the strategies they follow aiming to maximizing profits for both participants based on costs and future opportunities

.4 M- and l-auctions for Freight Transportation

The technology deployed in business transactions over wireless networks (m-commerce) combined with networks, satellite communications, automatic position sensing and wireless connectivity and the reduction of related costs, permitted the development of geographically-sensitive content. Both mobile auctions and mobile advertising perceived as emerging classes of m-commerce applications (Sairamesh et al., 2001), (Varshney and Vetter, 2002). Generally, m-commerce enhances the ability of information interchange independently of users' location (Lau et al., 2006).

The enhancement of m-commerce services with Geographical Information Systems (GIS) leads to the development of Location-Based Services (LBS) which add value to users and revenue to providers by enabling the offering of location-aware services (Adams et al., 2003). LBS are based on the geographic relevance of information (Choi and Tekinay, 2003), (Ibach et al., 2005) and are offered upon user request or through an automatic triggering function (D'Roza and Bilchev, 2003). The position of the mobile device is determined with the use of either satellite positioning systems or cellular communications to serve a wide range of location-sensitive businesses such as transportation, sightseeing, navigation, supply chain management etc. (Xia and Bae, 2007). Such transactions may be carried out through trading mechanisms with the use of mobile devices (smart phones, PDA's etc.).

In the freight transportation context, LBS add value to commercial transactions whenever the distance between shipper and carrier becomes a prerequisite for the provision of a service. Thus, the combination of m-commerce with LBS enables the implementation of pricing tools which take into account carriers' current location to announce and execute geographically focused auctions over mobile networks (m-auctions). Emiris et al., (2007) combined the domains of m-commerce, auction-based logistics services and LBS, into a unified whole with application to dynamic matching of demand and offerings for freight services. They engage LBS in an m-auction context to locate and filter potential carriers (bidders), announce the auction to them, carry-out the auction and take advantage of information services (e.g., guide winner to loading site). They propose a technology model, an appropriate information workflow and they show that the application is economically and technically feasible. This model evolved further to support subcontracting with trans-shipment, where a winning on-the-move carrier is able to re-auction a shipment to carriers moving outside his legally-restricted area of coverage (Emiris and Marentakis, 2008). Most recently, Marentakis and Emiris (2009) examined how LBS technologies can be used to automatically collect qualitative evaluation criteria in multi-attribute freight auctions, simplifying it to a single-bidding-attribute auction.

.5 Typical Applications

E-auctions have been widely used in specialized freight service marketplaces (e.g., http://www.bestbidshipping.com/ www.bidfreight.com, http://www.cargoauctions.com, http://www.freightbid.co.nz/, http://www.uship.com/freight/,http://www.cargolaw.com/ http://www.bidmyfreight.net/, http://bidforfreight.ie, http://www.expediteloads.com, http://www.freightebay.com/, http://www.freighttender.com/, etc.) to trade freight service and corresponding value-added services.

6.3.2 Use Case 1: Filtering Potential Bidding Carriers

.1 Scope

Auction-based marketplaces dynamically match shippers' demand and carriers' capacity offeringa in a short time, low cost and low effort manner. The combination of mobile auctions and mobile advertising provides a procurement negotiation tool which takes into account carriers' current location to announce and execute geographically focused auctions. In other words, an interesting characteristic of m-commerce is that it abolishes geographical limitations and enhances the ability of information interchange within a supply chain network

(Lau et al., 2006). This application aims to couple the domains of m-commerce, auction-based logistics services and LBS, into a unified whole and to investigate the inherent structural complexities; furthermore, it attempts to estimate the LBS communication data workload for the special auction marketplace examined.

With the use of mobile technology the participants of freight transportation marketplace form a dynamic virtual mobile community are able to respond rapidly in trading processes (Schubert and Hampe, 2005) like mobile-auctions. As a result shippers are able to adapt quickly their supply chains to large-scale unpredictable changes supporting agility (Smart and Harrison, 2002). The LBS-enabled marketplace enables carriers to bid while they are on the move. The Less-Than-Truckload (LTL) freight business is a typical example of perishable good - sensitive to time and location; the available capacity of a truck has no value when it bypasses a loading point (e.g., logistics center); that is, the location of the truck is a critical issue for the value of the available (unused) capacity of the truck. Moreover, trucker's desire to gain revenue from this capacity increases while approaching the distribution center. It can be easily presumed that a moving carrier is expected to bid more aggressively for a shipment contract as he approaches the loading point. The existence of different carriers' valuations according to their distance from loading point, leads to low vulnerability because it is hard for bidders to collude due to temporality of valuation. Finally, a shipper knowing carriers' location is able to make rough estimations about their valuations. Integration of LBS to the freight procurement mobile auction offers many other benefits summarized in Table 6.4.

Participant / role	**Benefits**
Auctioneer / Marketplace owner	Lower communication costs Magnification of subscriber base Lower transaction costs
Carrier	Revenue management / capacity utilization Co-operation opportunities New markets – especially for individuals Low participation costs LTL enhancement Subcontracting between carriers
Shipper / Logistics Center	Reduced freight rates (less than market price) Growth of potential supplier base Response to ad-hoc needs High procurement speed Better control on supply chain flows
Value-adding service providers (insurance, law, banking, collecting e.t.c.)	Market growth Business opportunities Advertising
Communication infrastructure providers	New source of revenue New service development Roaming
Other participants (IT, consulting e.t.c.)	Growth of business

Table 6.4: *Benefits for Marketplace Participants*

.2 *Marketplace Description*

The marketplace examined in this chapter will be based on a reverse (procurement) auction mechanism where a buyer (shipper) offers a tender to invited suppliers (carriers) who bid for the right to fulfil a contract at the lowest price, usually in a very short time span of hours or, in some cases, minutes (Smart and Harrison, 2002). Multiple sellers (carriers) compete for undertaking the shipment of a single buyer (shipper) by offering the lower price. In a simple case, auctions are performed one at a time, carriers bid on single lanes and the evaluation criterion is strictly the price. In more complex cases, carriers may bid on multiple attributes (e.g., pick-up time windows) and different combinations of lanes / auctions to accomplish economies of scale.

In the present application, two scenarios will be examined: the first one assumes that carriers are large LTL transportation companies, while the second one assumes an extended sellers base consisting of individual carriers. The last case is a typical form of a temporal virtual enterprise which combines the advantages of big and small enterprises as proposed by Do et al., (2000). The marketplace uses LBS to discover subscribed and appropriate carriers' equipment dynamically. This type of information is of special interest for freight business, as it is a tool for the shipper to increase its information about carriers' value; moreover, the shipper addresses his needs to a special – geographically defined - segment of carriers, reducing communication costs and computational complexity (e.g., to determine the winner).

In the proposed application, the marketplace operates on the basis of a second-price sealed-bid (Vickrey) auction, where each carrier submits a single bid; the project is awarded to the carrier with the lowest bid, who gets reimbursed at the value of the second lowest bid. Vickrey (1961) showed that bidders' optimal strategy in 2nd price sealed-bid auctions is to bid their actual cost. If the bid exceeds bidder's marginal cost the probability of winning will decrease without affecting the payment because the 2nd price does not depend on the winner. It is obvious that a bidder loses if the bid is lower than his marginal cost. When bidders' valuations are independent and private –as in present case– Revenue Equivalence Theorem applies and all basic auction types (English, Dutch, first-price sealed-bid and Vickrey) have the same revenue.

.3 *Model Description*

The proposed marketplace brings together one shipper (acting as buyer) and several carriers (acting as potential sellers), where both entities are recognized as subscribers. An auctioneer acts as an intermediate to organize, manage and regulate the auction process. The innovative characteristic of this marketplace is the presence of an independent LBS provider being integrated with the marketplace infrastructure. An LBS provider aims to provide real-time information about carriers' current location before and during the auction process. To ensure information consistency and integrity, all messages will be transmitted in a specific abstract data format. The mechanism employs a multi-dimensional (in terms of number of items, units and bid characteristics) reverse 2nd-price sealed-bid (Vickrey) auction with reserve price. The marketplace architecture is shown in Figure 6.9.

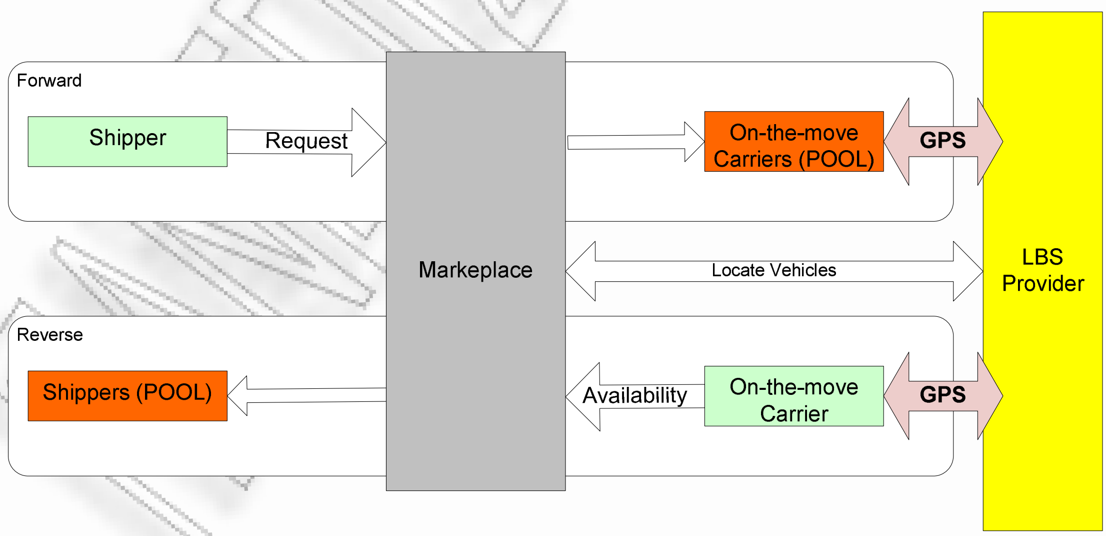

Figure 6.9: *Architecture of m-auction, LBS-Enabled Marketplace*

To systematically study the complete auction process from a software-centric point of view, we adopt the session model shown in Table 6.5.

Session
Conclusion Session
Evaluation Session
Auction Session
Designation Session
Call Session
Connection Session

Table 6.5: *The Auction Session Model*

A detailed workflow analysis of the process is presented as a sequence UML diagram in Figure 6.10. In this diagram, messages to/from LBS provider are dashed. The core difference between this workflow and the one presented previously in Figure 6.7 is that it refers to a reverse auction where the initiator is the shipper who requests the service.

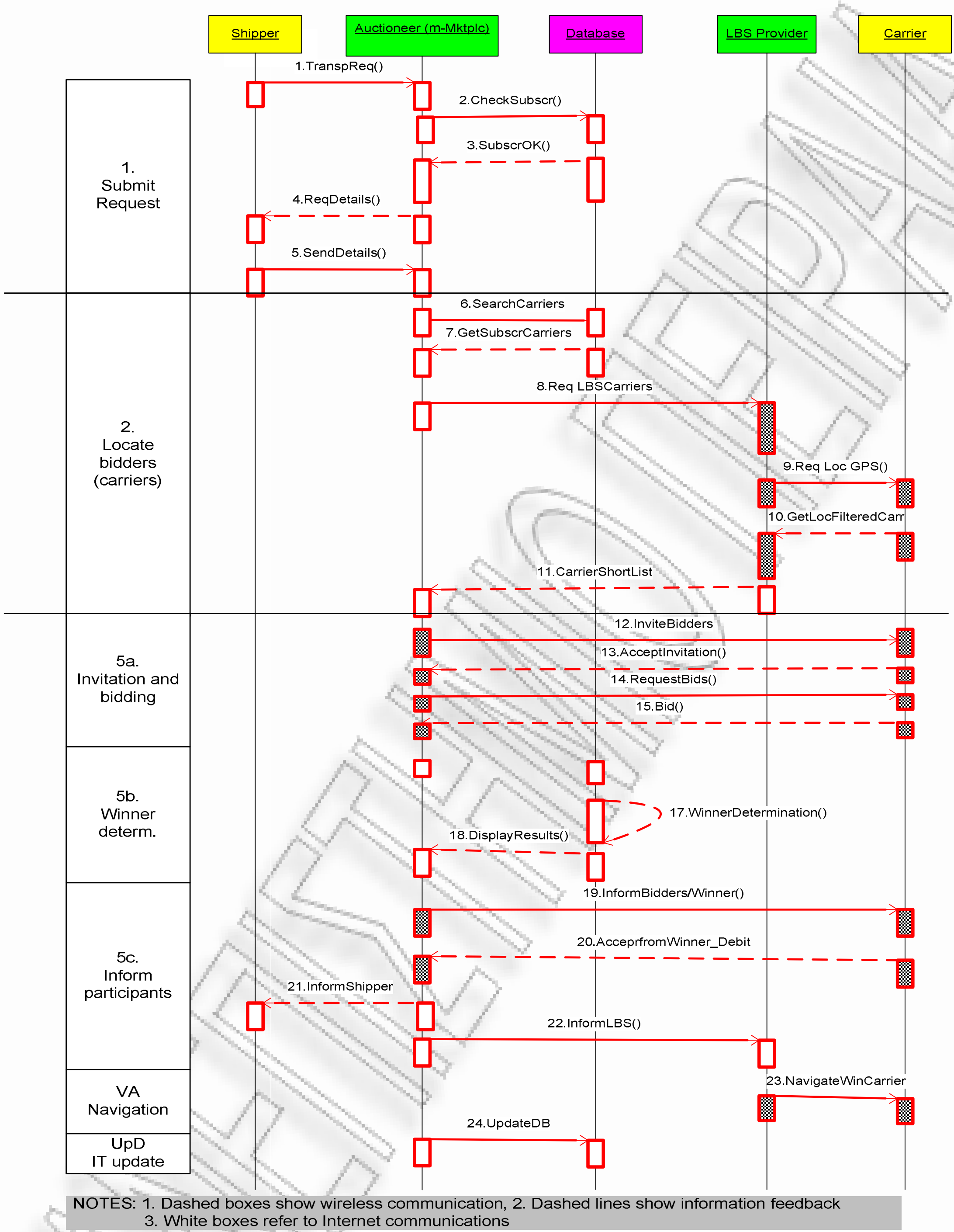

Figure 6.10: *UML Diagram of Workflow Analysis*

.4 *Communication Requirements*

Efficient integration between marketplace and LBS requires the presence of mobile communication technologies (GSM phones or PDA's) and location sensing equipment. Minimum critical requirements are: simultaneous data transmission, continuous connectivity, proper user interface design (due to display size limitations), identification and authentication. Equipment should fulfil some minimum networking requirements: Multicast Support, Location Management, Network Reliability, and Support for Roaming Across Multiple Networks. The design of any LBS based mobile marketplace should take into account the following factors (Varshney, 2003): (i) Location accuracy, (ii) Response time and priority, (iii) Network coverage, (iv) Number of devices involved, (v) Wireless dependability and reliability, (vi) Type of communications, (vii) Number of location queries per transaction, and (viii) Frequency and duration of transactions. Varshney also states some other issues, such as privacy, security, ownership of location information, device complexity, user interface, overhead of LBS, business models for pricing and revenue sharing, vendor support and service interoperability.

In this application, we assume a freight transportation marketplace where multiple carriers compete for one buyer's shipment at a time. For simplicity reasons, we do not take into account messages concerning information and support services, such as auction historical data or partner's reputation index request. As shown before, the minimum number of messages transmitted from/to LBS provider is 8. To calculate the total number of messages some auction mechanism-related parameters should be considered; these are outlined in Table 6.6. Based on the market model described before, the total number of messages is the product between the base number of messages (8) and each of the parameters.

Parameter	Value	Multiplier
Auction Type	Vickrey (2nd price, sealed bid)	
Number of Shippers	1	
Number of Carrier (Individuals)	#	C_i
Number of Carrier (Companies)	#	C_n (=f(C_i))
Number of Bidding Rounds	#	BR_n
Number of Location Requests	#	$LR_n = BR_n$
Number of bid dimensions	#	1

Table 6.6: *The Auction Mechanism Related Parameters*

The communication workload model used for the purposes of this research, assumes that there is a normal distribution of the number of requests during the 24-hours period of one working day and a uniform distribution within any 1-hour interval. This model is considered to be representative of the communication traffic produced by this electronic auction system. According to this model, the number of messages generated by the system is initially a function of the number of requests and the number of subscribers to this service. If there were no selection criteria, for any request, the number of messages transmitted would be the number of subscribers. Since the selection of recipients would be based on several criteria presented above, there is an expectation of about 40% reduction to the number of subscribers for any given request, i.e., the messages transmitted will be:

$$ICT = x \times y \times 40\% \qquad (1)$$

where:

ICT: Initial Communication Traffic

x: number of requests

y: number of subscribers

Assuming that for each bidding round, there is a 33% drop-out bidder rate, then the total message traffic required for the completion of a bid, is calculated accordingly, based on Table 6.7 below:

No of Requests	No of Carriers	Number of Signals to be generated	Bidder Reduction Rate	Signals for Transmission	Round Reduction Rate	First Round Remainders	2nd Round Remainders	3rd Round Remainders	4th Round Remainders	5th Round Remainders	Sum of Messages
100	500	50000	40%	30000	33%	20100	13467	9023	6045	4050	**131321**
100	120	12000	40%	7200	33%	4824	3232	2165	1451	972	**31517**
100	30	3000	40%	1800	33%	1206	808	541	363	243	**7879**
200	500	100000	40%	60000	33%	40200	26934	18046	12091	8101	**262642**
200	120	24000	40%	14400	33%	9648	6464	4331	2902	1944	**63034**
200	30	6000	40%	3600	33%	2412	1616	1083	725	486	**15758**

Table 6.7: *Communication Requirements per 1-hour Interval*

In order to calculate the communication load for any of the above cases, we have to take into account that for SMS exchange there is a requirement of 1 kb per SMS, leading to a communication bandwidth requirements varying from 8 Mb to 300 Mb per hour, i.e. 85 kbps. Of course this requirement does not cover any communication load injected by the GSM provider to ensure either successful communication acknowledgment or security encryption add-ons. Even if this workload doubles to cover redundancy, security and other “GSM – provider” add-ons, the required bandwidth seems to be easily commercially available at very low prices.

6.3.3 Use Case 2: Multiple Initiators, Collaboration and Spatial Services

The purpose of the present case is to propose an e-auction marketplace for freight transport services trading and to expand so as to gain advantage of spatial attributes by deploying location-sensitive information retrieval and processing technology. The proposed marketplace will support both forward and reverse auction formats where the auction initiators are the carrier and shipper respectively. The proposed business model utilize wireless positioning in a three-directional way: (i) initiation of trade either by carriers or by shippers, (ii) value-added spatial services (guide-me, find-me, get-together), and (iii) co-operation of small carriers. Operationally, it is designed to support all three mobility dimensions as described by Kakihara and Sørensen (2002), namely: (i) Spatiality (Where), (ii) Temporality (When), and (iii) Contextuality (What way, circumstance (e.g., available capacity), towards which actor(s). The operation of the proposed marketplace is based on the integration of Internet communication (wired), mobile communication (wireless) and GPS (satellite) networks.

.1 Model Generalization

The proposed freight service trading marketplace is developed within the context of the architecture described above with proper adaptations. From now on vocabulary adopted appears in Table 6.8:

Initiator	Role	Bidder	Auction Format	Price
Carrier	Seller	Shippers	Forward	Ascending
Shipper	Buyer	Carriers	Reverse	Descending

Table 6.8: *Role-Based Auction Vocabulary*

In certain cases, the initiators and their roles may be interchangeable: a carrier may want to consign his freight (if allowed) to another carrier for the end leg of his trip; a shipper may want to consolidate his shipment with other shippers' loads to fully utilize a hired truck. Describing buyer roles, Figliozzi et al., (2002) distinguish a number of initiators: a shipper wishing to transport a load, a carrier needing extra capacity by subcontracting or a third part wishing to resell this capacity. One of the innovative attributes of the proposed marketplace is that it can easily support role interchange via the use of "role_type" parameter database table from which the initiator has to choose from immediately after logging in.

For the typical reverse auction case for freight transport service procurement, buyers are shippers and sellers are carriers participating as bidders. Shippers announce randomly transportation needs and carriers compete for these. Each request is described by a pick-up location, a delivery location, time-windows for pick-up and delivery, truck type and license. The pair of pick-up and destination called a lane. Announcement of needs is real-time and the contract is allocated via an auction to the carrier with the lowest bid. When multiple transport needs are set, carriers may bid in multiple auctions simultaneously or in sequence.

Another option is to bid for combinations of transport jobs; the problem then becomes more complex for both carrier and shipper. Before the auction, interested carriers are screened via an eligibility check, referring basically to legal issues. Other carrier attributes and quality variables may also be used as evaluation criteria. The model supports this case by a simple interchange of roles in rectangles (Figure 6.11).

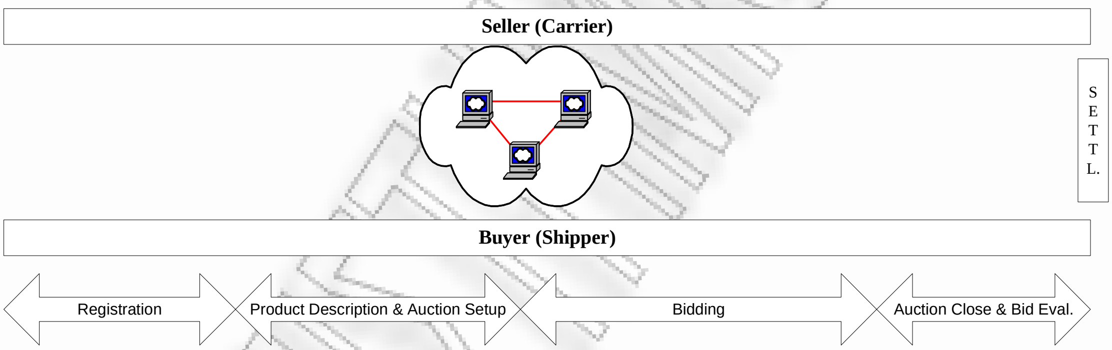

Figure 6.11: *Model Modification: Reverse e-auction for Freight Transportation Procurement*

During the registration process both shippers and carriers enter data related to their ID (e.g., name, address, business); shippers enter their preferences (freight data, warehouse locations, special transport needs) and carriers enter their available resources (trucks, capacity, equipment, licenses and specialties). During registration shippers should define their preferences and needs while carriers are able to define their abilities and targets. These data are used for a preliminary match between needs and offers aiming to promote partner relationships and eliminate unnecessary workload during the auction process. The shipper enters the attributes of the freight transport service she wants to procure via *define* or *update* process and customize an auction format defining data like auction type, reserve price, duration via the setup auction process. Before the auction begins, the shipper is able either to alter the auction format via the *update* process or to cancel it using the *cancel* process. Registered carriers are informed about the auction initiation or progress either by the *alert* process or using the *search* process by themselves. In case a carrier is interested in participating in more than one auction, she is able to create a private short list via the *select* process to access and monitoring them easily. Respectively a shipper is able to maintain his own auction short list using a *select* process. When auction starts, carriers submit their bids using the bid process and they are able to view, alter or withdraw them. If the price progress is imposed by the shipper during the auction (e.g., in Dutch or hybrid-Dutch auction types), then the shipper is able to define the ask price using the offer process. All participants stay continuously informed during the bidding process via the *notify* process. Once the auction closes (either automatically or manually) the system determines the winning carrier and price via the *evaluate* process, either automatically or manually. This information is communicated to all participants via a post-auction *notify* process. Finally evaluation data are transferred to a backend ERP system for trade settlement and reporting. Ideally the backend system includes a Customer Relationship Management (CRM) application which is updated by a pre-defined set of database tables updated during the auction.

.2 *Database Architecture and Parameterization*

A specific relational database is developed for the Kumar and Feldman (1998) process model supporting the complete process – from the participant registration and auction set-up stages to final settlement and back-end information systems update. Access to each table via SQL-statements is done in a structured way in discrete stages of the process according to the system architecture, safeguarding data coherence. Finally the proposed database utilizes relations between tables to avoid data redundancy and unnecessary data entry actions.

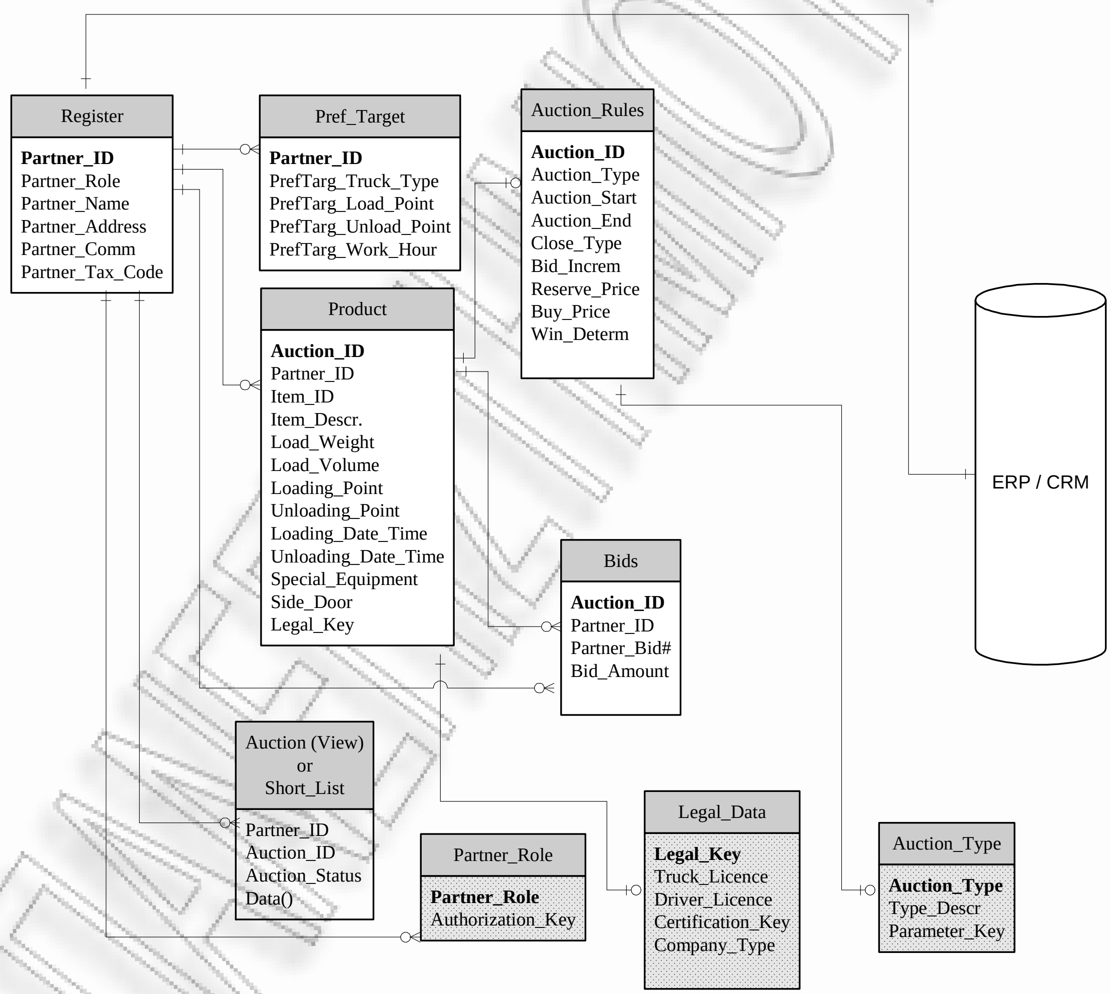

Figure 6.12: *Database Structure Model*

A primitive structure of the database is shown in Figure 6.12. Primary Keys are indicated in bold characters. This primitive form supports only single-dimension auction cases but it can easily be expanded. For example, multi-item auctions need the split of table Product to two relational tables, e.g., the Item_Table and the Auction_Table tied via an auction_ID field serving as primary key. The proposed database extends the proposed by Kumar and Feldman

(1998) model, introducing a number of additional customizing tables presented as dashed boxes.

The database supports interchangeable buyer and seller roles for carriers and shippers. To achieve this, an additional customizing table structure has been incorporated in the proposed database model, namely, the Partner_Role table. Immediately after the registration / log-on process, a partner has to select the role for the current session. According to his role he retrieves an Autorization_Key which defines a set of rules for transactions he is allowed to execute and transactions that are restricted for the current session. For example a partner who logs-in as a seller carrying out a forward auction is not allowed to modify a bid except from the case of the Dutch auction format where he is obliged to modify (descend) bids while bidders are not. The Autorization_Key remains constant during the whole auction lifecycle and cannot be changed in any way – otherwise auction fairness becomes weak.

This auction marketplace is able to support all four basic auction types and allows auction initiators to create custom auction formats creating single or multi-step mechanisms. This is facilitated by the introduction of an additional customizing table structure, the Auction_Type table. This table contains a Parameter_Key which guides auction initiators to define specific parameters for the selected auction type and it also carries a set of predefined parameters. A typical example for the simple forward Vickrey auction type initiated by a Shipper acting as buyer is shown in Figure 6.13. The definition of the Parameter_Key becomes much more complex in case of hybrid auction types (single or multi-step combinations of basic auction types) and in cases of auction formats like multi-dimensional or combinatorial. Finally, the database uses a Legal_Data customizing table which contains a combination of rules and restrictions defined by law in a form of a Legal_Key composed by product (freight load) characteristics and requirements.

BASIC DATA	
Partner_Role	Buyer
Auction_Type	Vickrey
....	...

BUYER INPUT		
Parameter	**Optional / Mandatory**	**Visible to Bidders (Y/N)**
Duration	Mandatory	Y
Reserve_Price	Optional	Y/N
....	....	...

PREDEFINED PARAMETERS	
# Bids / Bidder	1
Winning_Bid	2nd lowest
Bid_Visibility (during auction)	NO
....	...

Figure 6.13: *Auction Customizing Sequence*

The corresponding input screen is shown in Figure 6.14.

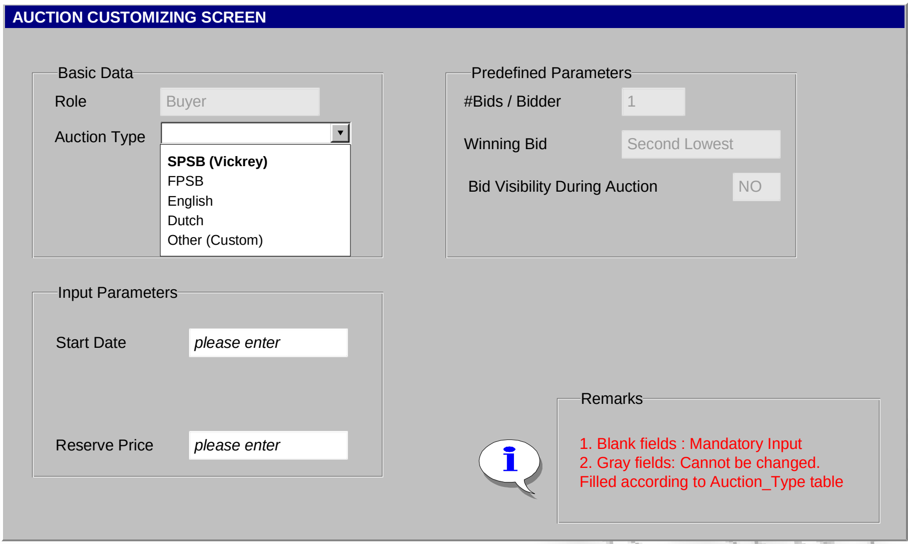

Figure 6.14: *Auction Customizing Screen*

Any registered participant may access specific services via a Web client as shown in corresponding Use-Case UML diagram (Figure 6.15).

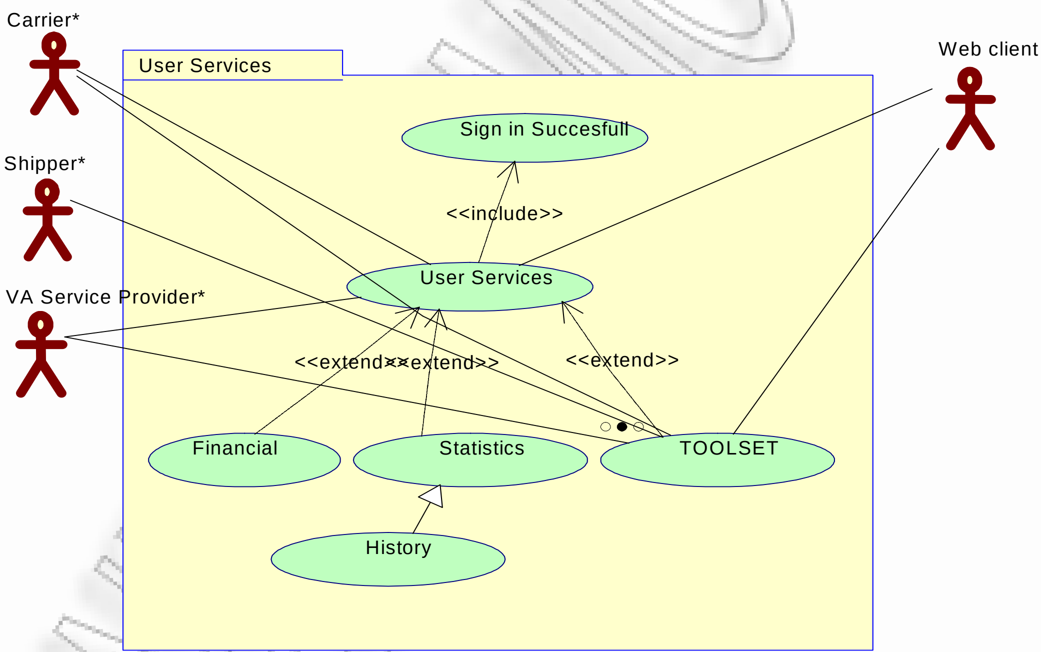

Figure 6.15: *Marketplace Services*

Except of freight service trading via auctions, the proposed e-marketplace also serves as a platform where partners communicate, search, negotiate, retrieve information, etc. (Figure 6.16). For example, the marketplace may provide additional value-added services like: (i) Links to other web sites of interest; (ii) A Search Engine to retrieve information related to freight and logistics services, (iii) a Chat Service for private communication between partners supporting for example direct trading or private negotiations, (iv) an E-mail account, (v) a Document Library serving as a knowledge base for participants, (vi) a Computer-Based Training service to strengthen participants' familiarity with marketplace operations, and (vii) Application Service Providers' (ASP) supporting participants to outsource their data processing operations.

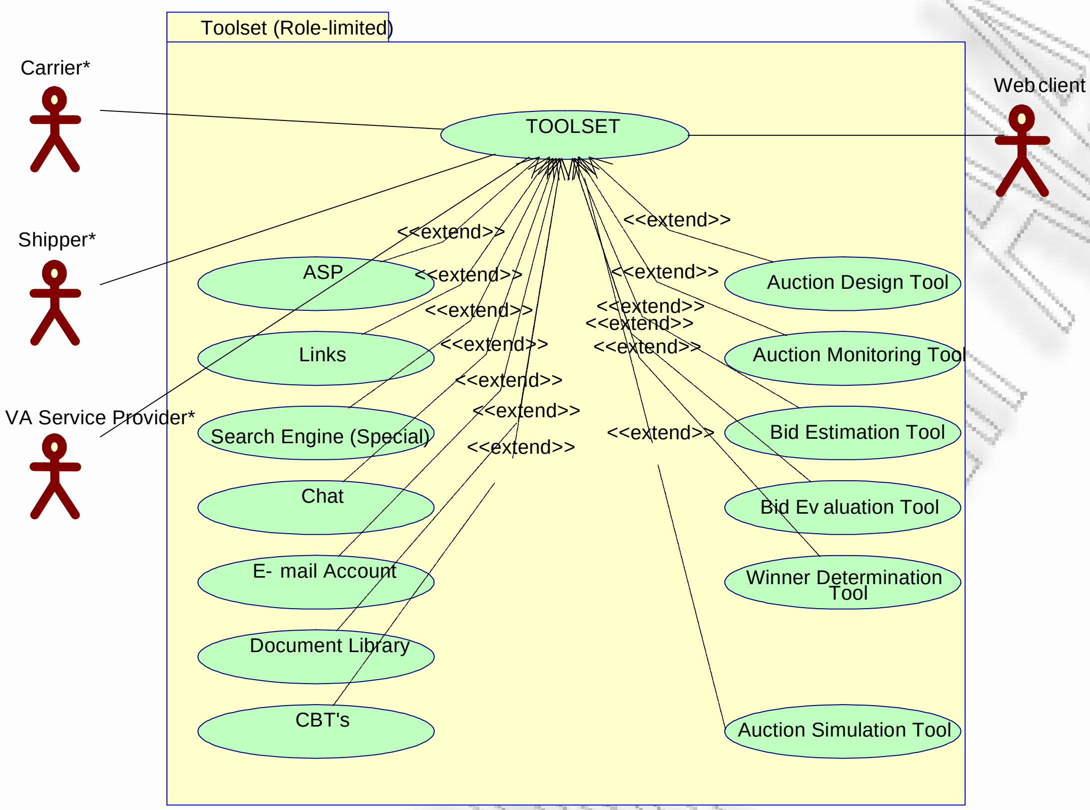

Figure 6.16: *Service Toolset – Use-Case Model*

.3 *A Generic Architecture*

Information concerning vehicles' location is of special interest for freight business for many reasons: a shipper increases his information about carriers' value; he also uses this information to announce his transportation needs to a special geographically defined segment of carriers in order to reduce communication costs and computational complexity. On the forward type of auction carriers are able to offer their services to partners (e.g., shippers, load consolidators, other carriers, etc.) located in a certain geographical area. This Use Case extends the e-Marketplace proposed in Use Case 1 to support the freight transport services trading via m-auctions and e-auctions as a multi-access system for mobile and static participants. The system proposed in this section aims to overcome static (spatial) nature of web-based applications bridging the market opportunities gap between static and moving carriers by exploiting mobile communications and merging heterogeneous networks.

It also attempts to combine the domains of m-commerce and LBS into an auction-based marketplace for the trade of freight transport services. As far as we know it is a novel application and business case.

This section describes in detail the proposed system for the reverse auction case. The innovative characteristic of the proposed marketplace is that it integrates an independent Location-Based Services (LBS) provider into it, to provide real-time information about carriers' current location before, during and after the auction process. In this marketplace a shipper (buyer) offers a tender to invited carriers (suppliers) who bid in a reverse auction to win the transportation contract at the lowest price in a very short time span of hours or minutes.

The scenario examined here refers to the simple case where a shipper invites multiple LTL carriers via mobile communications to submit a single sealed bid. Development of LBS requires extensive modeling of four types of entities (Jiang and Yao, 2006): users and their needs (types, devices, interests, behaviors), location (georeference system, World Geodetic System, symbolic models, address), context (location, environment, identity, and time) and geospatial data processing (visualization, query processing). The core idea of the proposed location-aware system is that it aims to locate potential participants (carriers) movement in a specific-interest geographical area, inform them via a message and continue to an auction with them. It may serve many freight transport trading situations simple or more complex.

- <u>Situation 1 - Carrier located in Logistics Center</u>

Eligible carriers are only those having available capacity more than required capacity ($C_{avail} > C_{req}$). LBS does not apply here (

Figure 6.17).

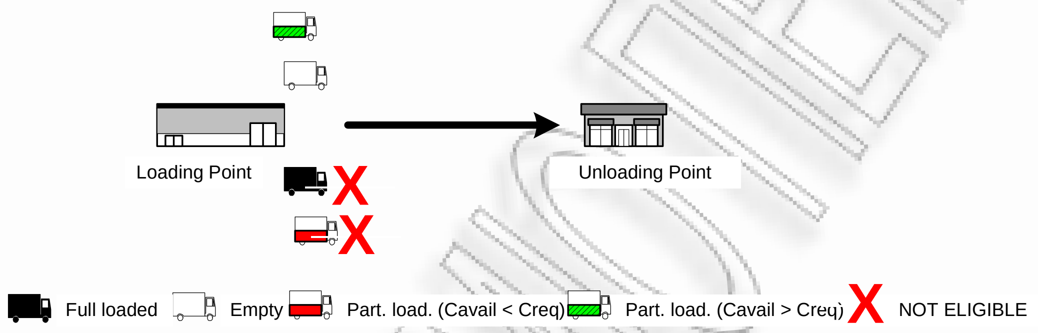

Figure 6.17: *Freight Situation 1: Carriers Located in Logistics Center*

- <u>Situathion 2 - Carriers on the move</u>

Eligible carriers are only those having available capacity more than required capacity ($C_{avail} > C_{req}$). LBS is used to find carriers location, direction and speed. Eligible carriers are those within a certain distance from loading point and those heading for loading point following a route to unloading point with a minimum speed (Figure 6.18).

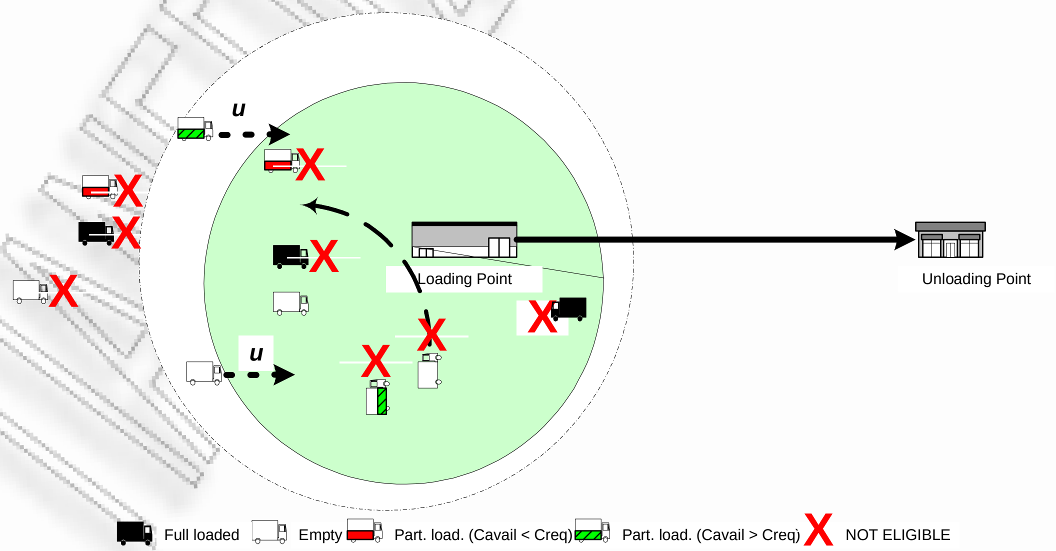

Figure 6.18: *Freight Situation 2: Carriers On-the-move*

- <u>Situation 3 - Carrier searching for subcontractors due to legal limitations (e.g., license) and auctioning contract from a transshipment place</u>

Here the carrier acts as a buyer. Eligible carriers are only those having available capacity more than required capacity ($C_{avail} > C_{req}$) located. Additionally, eligible carriers are those within a certain distance from transshipment location and those heading for transshipment location following a route to unloading point with a minimum speed (Figure 6.19).

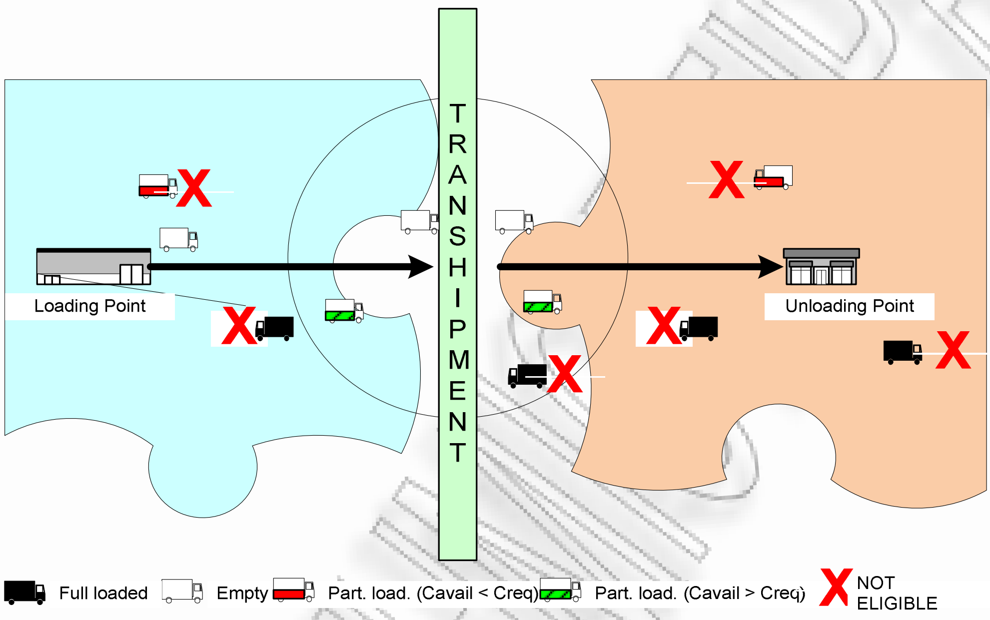

Figure 6.19: *Freight Situation 3: Carriers Acting as Subcontractors*

Additionally, proposed technology offers a range of possible non trade-related applications for carriers, depending on the architecture used (Table 6.9).

Service	User	Application
Where am I now	Carrier	Positioning
Following	Shipper	Tracking
How can I get there	Carrier	Routing
Where is nearest logistics centre	Carrier	Business offer discovery
Where are nearest LTL trucks	Carrier / Shipper	Service discovery / advertising Transhipment / Co-operation
Call 112	Carrier	Emergency case

Table 6.9: *Other Non-Price Negotiable Services*

.4 *Communication Flow and Volume of Data*

The generic architecture of the marketplace is the same like the one presented in Figure 6.9. The marketplace utilizes LBS before the auction execution to locate potential carriers' spatial state (location, direction and speed). Based on these dimensions the system announces the auction to subscribed trucks located within an area defined by an arc and trucks moving towards the boundary of the arc with a minimum speed.

The software-centric presentation of the complete auction process is based on the Session Auction Model proposed by Shih et al, (2005). The system employs three agent types (buyer, auctioneer, seller) and six transactional sessions (Table 6.10) which here are: Connection

Session (buyer send message to auctioneer requesting auction and describing the item and it's attributes), Call Session (buyer agent send multicast message to discover sellers able to offer desired item), Designation Session (buyer selects sellers' agents to negotiate with), Auction (a copy of seller's agent is sent to buyer agent to execute the auction process), Evaluation (decision making for winner determination, allocation and payment) and Conclusion (end of process).

Session	**Steps**
Connection Session	1-5
Call Session	6-11
Designation Session	12-13
Auction Session	14-15
Evaluation Session	16-18
Conclusion Session	19-21

Table 6.10: *Mobile Auction Session Model*

Efficient integration between marketplace and LBS requires the presence of mobile communication devices (e.g., mobile phone) and location sensing equipment (for the case studied here, GPS). Minimum requirements consist of simultaneous data transmission, continuous connectivity, user interface generic design for most devices' display size and type, identification and authentication. The design of the LBS should take into account the following factors (Varshney, 2003): (i) location accuracy, (ii) response time and priority, (iii) network coverage, (iv) number of devices involved, (v) wireless dependability and reliability, (vi) type of communications, (vii) number of location queries per transaction, and (viii) frequency and duration of transactions. The detailed data workflow model that has been previously developed as a UML sequence diagram to control the overall process and estimate the data volume is the one presented in Figure 6.10.

Based on this workflow model, Emiris et al., (2007) estimated the expected communication requirements for a given usual transport scenario showing that the required bandwidth for the overall process is commercially efficient and viable.

.5 *Expansion of the Model*

The proposed model (Figure 6.20) incorporates a new entity – that of the LBS provider that collects and transmits registered carriers' spatial information to interested shipper. The auction initiator (shipper) search for carriers then filters the set of potential carriers and selects a subset of carriers satisfying specific spatial attributes. Then the system sends SMS to this subset of carriers asking for participation. Interested bidders data are temporary stored in a Short List which checks eligibility during the bidding process and after that. After the auction ends, winner and losers are notified via an SMS. During the transport a shipper is able to monitor her freight using a relevant LBS service. The system then sends this tracking data to the Settlement System for billing and future reference (eligibility checks).

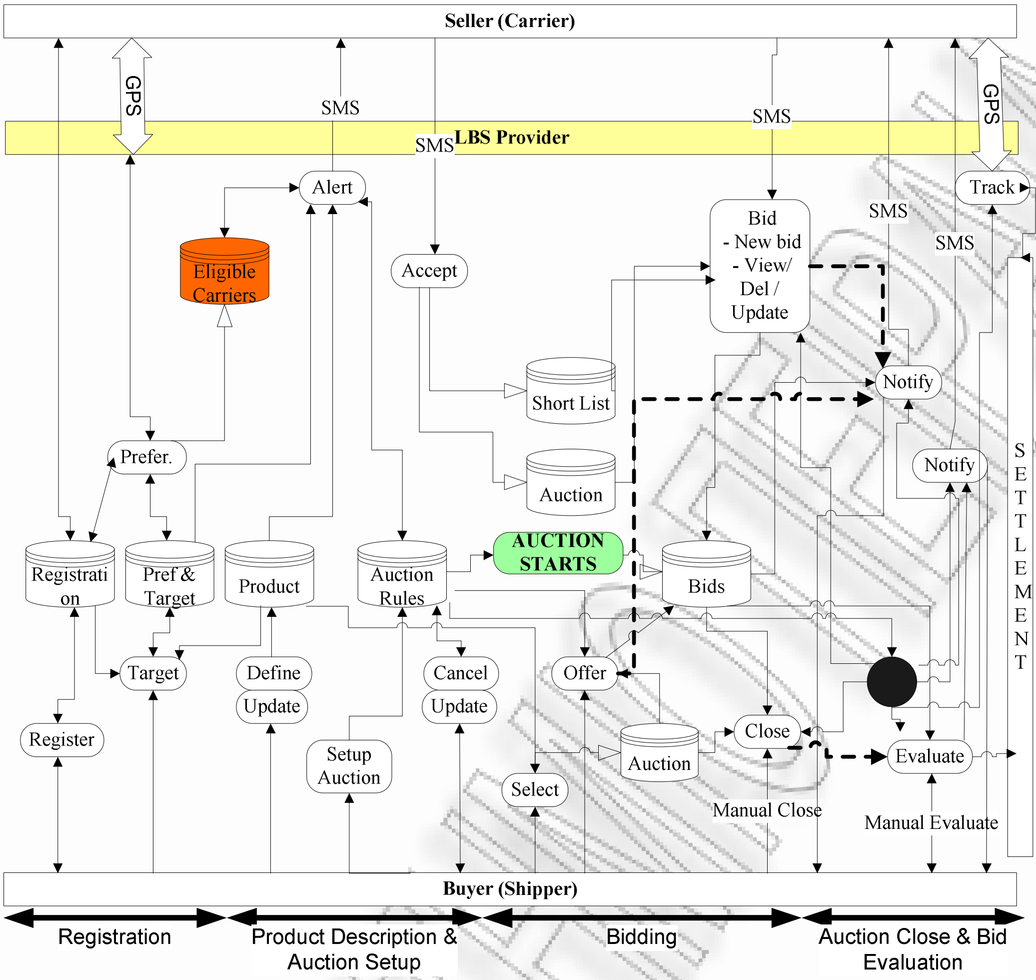

Figure 6.20: *Model Modification: LBS-Reverse m-auction for Freight Transport Procurement*

In a combined use of m- and e- trade, mobile users compared to wired users are not competitive enough due to mobile communications' shortcomings (bandwidth, latency, connection stability, etc.). These characteristics create multicast-related asymmetries and affect fairness negatively. Yet, equality between m-users is insecure for the same reasons. To overcome this problem the proposed system incorporates a set of two mobile communicating agents – one for each trading side - which collects and stores the information sent by participants during the auction and transfers it to web-servers (Figure 6.21) and vice-versa.

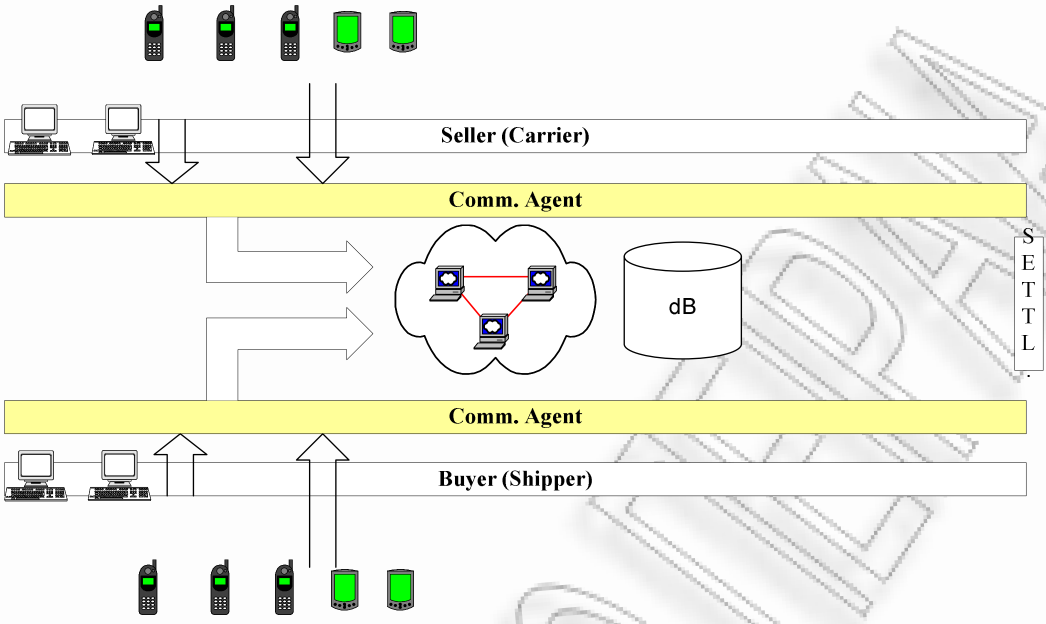

Figure 6.21: *Incorporation of Communication Agents*

The two proposed models (e- and LBS m-) may be easily merged to support both mobile and web- users, being TL, LTL, loading-point based (e.g., Logistics Center) or On-the-move.

.6 *Auction Mechanism and Bandwidth Consumption*

As an example, the proposed auction mechanism parameters are enumerated in Table 6.11.

Parameter	**Value**
Auction type	Second-price sealed-bid (Vickrey)
Auction format	Reverse
Duration	Predefined
Reserve price	Winning bid <= market price
Number of bidders	• Subscribed • f(distance, heading, velocity) + tolerance
Entry fee	0
Cost of bidding	• # SMS (€) • Participation Acceptance, bid, contract acceptance (winner only)
Immediate sell option	Yes in market price
Bidder subsidizing	SMS cost for weak bidders (e.g., individuals)
Evaluation Criterion	Price
Winner determination and announcement	Instantly

Table 6.11: *Auction Mechanism Parameters*

The auction type proposed in the current case is the second-price sealed-bid (Vickrey auction) auction type for two reasons related to operational and efficiency properties: (i) bids submitted by mobile devices are sealed, and (ii) being an one-shot auction type it has predefined duration, it may be short in time, and winner determination is relatively easy.

Concerning efficiency, in the Vickrey auction the winner is the carrier who submitted the lowest bid and her revenue equals the second losing bid (reverse type). Vickrey (1961) showed that bidders' optimal strategy in 2nd price sealed-bid auctions is to bid their actual cost. If the bid exceeds bidder's marginal cost the probability of winning will decrease without affecting the payment because the 2nd price does not depend on the winner. It is obvious that a bidder loses if the bid is lower than his marginal cost. As a result, it is strategy-proof and allocates items optimally. It makes untruthful bidding meaningless and allocates the load to the (rational) carrier with lower cost regardless if her belief of other carriers cost. Since it provides incentives for truthful bidding there is no need for much iteration, complex strategies and enhanced security parameters (Table 6.12).

Auction type	Communication Complexity	Dominant Strategy	Optimal Allocation
English	Multi-round	Yes	Yes
Dutch	Multi-round	No	No
First-price sealed-bid	One round	No	No
Second-price sealed-bid (Vickrey)	One round	Yes	Yes

Table 6.12: *Auction Type Comparison*

For the case described here bidding behavior depends heavily on a set of special parameters which affect intensity and aggressiveness (Table 6.13):

Bidding behavior parameter	Trend	Effect on intensity and aggressiveness
Available Capacity	▲	▲
Distance	▼	▲
Auction Closing Time	▼	▲
Cost	▲	▼

Table 6.13: *Carriers' Bidding Behavior*

By default, a Vickrey auction has a predefined closing time. For the case studied here, actual closing time is depends on each truck location; when a truck passes by the loading point, the auction closes for it. So actual duration is subjective and different for each bidder, depends on location and velocity and it may be less than the announced auction duration. Obviously a sealed-bid auction has the minimum number of bids – one from each bidder. Emiris et al., (2007) have estimated the expected communication load for the case described above when mobile communications are done via SMS (See Use Case 1 in section 6.3.2). They show that with a minimum number of 8 SMS for each shipper – carrier transaction the m-marketplace is commercially viable. The auction parameters used are shown in Table 6.14.

Parameter	Value	Multiplier
Auction Type	Vickrey (2nd price, sealed bid)	
Number of Shippers	1	
Number of Carrier (Individuals)	#	C_i
Number of Carrier (Companies)	#	C_n (=f(C_i))
Number of Bidding Rounds	#	BR_n
Number of Location Requests	#	$LR_n = BR_n$
Number of bid dimensions	#	1

Table 6.14: *Auction Communication Load Parameters*

The Initial Communication Traffic (ICT) can be calculated as follows:

$$ICT = (N_{carriers} \text{ X DropOff\% X Particip\%) X LocPosReqfreq X MessageSize X NumbOfMessages}$$

For the case studied herein, location search and update frequency is a critical issue as trucks outside the pre-specified area may enter the geographic area of interest in some minutes, so frequency depends on velocity and heading of the truck. So the question is how to give quick response to query related to potential participants' location (e.g., which subscribers are located in a radius of 70 Km from the Distribution Center and are moving to the South?). A novel query solution method has been proposed by Wu et al., (2005).

For an overview of spatial queries see Brimicombe and Li (2006). Adopting Choi and Tekinay's (2003) formulation, the optimal frequency for updates is:

LocPosReqfreq = TruckSpeed / Size of Area

Typically the velocity of a vehicle is not constant but it is convenient to acknowledge the road's speed limit. Of course, with the use of technologies like GPS the average speed can easily be estimated. Any auction mechanism should ensure fairness; In a Vickrey auction, auctioneer has to announce second price (winner has no doubt about the amount she has to pay) and keep private losers; bids. In the proposed system auctioneer informs all bidders about their bid status immediately after the winner determination.

6.3.4 Use Case 3: Automated Multi-attribute Bid Evaluation

.1 Problem Overview and Multi-attribute Auctions

Procurement of freight transportation services is a critical and costly procedure in Supply Chain Management strongly affecting overall cost, efficiency and customer service level. From a technological point of view, it offers an extremely interesting field for the application of modern research findings and innovations in Information and Communication Technology (ICT); moreover, it serves as an extended landscape for the deployment of combined research disciplines from many scientific areas. The proposed scheme in this Use Case deals with innovative applications of Location Based Services (LBS) in auction-based freight transport procurement and control, focusing on evaluation and selection of supplier of freight transport service (carrier) based on spatial and temporal characteristics. It describes how the proposed auction architecture reduces bidding complexity by converting a multi-attribute auction process to a single-attribute bidding auction.

An auction type where the winning bid depends on more than one attributes (except from price) is called a multi-attribute auction and the evaluation of bids usually results from a scoring rule (or scoring function) that transforms attributes values to a total score. A typical scoring rule is the weighted scoring function which for an auction with *j* bids evaluated based on *n* attributes x_i^j (i=1,…,n) takes the form:

$$S(x_j) = \sum_{i=1}^{n} w_i S_i(x_i^j) \quad \text{and} \quad \sum_{i=1}^{n} w_i = 1$$

where w_i is the weight for the attribute x_i^j in bid j, $S_i(x_i^j)$ is the score for this criterion in bid j and $\mathbf{x}_j$ is the iX1 vector that contains the distinct attributes for bid j.

.2 Introducing LBS to Automate Bidding Process

Conceptually, the marketplace described in this Use Case operates on the basis of a reverse multi-attribute second-price sealed-bid auction evolving in a mobile environment where auction announcement, bidding process and communication between participants is done over mobile network. This section assumes two types of participants; a) Shippers (buyers of freight transport services) submit requests aiming to buy transport services in prices lower than the market price and b) Less-Than-Truckload (LTL) or Empty-Trip Truckload (0-TL) Carriers (sellers of freight transport services) submit single multi-attribute bids aiming to create revenue from unused capacity by winning the transport contract. The marketplace integrates wireless networking and automatic position sensing (GPS) to formate an extended LBS-based auction infrastructure (Figure 6.22) offering three core marketplace and auction-related services, namely: screening, scoring and tracking.

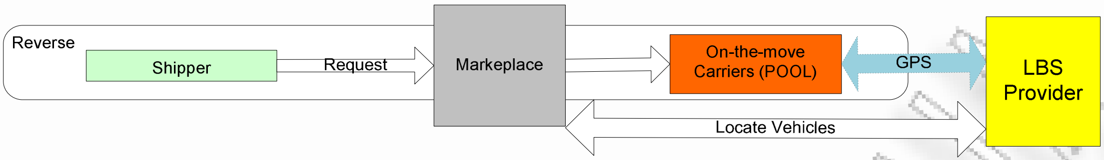

Figure 6.22: *Architecture of the LBS-Based Auction Marketplace*

This application assumes that the marketplace operates on the basis of a reverse second-price sealed-bid (Vickrey) auction where each bidder (carrier) submits a single bid not visible to rivals and the winner earns the contract collecting the second lowest price from shipper. It is also assumed that bidder's *i* bid (B_i) consists of two parameters, namely the bid price (P_i) and a single attribute, namely the loading time (T_{Li}) as an expression of type: $B_i : Pi \wedge T_{Li}$. Each bid *i* is evaluated as a weighted sum S_i of these two parameters giving a score: $S_i = c_i$ X P_i, where c_i a time of service (loading) coefficient taking values from [0,1]. The coefficient $c_i = u + l_i$ represents a weight for each bid B_i for its service quality characteristics calculated automatically as a sum of current load's urgency factor *u* (subjective or fuzzy constant defined by the shipper depending on his infrastructure or logistical parameters like storage capacity, shipment deterioration etc.) taking values from [0.1,0.5] and LBS-based estimation of loading time l_i (depending on bidding carrier's distance from loading point and velocity) taking values from [0,1-l_i]. Adopting Price/Service Trade-off the bid with the minimum Si modifies (actually reduces) the corresponding monetary bid and the winning carrier receives payment equal to the next higher bid as shown in the example of Table 6.15.

P_i (€)	u	l_i	$C_i = u + l_i$	$S_i = c_i$ X P_i	Trade-off	Modified Bid (€)
100	0.3	0.2	0.5	50		100
120	0.3	0.3	0.6	72		120
140	0.3	0.5	0.8	112		140
120	0.3	0.1	0.4	**48**	120-48 = 72	**72**
90	0.3	0.7	1	90		90 (Payment)

Table 6.15: *An Example of Price/Service Trade-off*

The LBS architecture proposed in this section simplifies the bidding process by allowing bidders to submit only monetary bids instead of submitting complex bids consisting of price and loading time. LBS infrastructure receives each carrier's spatial characteristics (location, heading and velocity) and calculates l_i as the ratio $l_i = d_i/v_i$ at the time of bidding where d_i is the distance from loading point and v_i is vehicle's velocity.

6.4 Application 3: Using l-auction Complementary to Revenue Management (RM) in Freight Transportation Services

Revenue Management (RM) (also known as Yield Management in the airline industry) has been widely adopted by companies worldwide as a means to coordinate efficiently sales and demand and increase profitability. It deals with questions like: how to sell (negotiations, posted prices, auctions), which products to sell (individual, bundles), how to segment customers or markets, how to set prices, how to deal with time, how much to discount, how much to sell, how to find winner(s), how to define the price etc. The key driver for the price formation is the asymmetries between buyers (information and valuation). This leads to a multi-dimensional problem of finding the best price for demand patterns related to individuals or specific sets of customer/groups, product/bundle, time/period. During the last decade many service companies moved along these lines and engaged new sophisticated techniques to better utilize current and future available capacity and maximize their earnings. At the same time, the evolution of commercial Internet applications leveraged the accessibility to markets and intensified competition in terms of time, cost, geographical coverage and responsiveness to demand variability.

In the freight transportation industry, from a shipper's perspective, buying services in advance is a tool to ensure availability of capacity, to treat uncertainties related to future demand, price fluctuations and also to establish contracts ensuring lower transactional costs and lower prices. On the other hand, carriers offer their services in advance aiming to plan effectively and utilize their available capacity, make better forecasts with the use of actual data and identify and respond to different market segments. Recent advances in Information and Communication Technologies (ICT) provided a set of tools to better extract and utilize real-time information on carriers' spatial and temporal characteristics which is fundamental for the Logistics and Supply Chain Management domain.

6.4.1 Overview of RM

Revenue Management (RM) (or "yield management") aims to maximize revenue by matching customer demand with available inventory/capacity of products or services, respectively, through a price alteration mechanism based on time of demand and offering. The present section adopts a slightly modified definition of RM proposed by Kimes (1989) according to which RM "*is a method (or set of methods) which can help a firm sell the right inventory/capacity to the right type of customer, at the right time, and for the right price*". Chase and Apte (2007) recognized yield management as one of the "*big ideas*" in the research of service operations, especially for small- and medium-sized capacity constrained firms to determine how much of each type of inventory to allocate to different types of demand. The most prevalent and common characteristics of revenue management systems (such as, *discrete units of resource, fixed capacity, predetermined prices, buildup willingness to pay, one discount price class, mixed reservation demand, certain show-up of the discount reservation, no group reservations, no diversion effects, no displacement effects, no bumping procedure, a nested asset control mechanism and a simple static decision rule*) have been gathered in a taxonomy scheme by Bodily and Weatherford (1995).

The evolution of ICT pushed the rapid growth and adoption of RM systems because they increased the available data related to actual demand and customers' behavior, they facilitated the change of prices at almost any time and they offered decision-support tools to analyze and forecast demand (Elmaghraby and Keskinocak, 2003b); furthermore, they enabled last-minute offerings and they supported the collection of ample reliable data required for the formation of an RM policy, thus increasing their efficiency and reducing information asymmetry between buyers. Srivastava (2001) proposed such a practical dynamic pricing design methodology in the context of e-business; in her assessment framework she focused on the objectives served through new market channels which namely, are: pricing to create new markets (reverse auctions), pricing perishable goods and maximize customer value extraction (yield management) and pricing for fragmented markets and creating limited time buying opportunities (demand aggregation).

Freight services are proper for the application of RM systems since they possess many of the attributes that render them attractive (discussed in more detail later). Chiang et al., (2007) however, showed that for applications of RM in the freight cargo industry (besides air cargo) there were only five research articles at that time; Moreover, literature on RM for supply-chain freight transportation operations is relatively limited compared to the literature focusing on RM for services in the travel business (hospitality, travel, car rental etc.). Even in the case where these areas use similar means of transport (e.g., civil aircrafts), they exhibit many differences. Bartodziej et al., (2007), for example, stressed the fact that the literature on air-freight RM is very limited compared to passenger airlines and demonstrated that models developed for passenger air transportation revenue management cannot directly apply in air cargo. Berman, (2005) summarized the services that are well-fit for RM systems (amongst which are freight transport services) and highlighted the classes of proper service attributes for application of RM, namely, *demand characteristics* (periodic variations of demand, e.g., daily, weekly or monthly, demand that can be segmented, differences in price elasticity by market segment), *existence of reservations* (improved demand predictability, differences on reservation times, overbooking), *cost characteristics* (e.g., low costs of marginal sales compared to marginal revenues, high fixed costs) and *capacity limits* (relatively fixed capacity, excess capacity in certain times, perishability).

The freight transportation industry fulfills the core RM requirements, as typical transportation firms manage a fixed fleet capacity, which is perishable at the moment of truck departure, the customers (shippers) may book and the firm may sell in advance, respectively, the shippers' demand is stochastic and they can be segmented, while carriers may use historical data to forecast future demand. In a similar fashion, overnight shipping and package discounting for low-priority cargo are areas where RM systems may apply. In the recent years, primarily due to the explosion of the internet, the RM in general is undergoing a major conceptual shift especially in the B2C case, where segmentation is not always apparent and offerings move on a lower price spectrum. Weatherford (1997) examined the application of RM in perishable assets, where the mean demand for a price class depends on the price itself as well as on the neighboring price classes (this is termed “cross-elasticity”), claiming that this is a typical case for many firms in the transportation industry. The particular attributes of freight services (some of which appear also in other market segments) under the prism of RM are:

- ***Pricing***: Market prices for a single trip, expressed in monetary value, fall in a range depending primarily on the volume (or weight) and the distance and secondarily by the type of trip (Full Truck Load (FTL) vs. Less Than Truck Load (LTL) and the requirements for license type (local, national, international). There also exist additional pricing techniques, such as: price segmentation for different classes of shippers based on the volume, price segmentation for different booking periods, low price patterns for trips for the movement of an empty truck to a loading site (*repositioning trips*), and custom prices for urgent shipments (e.g., for express logistics/courier companies).
- **Fixed capacity**: Although the starting point for a freight company is that capacity is fixed, the capacity may occasionally be altered by adding or removing trucks in a route. Increasing the capacity is feasible in freight transportation even though it incurs high costs, (although not as high as in the airline industry where capacity increase is far more complicated and often unfeasible). The case of excess demand is tackled by either distributing excess demand to future routes or by outsourcing an entire itinerary, or by leasing third-party trucks to adjust capacity; overbooking is usually not adopted.
- ***Perishable capacity***: The capacity of trucks is not storable and has no (or little) value once the truck departs. This may be relaxed in some degree for itineraries with multiple stops.
- ***Network effects***: A carrier may have to select from a set of requests in order to find the best itinerary in terms of profit, duration and distance traveled. The problem becomes even harder when the carrier is able to negotiate on pickup and delivery time windows and sequence with the shippers. In the case of long-distance trips, the carrier may be able to cooperate with other carriers developing subsequent trip "legs" aiming to minimize repositioning trips.
- ***Advance sales***: In time-sensitive markets where nominal prices increase as the time to service decreases, early-bookers are typically capacity- and price-sensitive, while late-bookers are, in general, capacity-, and possibly price-, insensitive. Late-shippers usually appear because the planned trip schedules may change for a number of reasons like no-shows (less frequent), cancellations or late deliveries. Applying fees or penalties for such anomalies is avoided because this may negatively affect B2B relationships.

- ***Low marginal cost***: The cost of pickup and transportation of a freight unit is very low compared to the high fixed cost (for example) for acquiring or hiring an additional truck.
- ***Demand fluctuation***: Demand is hardly known in advance, with the exception of seasonal patterns. The variety of the type of services, which may be standard (truck type, day, departure time), flexible (truck types, days, departure from-to), fuzzy (payload, "morning", "noon") or stochastic (depending on previous arrival), further complicates the task of forecasting the demand and adds new dimensions to this problem. In that sense, RM may be employed to shape high prices in periods of high demand and vice-versa while trying to increase capacity utilization.
- ***Market segmentation***: The freight market is segmented both in terms of price and capacity; however, nesting policies are not popular in road freight transportation. Additionally, freight transportation is also geographically segmented in the sense that traffic is *asymmetric*: for a carrier, outbound traffic usually differs totally from the inbound traffic, creating capacity utilization problems during the repositioning/ returning to depot trips.

6.4.2 Auctions in the RM Context

The relation and combined use of auctions and RM techniques has been given special attention by researchers during the past decade. Simon and Butscher (2001) claim that simple auctions are the best strategy since the customers pay exactly the maximum amount they aim to spend for a good or service – conceptually defined as *Willingness to Pay (WTP)*; when the customers' population is efficiently large, auctions ideally extract the customers' prospective WTP. Baker and Murthy (2002) examined the combined use of auctions and fixed pricing in RM and proposed a hybrid model supporting the simultaneous use of fixed pricing and auction-based pricing with a reserve price (minimum or maximum acceptable price) allowing potential buyers to use either of the pricing methods and losing bidders to buy the asset through the fixed price market. They compared these models through a series of scenarios finding that the hybrid model outperforms the pure auction and fixed price model. Later, Baker and Murthy (2004) examined how auctions may support RM in highly-segmented markets like airlines. They examine four RM strategies combining time-dependent auction and fixed-price techniques in two different time segments, namely, early and late segment (auction-auction, fixed-auction, auction-fixed and fixed-fixed), finding that in most cases, applying auctions in late segments is a more efficient combination.

Talluri and Van Ryzin (2005) describe the relevance between auctions and RM and claim that auctions require less information about customers than any other pricing format allowing *first-degree price discrimination*, that is, they reveal the customers' WTP; furthermore, they state that in auctions prices are typically defined by the buyers, so auctions operate as direct *price discovery* mechanisms in a sense that prices adapt to market conditions. Chiang et al., (2007) classify auctions as one special category of RM problems along with other interrelated areas, namely, pricing, capacity/inventory control, overbooking and forecasting. They examine auctions separately from pricing problems, in order to emphasize their importance in future RM applications and present previous research efforts in the application of auctions in RM. They find that such efforts are limited and are primarily focused on the design of auction mechanisms as a substitute for typical RM models. They claim that future research should focus on how to integrate auctions in pricing strategies, and on the prerequisites for their effectiveness. Finally, Müller-Bungart (2007) stated that dynamic pricing and auctions are two major pricing methods used to influence demand. Although auctions offer less price control, they are an ideal method to make customers reveal their WTP; nevertheless, price control in auctions may be enhanced by injecting specific parameters in the mechanism, such as, reserve/buy price, evaluation of qualitative attributes, etc.

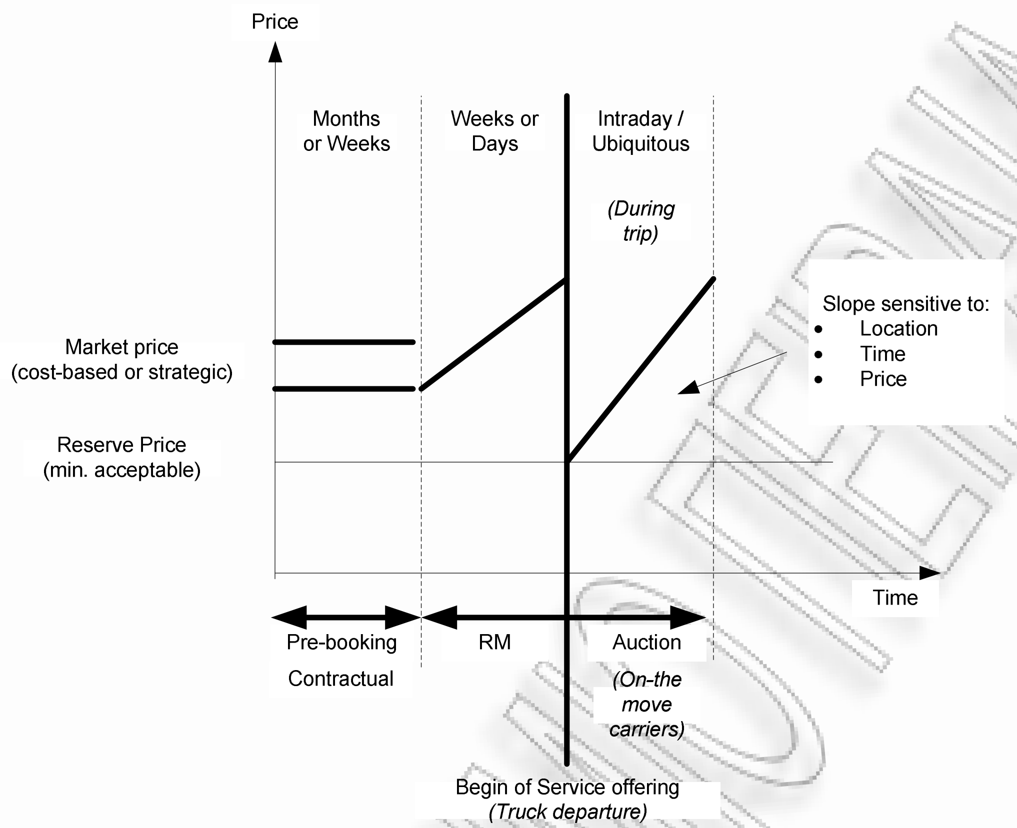

Figure 6.23: *Pricing Strategy Timeframe*

It has become evident from the above works, that under specific (yet realistic) circumstances, auctions may complement and support efficiently RM systems, especially during last-minute offerings, by motivating users to express their true WTP, and by rapidly allocating unused capacity in a price equal or near to the customers' actual WTP.

Figure 6.23 depicts an indicative timeframe for the application of auctions, which are used to enhance the overall pricing system allowing management of demand for time-critical services in a last-minute timeframe or even during the service execution. In this figure, we observe that in the long term past periods which may extend from months to weeks before the service offering, the market price is typically fixed and defined according to the cost structure of the offered service or based on the strategic intentions of the service provider. In this phase, buyers can pre-book the service signing a contract aiming to minimizing risks related to service or capacity availability at the desired time. During the mid-term period which ranges from several days until the previous day of the service execution, typical RM strategies apply. In this period, the service provider alters the price using a predefined RM strategy scheme.

The present section proposes that after the beginning of the service offering (which in the freight transport case means that a truck has already begun its itinerary and is on-the-move), a mobile auction may be used to allow the trading of the service in real-time as an intraday ubiquitous trading instance. Since this process aims to trade unused capacity, the minimum acceptable price shown in the right-most area of the figure may be even below actual cost. In that case, the evolution of the price relates mostly to temporal and spatial attributes of the moving truck, for example, the location, the estimated time to load, etc.

The words in italics are application-specific and pertain to a freight transportation context. Auction mechanism parameters (e.g., reserve price) and market (or bidder)-related information are used to control price evolution.

6.4.3 Application Instance

This chapter focuses on applications that involve a logistics center (LC) that receives dispatch orders from shippers and assigns them to contractual freight truck carriers located in the LC (using LC as depot) and/or trucks moving through the LC for loading and unloading. The assignment is the result of an auction process, variations of which are presented in the sequel. The LC thus operates as a public electronic marketplace acting as a market moderator and auction initiator and has the role of freight brokerage integrator between shippers and carriers. The LC serves three types of shippers, namely, key accounts, ad-hoc, and last-minute, each characterized by a set of attributes (Table 6.16).

ATTRIBUTES	SHIPPER TYPE		
	Key accounts	**Ad hoc**	**Last minute**
Contract	Long-term	Trip-based	Trip-based
Required capacity	Fixed predefined	Variable	Variable
Trip	Predefined trips	Variable	Variable
Frequency	Fixed predefined	Variable	Variable
Price	Fixed predefined	Early booking	Negotiated
Pricing strategy	Market spot price, cost-based or strategic pricing	RM techniques, demand-based, defined by LC	Auction, WTP

Table 6.16: *Types and Attributes of Shippers*

The available capacity of carriers is first disposed to the key accounts' shipment needs. The demand from ad-hoc and last minute shippers serves as the driver for utilization of spare or remaining capacity (expressed as available remaining loading space, weight or loading units or combinations between them), subject to time (departure, arrival) and place (loading site / unloading site) specifications, that form an *itinerary*. Obviously, the capacity is a *perishable asset (PA)* since its value becomes zero if it remains unsold after the actual shipment date; for example, the unused capacity of a less-than-truckload (LTL) freight itinerary truck has zero value immediately after the departure time, and is also zero in truckload (TL) return or repositioning trips. If, however, carriers were allowed to participate in dynamic, competitive marketplaces (e.g., through an auction) with a chance to increase the utilization of unsold capacity even when they are on the move, the impact of such problems might be alleviated. This situation is indicated in Figure 1 as the rightmost (Auction – On the move carriers) phase of the capacity allocation process.

The proposed marketplace consists of three participating entities, namely the LC (acting as “auctioneer”), the carriers (acting as “sellers” or “bidders”) and the shippers (acting as “buyers”), involved in a procurement (“reverse”) auction which conforms to the following ground rules:

- There are no different price classes for the same trip (as opposed, for example, to economy and business classes in passenger transportation)
- The auction participation costs are the same for all bidders
- The carriers that have the right to participate have been pre-evaluated for their suitability and their trucks’ capacity is sufficient for auctioned freight
- There are not strategic differences among shippers or among carriers

6.4.4 Adding Mobility and Location Awareness

This section describes the *operational* characteristics of the location-awareness concepts by incorporating mobile communication networks in the marketplace infrastructure. It deals with technologies to locate on-the-move carriers and modify auction mechanism properties according to each carrier’s spatial data.

The effectiveness of auction-based methods can further be enhanced if temporal and spatial attributes of the service and/or the customer are taken into account. The communications infrastructure and related tools thus play a vital role in conveying this information and enabling the interaction between the interested parties in near-real time. Furthermore, the knowledge of the actual position of a carrier and consequently the estimation of the arrival time for loading may prove beneficial for both stakeholders supporting time-critical operations; from a logistics management perspective, a shipper may plan the use of loading docks and equipment more efficiently while carriers may be able to load immediately after their arrival at the loading site thereby minimizing dwell time. The illustrated architecture is time-efficient, enables geographically-related interested carriers express their WTP, and may be used irrespectively of other pricing techniques which may be perceived as unfair or are inefficient for last-moment booking.

The abstract model of the proposed marketplace is shown in Figure 6.24. The LC receives shipping requests from shippers (Step 1). Each request contains information about the shipment characteristics, the loading time, the destination place and time and the auction price range. The LC sends a request to a LBS-provider (Step 2) in order to locate and filter-out potential bidders (Steps 3 and 4). The auction is announced to bidders and carried-out over mobile communication services provided by a provider (Step 5). The results of the auction are then announced to shippers (Step 6). Loading time for each carrier is estimated as a function of his current location which can be found using Geographical Positioning System (GPS) in Step 5 iteratively for all auction rounds. Furthermore GPS is used to filter subscribed carriers and announce the auction only to carriers located within a specific geographical area and heading in a certain direction. After the screening process, the LC defines the starting price for each geographical segment, corresponding premiums and the auction mechanism characteristics. The auction is announced and conducted over wireless mobile Internet and conceptually the marketplace is a typical application of Location-Based Services (LBS).

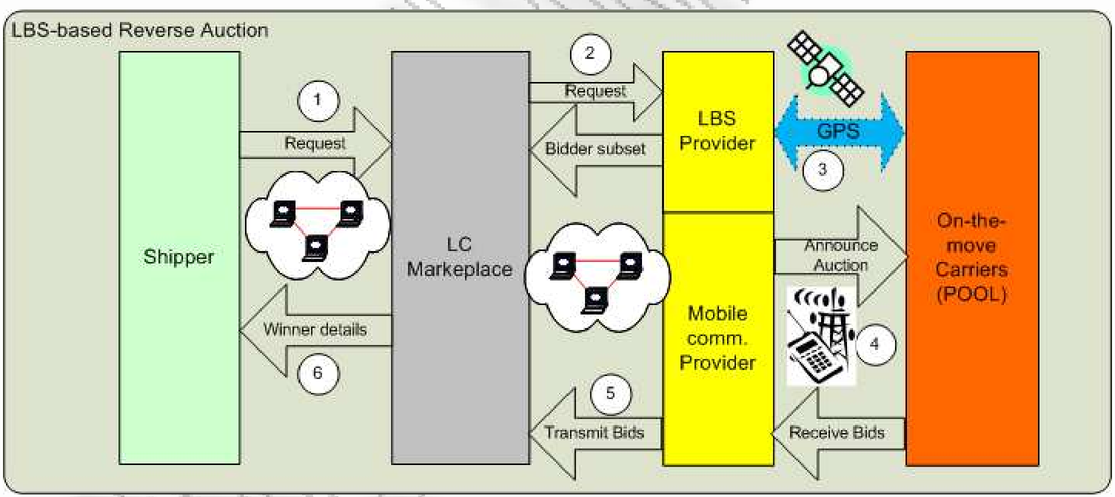

Figure 6.24: *Abstract Model of the LBS-Auction Marketplace*

Importantly, the communication cost is very low (mobile internet). On the one hand, the LC sends messages only to subscribed (and certified for their reliability) carriers. On the other hand, carriers have only to submit their intention (single bid) using a GPS-enabled PDA in both auction mechanisms. Since one carrier submits his intention, the auction ends. Focusing on the bid subsidizing properties of the proposed model, the auctioneer defines a premium amount pattern related to winner's actual location before the auction process. After the completion of the auction, the LC uses LBS to find the actual current location of the winning carrier in order to calculate the premium which will be added to the winning price. An indicative example of the subsidizing pattern applicable in both mechanisms is shown in Figure 6.25.

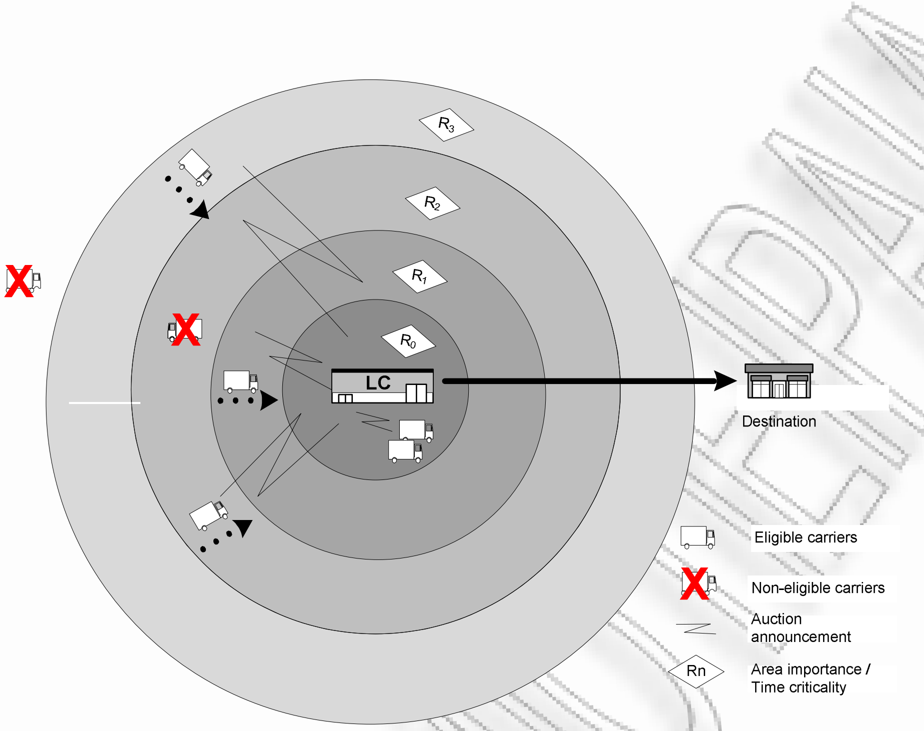

Figure 6.25: *Zone Partitioning for Carriers' Subsidizing*

The area partitioning method in Figure 6 is indicative, and it may be based on other methods as well, such as, geographic regions, demographic data, road network, postal codes, etc., which are easily accessible and available in current commercial Geographical Information Systems (GIS) and geospatial databases. For each bidding carrier, the auctioneer using LBS may estimate the ToS and may discriminate positively the carriers located near (or even in) the LC. This is expressed as a premium *p* which is maximum for carriers located in the LC (area R_0) and purely decreases in more distant regions; that is, $p(R_0) > p(R_1) > p(R_2) > p(R_3)$, etc.

The implementation of m-auctions is prone to technical failures from many different sources. Focusing on the technical requirements for the implementation of any m-auctions, a number of multicasting technical requirements are present. These have been elaborated in Varshney (2005). In summary, the core quality considerations related to technical infrastructure and capabilities that may affect the m-auction implementation are: (i) the elimination of transmission delay, (ii) the maintenance of highest possible transmission rate, and, (iii) the minimization of data loss. A general (yet simplistic) model to describe the probability *p* of successful implementation of an *N*-round auction for a moving bidder *i*, is $p = (1-p_i)^N$, where p_i expresses the probability of failure that may be attributed to the above causes.

Both networking and multicast requirements depend heavily on the morphology of the area a vehicle is moving in. For example, when a truck is moving in an area with tall mountains, it is likely to face low signal strength which deteriorates multicast properties (which of course depends on mobile communication provider's infrastructure). It is reasonable to claim that these shortcomings are more probable to occur if the auction process has a long duration.

6.5 Summary and Conclusions

In this chapter we engaged our previous findings in order to present the conceptual design of some emerging applications in the services area. Specifically, we showed how l-auctions may support the trading of tourism and freight transportation services. In the services area, we also presented how l-auctions may complement typical RM price setting applications. The common denominator in these applications is that they have common decision-making dimensions which are:

- Temporal dimension (“when”)
- Spatial dimension (“where”)
- Formal dimensions (“what” type of service)
- Qualitative dimensions (“how much” – value of attributes)

Focusing on the time-related attributes of the service, we approached the problem from two different viewpoints:

- A “*micro-temporal*” approach: we investigated two heterogeneous applications of l-auctions, one in the logistics services and one in the tourism services. Apart from the different business areas, a core difference is the market context: freight transport marketplaces are mainly B2B markets, while service tourism marketplaces are basically B2C markets. These contexts have several differences; for example, B2B markets are more focused and participants’ behavior is more predictable compared to B2C markets. Another difference is the additional functionalities required; for example, an emerging functionality in B2B markets is the support of collaboration or competition relationships between participants. Further to the above, we believe that the real merit of these applications is that they open several roads for additional functionalities in various time- and location-sensitive markets.
- A “*macro-temporal*” approach: we attempted to integrate l-auctions within a RM pricing practice. More specifically, we presented under what conditions an l-auction policy may enhance the RM-based pricing strategy; furthermore, we indicated that the l-auction applies at the latest stages in pricing strategy time-span aiming to capture last-minute buyers (or sellers in a reverse auction).

The major findings can be summarized as follows:

.1 Tourism Services

Tourism services constitute a promising area for the development of marketplaces based on the application of ICT and mobile communication technologies. Since tourism services entails high degree of mobility, the effectiveness of the marketplace increases when it supports on-the-move market participants for location-aware services subject to participant’s actual (or projected) location using technologies like LBS. The latter introduce benefits for all marketplace participants: additional revenue for mobile and GPS providers, relative, timely and engaging content delivery for buyers and seller and improved market experience.

Our work presented a marketplace which engages LBS and mobile devices to locate on-the-move travelers and offer tourism services according to their locations. The intention of this concept is not to replace existing yield-management and dynamic pricing practices but rather to serve complementarily to revenue management models especially for short or not-continued number of stays. The model can easily apply to a large variety of tourism and hospitality services. From a tourism service provider's point of view, the model allows him to offer unused service capacity through an innovative low-cost channel for geographically-focused and subscription-based customer target group. Although this group seems restricted at a first glance (5-10% of the total potential customer base), it may positively affect service provider's revenue, when for example the provider faces refundable cancellations. Contrary to typical "push" marketing strategies, the proposed model allows the pricing of services using customer's WTP through a simple auction mechanism. From a traveler's side, the proposed model allows him to benefit of last-hour (or even last-minute) offers, by expressing his real WTP without restrictions related to technical infrastructure or presence of a personal computer. The attempt was encouraged by a limited field survey on the attractiveness of the concept.

.2 Freight Transportation Services

In the present work, we also demonstrated the coupling of LBS and m-commerce into auction environments, in order to formulate an m-auction environment for operation in logistics related services. In particular, we examined the case of auctions where several bidders compete to win a freight by offering the lower price. An LBS system is used in conjunction with an appropriate database, to pre-select potential bidders that fulfill a group of criteria, such as appropriate equipment, and which are in a proximity to the freight to be carried. An m-commerce environment is used as the information exchange platform between the auctioneer and the potential bidders. In our study, we outlined the inherent parameters involved and we estimated the potential information load; furthermore, we demonstrated the feasibility of its implementation with common existing infrastructure, as the estimated load is not severe. From a technical point of view, the proposed marketplace combines the properties of different communication networks (internet, mobile and GPS) developing a marketplace model where geographically static and moving members are able to make trade transactions via auctions.

We further modified a previously proposed Internet auction model to support mobile auctions and conduct them on the basis of location-sensitive information. The model integrates location-awareness technology (e.g., GPS) to advertise auction, pre-select market members and monitor after-sales service. The spatial attributes of the marketplace, makes it an ideal platform supporting geographically-dispersed markets of moving traders like the freight transport market. Given that participation via Internet or mobile devices is inexpensive depending only on wireless communication, the marketplace is accessible to carriers of almost any size, with numerous benefits:

- Cost-effective accessibility to small carriers
- Reduction of empty miles (deadheading) and better capacity utilization
- Generation of collaboration or subcontracting opportunities especially for individual carriers to offer adjacent long-haul services independently of their license, or to increase their capacity to win large shipments

We finally described an innovative methodology for the automatic of non-price related attributes of carriers' bids with the use of LBS technology; this methodology is reducing significantly the complexity of bidding and evaluation process.

.3 Revenue Management

Research works on the application of RM methods in the road freight transportation domain are rather limited. The present work comes to contribute by proposing an enhancement of revenue management strategies for freight transportation, through the incorporation of location-sensitive m- auction mechanisms for short-term, last-minute markets, allowing service providers to participate even when on-the-move. In particular, the temporal and functional conditions for the application of m-auctions are identified and the behavior of bidders was evaluated for two distinct auction mechanisms.

The benefits of incorporation of location-related premiums in the evaluation of bids were highlighted and a systemic architecture for implementation of the setting was proposed. The findings of this work show that m-auctions may be an efficient pricing mechanism for perishable assets and can lead to beneficial results for the involved parties; furthermore, when m-auctions are combined with LBS they provide an ideal tool for capturing *time-critical* offers from *on-the-move* bidders and they are efficient for screening bids so as to isolate the ones that are of viable interest. Overall, in the area of RM, the identification of the logic of transition between different pricing methodologies (from fixed pricing to RM pricing and then to auction-based pricing and allocation) forms a research gap which need to be bridged.

Chapter 7

Experimental Study

The conceptual freight marketplace proposed in Chapter 6 [Section 6.4] is used as the basis for a series of behavioral experiments on the evolution and projection of efficiency for these auctions which are strongly integrated in an RM system. The experimental setting and the accompanying analysis breaks new ground in the auction design through behavioral observations which validate a series of hypothesis that concern the bidding behavior related to experience drawn from the experimental setting. This chapter contains material from our published work[9].

This chapter is structured as follows: Section 7.1 presents the concept of bounded rationality as a foundation to justify the need for exploration of participants' behavior during an auction; furthermore, it introduces the relevant emulated business environment and establishes an experimental landscape supporting two reverse auction mechanisms based on modified models of the standard FPSB and the Dutch auction mechanisms, respectively, each offering different amount of market information to participants. The next two Sections (7.2 and 7.3) evaluate the hypotheses set in Section 7.1. Section 7.2 presents and analyses the experimental results focusing mainly on the behavior of market participants (carriers) identifying how their behavior is affected from knowledge and experience gained through the progression of experiments subject to the gradual and controlled revelation of market information. It also summarizes potential benefits and shortcomings from both the carriers' and the shipper's points of view were pinpointed. Section 7.3 discusses outcomes. Section 7.4 provides an overview of the auction experimental tool z-Tree and presents the applications developed for the experimental settings. Finally, Section 7.5 summarizes findings.

[9] Emiris and Marentakis (2011)

7.1 Case Analysis and Auction Setting

Mobile auctions constitute a new, constantly and consistently evolving, digital market instance. Additionally, location sensitive auctions introduce further innovations that enrich the properties of m-auctions. Since this market is still developing, it is anticipated that potential market participants may not be aware of the auction process. This lack of awareness may, in the short-term, have negative impact on their behavior and their overall rationality which may prove unfavorable for the market effectiveness (Shen and Su, 2007).

In the real world, bidders do not always make rational decisions due to cognitive and emotional limitations. This deviation from what is considered to be a "normal" behaviour does not negate the fact that decision-makers are adaptive and goal-oriented and has been stated by researchers mainly in the economics and political sciences regime as "*bounded rationality*". Jones (1999) identified decision-maker factors and classified them to internal ones, namely, search behaviour, alternatives, attributes, calculations, cognitive illusions, framing, self-control, multi-attribute trade-offs, design and updating, emotional identification, and external (environment) ones, namely, ambiguity, uncertainty, repeated decisions and interaction with the environment. He claimed that in such cases, the scientific approach goes beyond the hard assumptions of mathematical models and should extend to the behavioural study of decision-makers. Focusing on the auction-based freight marketplaces Figliozzi et al. (2003a, 2003b) acknowledged the existence of bounded rationality in carriers' decision-making process considering four major reasons: (i) limited ability to identify competitors' behaviour, (ii) limited ability to exchange reputation signals, (iii) limited memory to process past outcomes and future paths, and, (iv) limited ability to solve stochastic optimization problems. They also underlined the importance of learning and its positive impact on adaptation and identified the complexity and relevant decision factors for carriers participating in freight marketplaces (Figure 7.1).

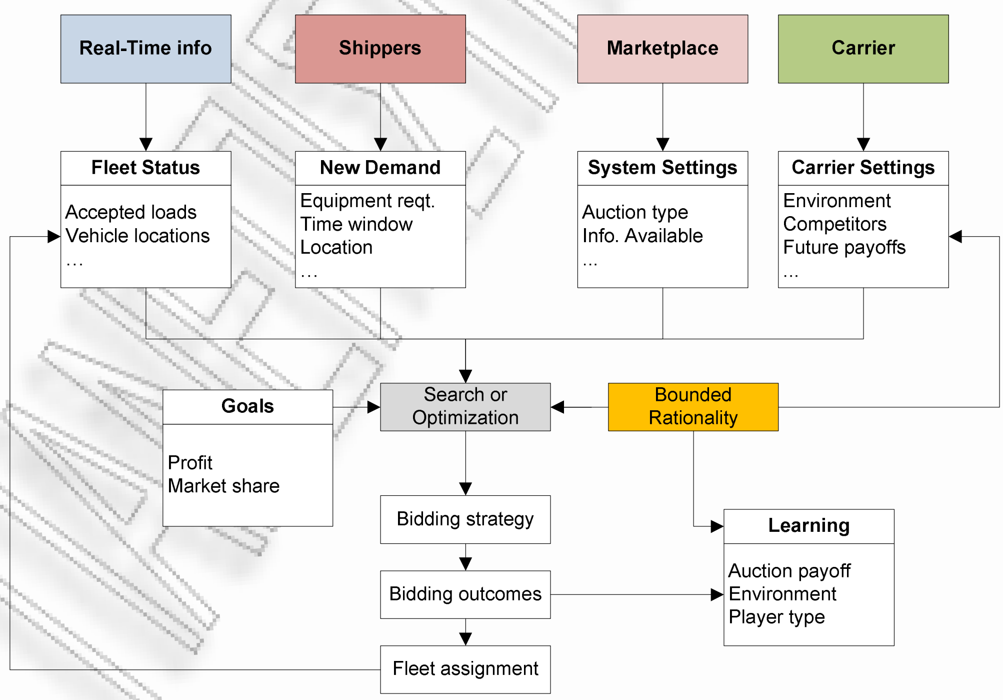

Figure 7.1: *Carriers' Bounded Rationality in Freight Auctions (adapted from Figliozzi et al., 2003a)*

The remainder of this chapter presents a methodology which simultaneously supports the gradual design of auctions along with the training of bidders, aiming to improve market efficiency which is realized herein as an estimation of a price range that approximates an equilibrium situation. We characterize the proposed methodology as "progressive" for two reasons:

- Starts from a core set of characteristics which are gradually fine-tuned, refined and enriched through a customization process
- Auction design may differ subject to the application and integrates the experience recorded from behavioral findings

The value of this research lies on the fact that it does not require experienced subjects. Indeed, it is able to "train" the subjects through the progress; furthermore, it makes use of a generic model for the progressive design of auctions which is practical and comprehensive for all stakeholders. Overall, it matches the auction design parameters with experience and knowledge accumulated along the design process.

Based on the progressive design process, the evolution of experiments for the validation of our model is as follows:

- **STEP 1**: Design of auction mechanism
    - Auction mechanism formulation based on the application
    - Mechanism parameters and parameters' values initial selection
- **STEP 2**: Test in experimental setting (if previous experience is not available, reliable, or limited)
    - Pilot study
    - Results collection and classification
- **STEP 3**: Evaluation of results
    - Bidders' behavior
    - Efficiency (final price)
- **STEP 4**: Enhancement with additional attributes
    - Temporal attributes
    - Spatial attributes

First we propose that the ACE model -described in previous chapters- is used as a tool for the establishment and description of the auction setting. Thus, the experimental setting was based on the following two design decisions:

Design Decision 1: ACE model supports the auction mechanism design process

Design Decision 2: ACE model is used to communicate the auction mechanism parameters to auction participants

Next, focusing on the progressive design process we propose that the gradual market expansion helps participants to gain experience and improve their bidding behavior. Shen and Su (2007) claim that in many studies customers are assumed to make optimal decisions which is not realistic (limitations in information gathering and processing) since their decisions are highly affected from psychological and cognitive factors. The relevant hypothesis is expressed as follows:

H1: Gradual development of an auction mechanism trains bidders and has positive impact on their rationality and behavior in general. We will show that knowledge acquired through repetition of experiments is perceived as adaptive behavior, and thus, the system is not memory-less.

Finally, we focus on the impact of specific auction mechanism parameters injected in the expansion phase, in the auction outcome. The relevant hypotheses are expressed as follows:

H2a: Auction parameters that affect the intensity of the auction process and relate to bidders' reflexes can be used by the designer to modify the outcome of the auction

H2b: LBS may effectively be integrated in the auction process for price discrimination of spatial and temporal attributes of bidders without loss of fairness.

The conceptual model of the study is shown in Figure 7.2. Research hypotheses will be tested through a series of experiments in the rest of the present chapter.

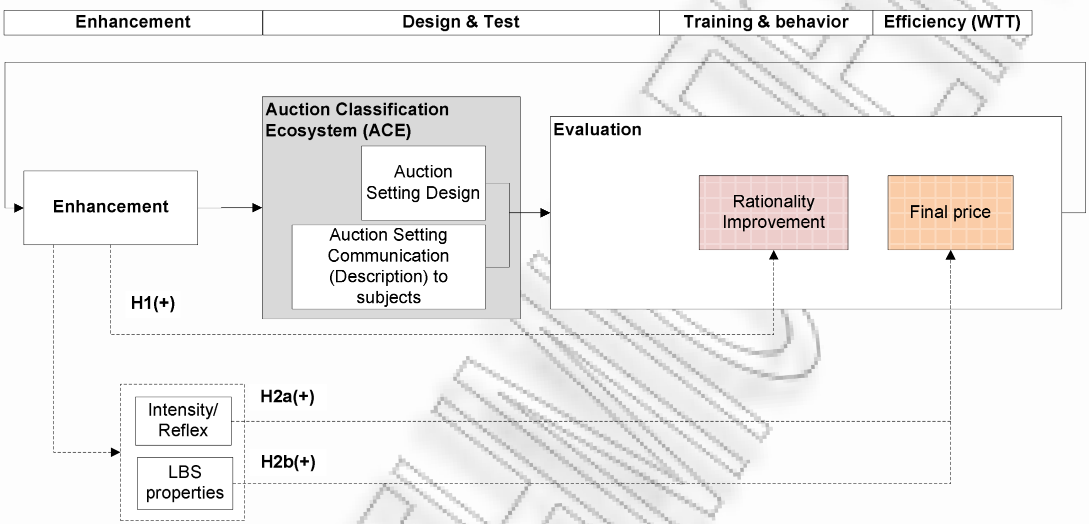

Figure 7.2: *Conceptual Model of the Research Study*

7.1.1 Case Framework

The road freight transportation market is characterized by high fragmentation and high costs with respect to the overall logistics costs. As a result, the inter-related problems of improving capacity utilization and reducing the shippers' cost become critical. In the absence of direct negotiation opportunities, auctions conducted shortly before shipment execution find an appropriate domain of application since they constitute an efficient means to capture the sellers' (carriers') intention to earn the freight within a highly competitive environment subject to their available capacity. The typically limited duration of the process renders auctions a last-minute complementary mechanism to RM and enables the integration of temporal and spatial attributes as bid evaluation criteria. The limited time-window of placing a bid in a last-minute setting, the increased competition that reduces the winning probability and the carriers' need for better capacity utilization in order to avoid less profitable or lossy trips, are the main factors that lead experienced carriers to place aggressive bids to the benefit of the shipper.

We test our hypotheses through a series of scenarios that are tested experimentally. Some of these scenarios are based on multi-round mechanisms which are expected to have positive impact on bidders' behavior since they can learn from experience (Shen and Su, 2007)

7.1.2 Use of ACE to Model the Auction Setting

In the context described above, we implement two auction strategies that present structural differences and we conduct experiments in order to reveal behavioral approaches from bidders for specific freight opportunities. The first part of our analysis ignores the potential benefits in the evaluation of a bid that result from the incorporation of LBS technology; this is purposely done so in order to evaluate the appropriateness of each approach. In the second part, we enrich our evaluation with the benefits of LBS in auctions and propose the architecture for the systemic implementation; furthermore, we conduct experiments to pinpoint the behavioral differences for the same pool of bidders when location-related premiums are considered in the bid evaluation.

	Mechanism 1 (Multi-Round FPSB)	**Mechanism 2 (Reverse Dutch)**	**Mechanism 1 (Multi-Round FPSB)**	**Mechanism 2 (Reverse Dutch)**
Level 1: Mechanism formation				
Characteristic	**Value**		**Mechanism characterization**	
Ratio of buyers/sellers	One to many		Forward	
Number of items	Single		Single-item	
Number of bidding attributes	Single		Single-attribute	
Number of sellers	One		Single-side	
Duration	Multi-round		Multi-round	
Bid type (information revealed)	Sealed		Sealed-bid	Open
Bid Order	Descending		Descending-bid	Ascending
Settlement price	First		First-price	
Closing rule	Time	Budget	Bid	1st bidder's activity
Level 2: Mechanism parameters				
Participation	Participation fees		Fixed	
	Number of bidders		Limited	
	Eligibility		Historical data	
Information revelation	Revealed data, time of revelation		Full data (ID, bid), after the auction	
	Bidding information, time of		Minimum bid, after each round	
Duration	Fixed	Dynamic	Single / multiple round	Going, going, gone
Price	Reserve price amount		Dynamic (min bid from previous round)	Dynamic (max bid from previous round) – location-based
	Reserve price visibility		Visible	
	Bid increment		Fixed in each round	Predefined clock step
			Non-restricted in final round	
	Subsidizing		Based on location	
Bidding	Re-entry		Not-allowed	Allowed
	Bid setting duration		Time	Specific, related to clock, one-shot
	# of bidding rounds		Dynamic (based on max. bids)	Dynamic (based on max. bids) and locations
	Closing announcement		Winning bid, winner's ID	

Table 7.1: *Auction Mechanisms Considered in the Experiments*

The auctions that the LC as an auctioneer organizes for each shipment are simple reverse ones, addressed to *N* (multiple subscribed) carriers who compete for each shipment by placing bids. The two auction mechanisms examined are: (i) reverse first-price sealed-bid (FPSB), and (ii) a reverse Dutch format – both evolving in single and multiple rounds with specific parameters. Importantly, the bid in a reverse Dutch auction increases. The duration of both mechanisms is controlled by the auctioneer and is set to a fixed duration per round in the FPSB case and to a (maximum) duration by altering the clock speed and/or the bid ascending rate in the Dutch case. An indicative, one-off participation fee of 5% of the market price is applied in each auction in order to discourage less serious carriers. Each of these mechanisms is identified in terms of its formation and its parameters using the *Auction Classification Ecosystem (ACE)* model developed by Emiris and Marentakis (2010), as shown in Table 7.1.

Based on the above, a total of six (6) slightly varying auction scenarios were studied for the two mechanisms. The experiments were conducted in a laboratory environment with multiple (≥10) participating carriers, and aimed to study the carriers' behavioral aspects as well as the auction outcomes subject to the auction mechanism characteristics. The experiments also compared bidding behavior, competitiveness and price evolution between two core business scenarios: (i) in the first scenario, the allocation price equals the winning bid level, while (ii) in the second scenario, the allocation price is increased by a predefined premium according to the winner's current location as a bonus for higher qualitative attributes of service (e.g., shorter loading time). The initial, simple one-shot FPSB auction served the purpose of training bidders. Furthermore, a multi-round auction mechanism has been designed (applying as experiment 1B and 1C) in order to enhance participant's experience on gradual information revelation and adaptation of behavior. A detailed analysis of the operation of this mechanism will be presented in Section 3.2.1.The experimental business environment was addressed to a homogeneous and focused set of bidders with high level of knowledge on their aims, the scope of the auction and their profit margins increasing their awareness and competition; a short auction timeframe was employed to enforce quick decision-making from the bidders. The parameterization of scenarios is tabulated in Table 7.2.

Each experiment is characterized by its mechanism (column 2), the use of the location awareness concept (column 3), the number of participants, and the number of auctioned items. Experiments 1A-1C use a FPSB mechanism while experiments 2A-2C use a Dutch auction mechanism. Location-awareness is introduced for the first time in experiment 1C and it is then used in experiments 2B and 2C. In every experiment the participants' base is the same and consists of N bidders competing for just one shipment except of experiment 2C where N bidders are competing for 10 shipments. Each experiment evolves in a number of rounds (column 6) which depends on the applied elimination strategies (indicated in column 7). The number of rounds may be 1 (for experiments 1A, 2A and 2B), variable (for experiments 1B and 1C, where the 3 bidders offering the highest price(s) are eliminated), or equal to the number of auctioned items (which obviously corresponds to a sequential multi-item auction). In the last case (2C) a special bidders' elimination rule was introduced in order to increase the winning probability of the weaker bidders. The closing rule is typical for each auction format as shown in column 8, while the bid evolution (column 9) is reversed compared to the typical auction mechanisms since all experiments are based on procurement (reverse) auctions. The speed and corresponding duration are typical for the auction formats used (column 10), being a fixed duration for FPSB auction formats or depending on a single bidder's action in a Dutch auction format. Finally, the award price defined in column 11 may be equal to the winning bid, or subsidized by a premium.

The setting of the premium (as a percentage) was included in order to incorporate on-the-move carriers, applies to the bidding price and is a descending function of the expected Time of Service (ToS, or equivalently, the distance from the LC). This setup reflects the dynamic nature of the freight transportation case and it is a simplified description of the business case which assumes that trucks approach the LC after each auction. Obviously, this is not always the case in the real world, since carriers may move away from the LC, travel at different speeds, remain in a zone for a more extensive time, etc. Nevertheless, this simple setting serves to study the feasibility and appropriateness of a mechanism that assigns premiums to most approximate (and more probable to win) carriers, while at the same time the dynamic pricing characteristics of auctions are preserved. The premium may be linear or piecewise linear, it may change dynamically in multi-round auctions, and reflects the LC's favoritism to most proximate carriers to the LC. The award price is thus formed as: *Award price = [final price]*(1+premium)*.

As an example, experiment 2B is based in a Dutch auction format which is enhanced with location-awareness attributes. In this experiment, N carriers compete for a single shipment in a one-off auction. The reverse Dutch format used implies that the proposed bid begins from a low price and increases gradually (depending on the clock speed and price increment) until a participant interrupts the process; then the auction ends and the bidder (carrier) is receiving the price increased by a premium, the amount of which depends on his current location at the time of bidding.

Experiment	Mechanism	Location-awareness	# Participants	# auction items (shipments)	Max. # Rounds	Min. # bidders remaining in each round	Closing Rule	Bid evolution	Speed	Award Price
1A	FPSB	NO	N	1	1	Not appl.	Single min bid	Desc	Predefined closing time	Winning Bid
1B	FPSB	NO	N	1	Variable	N:N-top 3	Single min bid	Desc	Predefined closing time	Winning Bid
1C	FPSB	YES	N	1	Variable	N:N-top 3	Single min bid	Desc	Predefined closing time	Winning Bid + premium
2A	Dutch	NO	N	1	1	Not appl.	Bidder's action	Asc	Variations: Clock Speed: 10/5 sec Price increment: 25/10 MU's 4 Variations in total	Winning Bid
2B	Dutch	YES	N	1	1	Not appl.	Bidder's action	Asc		Winning Bid + premium
2C	Dutch	YES	N	M	1	All except winners from last three auctions (N-3)	Bidder's action	Asc		Winning Bid + premium

Table 7.2: *Parameters of the Experiments*

The premium pattern used in the experimental setting is shown in Table 7.3. In all experiments, carriers were randomly yet uniformly assigned to geographical zones. The breakdown of the mechanisms and variants is presented in Figure 7.3.

Zone	0	1	2	3	4
Premium (%)	13	10	6	3	0
Expected time to load (minutes)	0~15	16~45	46~90	91~120	>120

Table 7.3: *Zone Premium Pattern*

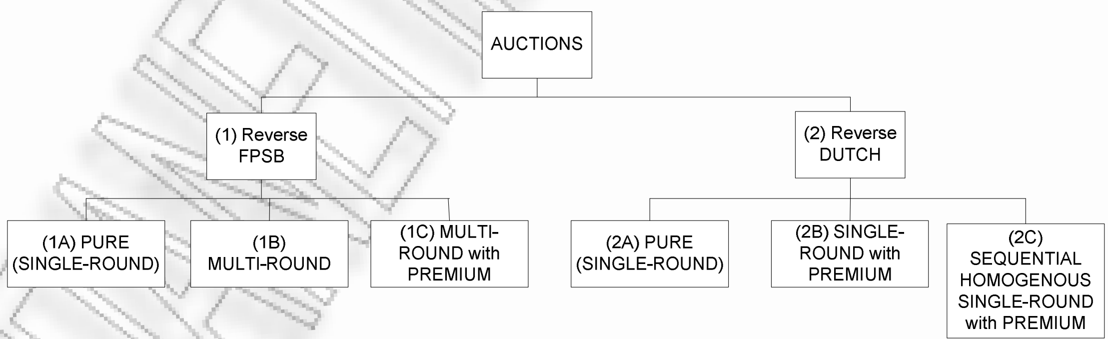

Figure 7.3: *Auction Variants Used in the Experiments*

.1 Mechanism 1: Reverse FPSB (Simple and Multi-round)

In the FPSB mechanism each bidder submits a single sealed bid; the bidder that submitted the lowest bid is awarded the object of the auction at the price (price in R1) equal to his bid (Case 1A). The multi-round mechanism employed herein (Case 1B) is based on a sequence of multiple FPSB auctions. At the end of each round, the bids are sorted in descending order and a predefined number (e.g., three) of bidder(s) with the highest bid(s) are eliminated. The remaining bidders continue to the next round with the same rules but with a reserve (highest) price equal to the minimum eliminated bid of the previous round safeguarding the descending evolution of bids. The lowest bid is the winning one (in round R_{N+1}), and winner's payment is exactly equal to his bid. If a premium is applied subject to the bidders' location (Case 1C), the auction is conducted as previously but the winner is paid the amount of his bid increased by the premium percentage; although this may not lead to the most economic outcome for the shipper, it provides the best outcome in terms of cost AND time of service.

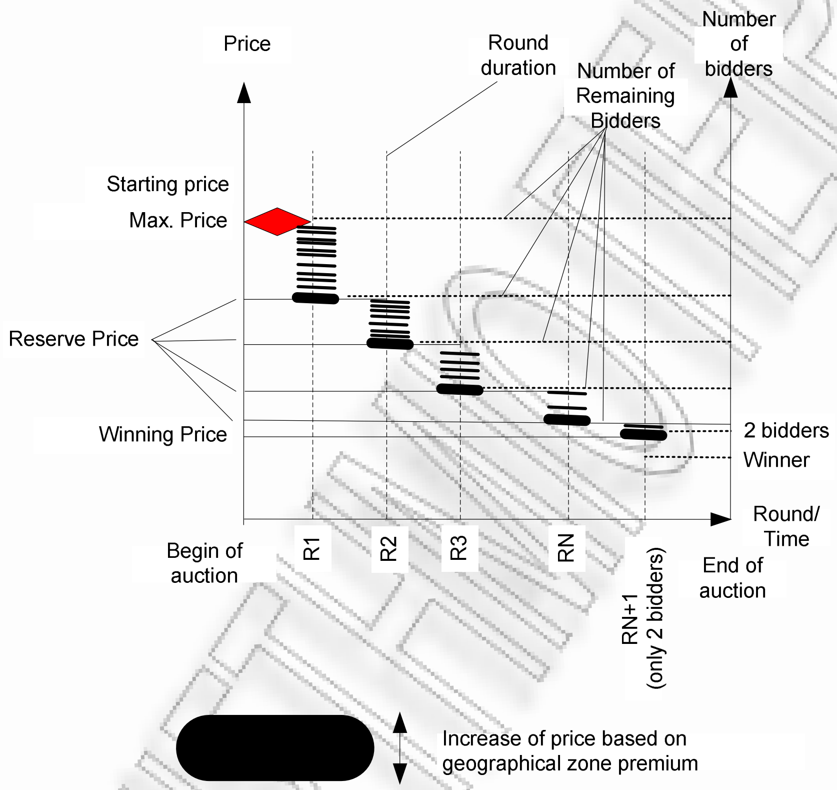

Figure 7.4: *FPSB Process and Price Evolution*

The auction evolution for these cases is schematically depicted in Figure 7.4. As explained in the legend of this figure, the width of the bid lines is proportional to the corresponding premium as defined by the bidder's location in Case 1C, which is the most complex one. In this case (1C), participants are competing for a single auctioned item. In the first round (denoted as R1 in the horizontal axis) the auctioneer announces the maximum acceptable price (reserve price in the reverse auction); the participants then submit their bids in a sealed-bid manner. The auctioneer then announces the three higher bids and the corresponding bidders' names; these bidders are eliminated while the rest of them are continuing on to the second round (R2). In this round, the lowest acceptable bid is used to update (in a descending manner) the reserve price. The process continues until only 2 bidders remain (round RN). The final two bidders submit their bids in round RN+1 and the lowest bid wins. The winner's contract price equals to his winning bid increased by a premium related to his current location (depicted by the width of the bid line).

.2 Mechanism 2: Simple and Multi-round Dutch Auction

In *Dutch auctions* the auctioneer announces the highest desirable price; then, the price decreases continuously or in discrete intervals until a bidder announces his willingness to pay the current price. This bidder is the winner and is awarded the object of the auction at the final price. An interesting property of a Dutch auction is that it assimilates a RM pricing since the price evolution is controlled exclusively by the auctioneer (contrary to the rest of basic auction types where price levels are defined by bidders).

The second group of cases examined herein is based on the “Reverse Dutch auction” mechanism which is based on the classic Dutch auction but in a reverse form, that is, it operates as an ascending-bid approach. The LC announces a starting minimum price which then increases in discrete steps until one carrier expresses his intention to undertake the freight transport in the current price (Case 2A); at this point the auction ends and the LC announces the winning carrier and price to all other bidding carriers. The price increases to a maximum level; if no carrier submits a bid, then the auction ends without winners and the shipper has the option to repeat the auction process. The increase rate of the price depends on various qualitative parameters, for example, urgency.

The minimum starting and the maximum price can be defined as a function of market price or based on RM techniques. The minimum starting price corresponds to the minimum price a shipper wishes to pay for the freight transportation service. Typically, it reflects the carrier’s cost which is not common for all carriers, thus it is not fixed; furthermore, this minimum price may even be below cost – especially for LTL truck routes when the truck has unused capacity for the same trip. The estimation of the minimum price is often based on historical data or based on the long-term contractual price. The maximum price, on the other hand, usually corresponds to the market price for the journey. This attempt of maximizing capacity allocation is central in several RM techniques.

A modified mechanism was developed for the scope of this article (Case 2B) supporting shipper’s preference to nearest-located carriers expressed as a carriers’ location-related premium. Each carrier in this mechanism is aware of a premium expressed as a percentage increase of the price level depending on his current location at the time of bidding. The same location-related subsidizing technique has been applied in a more complex mechanism (case 2C) which supports the sequential auction of several similar shipments in discrete location-aware Dutch auctions. The sole difference in this mechanism is that participation is purposely limited in order to enhance fairness and competitiveness. For this case, the winner of each auction was not allowed to participate in the 3 subsequent auctions. After each auction, all participants come closer to the LC by one zone – obviously after the fourth auction all carriers are located in the LC without asymmetries on premium.

A series of four variations was considered in each of the three cases based on different combinations of price increment (10 / 25 monetary units) and clock speed (10 / 5 sec.) aiming to examine the impact of these parameters on bidding aggressiveness. The auction evolution for these cases is schematically depicted in Figure 7.5.

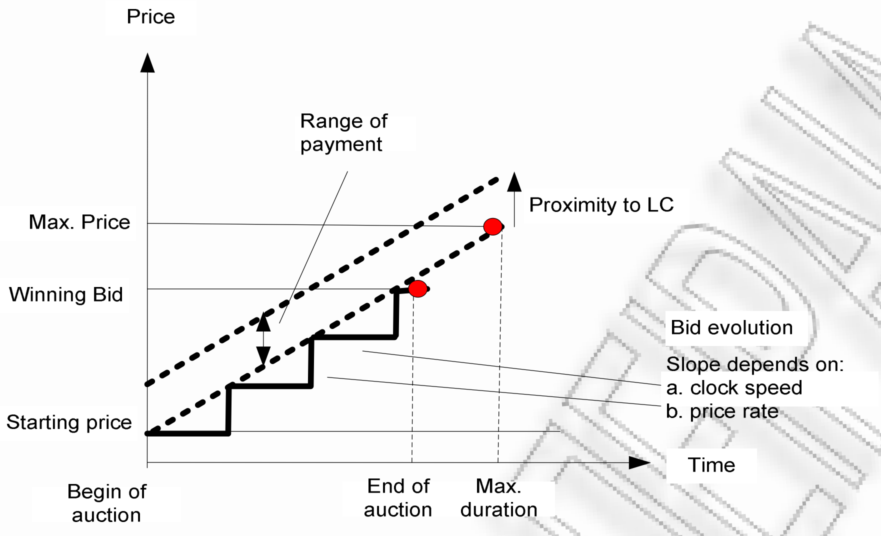

Figure 7.5: *Dutch Auction Process and Price Evolution*

7.2 Experimental Evaluation of Bidders' Behavior for On-the-Move Auctions

In this section, we elaborate on the experiments we conducted in our attempt to extract conclusions on the bidders' behavior in time-critical, on-the-move auctions, for different auction settings, parameters and scenarios. The experiments were addressed to a set of eighteen (18) participants, aware of the freight business, among a total of forty-two (42) candidates. The filtering of the participants resulted after evaluation of their degree of maturity and knowledge on specific business aspects. The final set of participants was subject to a brief and targeted training that explained the aspects of the experiments and the rules for each auction. The experiments were first targeted on the FPSB auctions and subsequently on the Dutch auctions.

It is worth mentioning that the experimental setting does not associate directly to a real business case; therefore, several actions have been taken during the design phase, which allow for the smooth implementation of the experiments. For instance, special attention has been given in the selection of a representative sample of subjects and the use of monetary values which are close to the real freight rates. The experimental results, however, should not yet be generalized since (i) they refer to an adapted laboratory-scale setting, and (ii) more replications are required; nevertheless, these preliminary results are encouraging for more extended studies in the future for both the behavioral elements of participants and the efficiency of the examined market.

In all our experiments, the market (reserve) price was set to 700 monetary units (MU), the cost of transportation was assumed to be 400 MUs (common to all carriers), the minimum price that a bidder was allowed to place was defined at 300 MUs (that is, below cost), and a participation fee of 20 MUs per bidder was set for each auction category, irrespectively of the number of rounds that a bidder may stay in. The total amount allocated for participation was 100 MUs per bidder; in other words a bidder had the right to participate in up to five (5) auction categories in total. Finally, the bidding step in the FPSB auctions was a multiple of 20 MUs. The experimental results are discussed in the sequel. The experiments provided evidence and better understanding of how bidders think and of how their behavior changes subject to auction parameters, environment and competition. The interpretation of the behavior was assisted by the bidders themselves, as they were asked to record and report their strategy before and after each auction setting.

The analysis of participants' behavior examines three dimensions: (i) the behavior in the early stages of each experimental setting, (ii) the behavior observed during the bidding process, and (iii) the changes of behavior due to zone-related premium. The first dimension provides evidence related to the lack of experience (*does not participate in first auction*), intention to gain experience (*participation with bid = cost*), intention to gain information about opponents (*participation with minimum profit*), irrationality (*participation with bid < cost*) and discouragement due to low prices (*does not participate due to low valuations*). The second dimension provides evidence on rational behavior (*maintaining mostly high valuation*) and examines how knowledge gained along the experiments affects positively participants' behavior (*gradually increase valuation*). Finally, the third dimension provides evidence on how participants utilize their zone-based premium in the development and evolution of their bids (*counterbalance valuation with zone premium*), and also checks whether location attributes and perceived opponents' location affects participation intentions (*discouragement due to zone*).

7.2.1 H1: Bidders' Behavior Improvement in FPSB Auctions

A brief description of the experiments conducted is shown below:

- Experiment 1A:
  This case deals with a single-round FPSB, where bidders submit their bids and the lowest bid wins. Bidders do not have any information about the other participants or the market tendency; as a result, this experiment recorded the "reflex reaction" of the bidders in a market opportunity and revealed the effect of lack of training as the winning bid was below cost (360 MUs). In that sense, this experiment served as a *brute-force* training mechanism.
- Experiment 1B:
  This case deals with a multi-round FPSB, where bidders submit their bids and the three highest bids (that is, at least three bidders) are eliminated after each round. Under this frame, the auction is decomposed into smaller, intermediate auctions that generate continuously smaller sets of perceived "potential" bidders. The main benefit of this approach for the remaining bidders is that they keep on gaining information and increasing their awareness on the market tendency; furthermore, this situation triggers their competition attitude which prompts some of them to continue and others to drop out.
- Experiment 1C:
  This case deals with a multi-round FPSB, which however are finally increased by a zone (distance) premium; the bidders submit their offers and the three highest bids (that is, at least three bidders) are eliminated after each round. As with experiment 1B, the auction is decomposed into intermediate auctions with smaller sets of perceived "potential" bidders, who are ever more informed and aware of the market tendency. The bidders in this frame, capitalize on their experiences from experiments 1A and 1B and are observed to submit more rational (that is, more profitable for them) bids. A most interesting feature of this approach is that the competition environment changes with time because distant carriers become more proximate; hence, the pool of "privileged" (positively discriminated) bidders becomes constantly enriched.

All in all this set of experiments turned out to serve as the training phase for bidders since:

- It acquainted bidders with the mentality of auctions,
- The multi-round mechanism supplied the bidders with a feeling of competitors' behavior, and
- It helped bidders develop strategy and bidding mentality as a function of contextual triggering factors.

Furthermore, significant interpretations for the behavior of bidders were obtained and classified as early stage and mature stage behavior. These are tabulated below (Table 7.4) and explained in turn.

Participant's statement	**1A**	**1B**	**1C**
Behavior in early stages			
Does not participate in first auction	3	1	1
Participation with bid = cost	2	6	3
Participation with bid < cost	3	3	
Participation with minimum profit	6	5	1
Does not participate due to low valuations		3	
Behavior after early stages			
Maintaining (mostly high) valuation	4		2
Gradually increase valuation			
Impact of zone premium in bid formation			
Counterbalance valuation with zone premium			7
Discouragement due to zone			2
Total number of participants	**18**	**18**	**16**

Table 7.4: *Participants' Statements in FPSB Auctions*

During experiment 1A, 3 of the 18 bidders preferred to watch the auction outcome in order to get a feeling of the market tendency. A significant number of bidders, specifically 6 of the 18 bidders, opted to offer bids below cost in order to "get the job and penetrate the market". Another 5 of the 18 bidders preferred to participate safely (that is, without losses) and submitted bids at cost or at a very small profit; these "secure" players prefer to not get the job rather than operating at a damage. Finally, a group of 4 of the 18 bidders offered very high prices and were eliminated at the very first stages; these are the participants that paid the price for lacking the sense of market tendency.

During experiment 1B, the reluctance to participate barrier was lowered, as evidenced by the fact that just 1 of the 18 bidders decided not to participate; nevertheless, 3 of the 18 bidders decided not to participate because they were negatively influenced by the end-price from 1A and expressed their unwillingness to compete at such a low valuation. Two of these were market observers in 1A while the third one was originated from the set of minimum profit bidders. The number of bidders that decided to participate with bid equal to cost significantly increased (6 of the 18 bidders). The 4 new bidders in this group were the ones that offered a high bid during 1A and were eliminated, so they adapted their strategy by lowering their expectations after receiving information on market tendency; this experience allowed them to stay in the bidding process until its more mature stages. Finally, the number of irrational bidders whose offers were below cost did not change (3 of the 18 bidders) in these auction settings.

During experiment 1C, the participating bidders were 16 in total, 1 bidder did not participate since he finally failed to become familiar with the auction, while 2 bidders did not participate because their zone position discouraged them. Although there existed 7 of the 16 bids nominally below cost, these bids were all valued above or equal to cost because they were counterbalanced by the premium (auction and market learners). In addition to these, 4 of the 16 bidders placed bids nominally or equal to cost (which is interpreted as stabilization of the rational group of players) and only 2 of the 16 bidders placed high bids and were very soon eliminated. The evolution of the bidding pattern during 1C, solidified the argument that, in the steady state, bidders learned to "bid for profit not for glory".

The existence of the zone premium had an additional positive effect for the bidders. As illustrated in Figure 7.6, the average bid level in each round of auction 1C, remains constantly higher than the respective level in auction 1B. The incorporation of the zone premium thus helped bidders achieve a more "fair" price converging to their cost, and enabled some bidders to stay in the auction process for more rounds and to develop a discrete step bidding strategy by using smartly their effective zone premium at the time of bid.

To summarize, this first set of experiments resulted to the benefit of the LC since all final prices are below carriers' cost and almost 50% lower than the market price, even though carriers increased their bids from auction 1A to auction 1C. This perceived irrationality originates from the lack of experience and information and may not appear in a steady-state, expert environment; however, as mentioned above, auctions 1A and 1B served primarily as learning tools to familiarize bidders with the auction concept. The positive effect of learning is amplified in the Dutch auctions that follow.

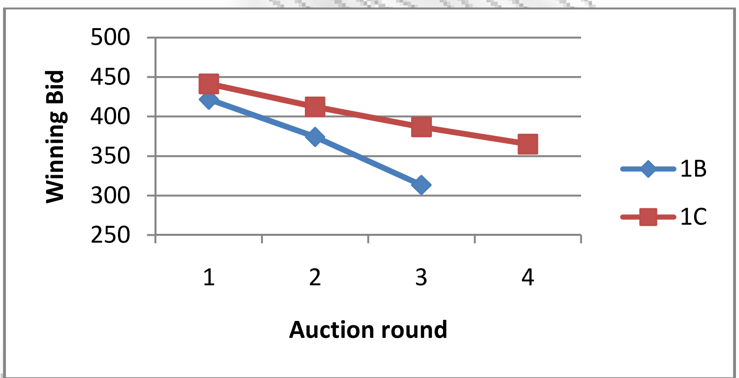

Figure 7.6: *Average Bid Levels in Auctions 1B and 1C*

7.2.2 H1: Bidders' Behavior Improvement in Dutch Auctions

In this series of experiments each auction was conducted several times as this type is executed in one round and is much faster. In each auction, only the winning bid is revealed, while the valuations of the remaining N-1 bidders that do not win remain unknown. The findings for each version of this auction are presented below.

- Experiment 2A:
  This experiment served for training of the bidders with the mechanism only, since the feeling about the market tendency was established on their minds in the previous set of experiments. Contrary to the FPSB type, the Dutch auction is very time-intense requiring the immediate response from the designated winner at the moment the bidding clock reaches his intended bid amount. Four different combinations of bid step (expressed in monetary units (MUs) and clock speed (expressed in seconds), specifically, 25MU/10sec, 10MU/10sec, 25MU/5sec and 10MU/5sec, were employed to shape their experience that resulted in a continuous increase of the value of the

winning bids, reaching at the end 460 MUs and exhibiting serious improvement compared to the FPSB experiments.

- Experiment 2B:
  This case introduces bidders to the concept of zone-subsidizing in the Dutch auction mechanism. Each participant is randomly –yet uniformly- assigned to a specific geographical zone which affects positively (or having no effect in case of far located carriers – Zone 4) their bids if they win. In practice, this corresponds to favoring carriers that are closer to the LC and are able to offer the service more promptly. Bidders are expected to estimate their valuations based on the zone premium knowing that their rivals act similarly. Although the nominal winning bids ranged between 425 and 450 MUs the actual (subsidized) payments including the premium were increased considerably and ranged between 453,2 and 508,5 MUs. During this case, the bidders were also trained to define counterbalancing relations between their location-based premium and the submitted bid in order to remain competitive (as shown by the fact that 5 out of 10 winners were located in zones >0 and 3 out of them located in zones >1). As with case 2A, the same bid step and clock speed combinations were applied.
- Experiment 2C:
  This experiment serves as the *stabilization* case, since participants carried their knowledge and experiences from all previous experiments. In this case, the LC has to assign 10 identical shipments to discrete carriers through a sequence of 10 identical Dutch auctions with zone premium subsidizing. In order to solidify fairness, a winner in an auction is not permitted to participate in the next 3 auctions. As in 2B, participants were randomly placed to specific geographic zones at the beginning of the auction. An innovative feature in this experiment is that it is emulating the on-the-move bidding process; after the end of each auction each participant moves one zone closer to the LC ($Z_{i+1} = Z_i - 1$) until they reach the LC.

Experiments 2A and 2B introduced informed bidders to the Dutch auction mechanism and the zone-bid counterbalancing process, respectively, and prepared them for the location-sensitive auction process. Significant interpretations for the behavior of bidders were obtained and classified; these are tabulated below (Table 7.5) and explained in turn.

Participant's statement	**2A**	**2B**	**2C**
Behavior in early stages			
Does not participate in first auction	2	3	5
Participation with bid = cost (publicity)	2		
Participation with bid < cost			
Participation with minimum profit	1	1	1
Does not participate due to low valuations	3	3	2
Behavior after early stages			
Maintaining (mostly high) valuation	3	2	
Gradually increase valuation	6	1	3
Impact of zone premium in bid formation			
Counterbalance valuation with zone premium		5	6
Discouragement due to zone		2	
Total number of participants	**17**	**17**	**17**

Table 7.5: *Participants' Statement in Dutch Auctions*

A summary of the results related to the behavior and experience gained by the participants is shown in Figure 7.7. In all experiments with Dutch auctions, bidders placed their bids above cost; a small portion placed bids at cost or with minimum profit. Some bidders decided not to participate when they felt discouraged with low valuations (3 initially and 2 in the final stage), or when their participation budget did not permit them to do so, rather than participate at a loss (between 2 and 5 out of 17). In all three Dutch auction schemes, the participants either increased their valuations or submitted competitive bids and offset them with the respective zone premium; as a result, the winning bids were discernibly higher than those in the FPSB cases. Despite the fact that the winning bids exhibit a slight increasing tendency, the large number of participants ensures that the market is not vulnerable to collusion behavior. Importantly, experienced (and successful) bidders preferred to adapt their valuations along their movement from zone to zone instead of increasing gradually their valuations. Finally, there exist no bidders discouraged due to their zone during 2C, as it turned out that all bidders viewed their location as a criterion to formulate and adapt their bidding strategy.

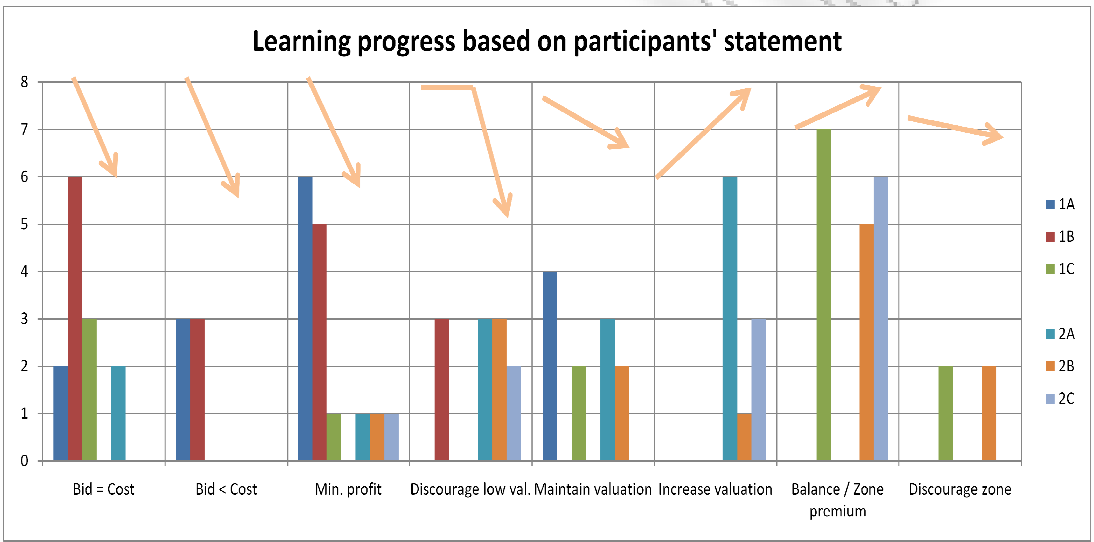

Figure 7.7: *Summary of Behavioral Outcomes*

7.3 Discussion on Auction Outcomes

7.3.1 Effect of Auction Type on the Final Price

The obtained results provided clear evidence that bidders' behavior progressively became more rational through their participation in more bids. During the training phase, FPSB auctions yielded very low prices which did not even cover the carriers' costs (Figure 7.8a). In the Dutch auction case (Figure 7.8b), the winning bids in 2A were marginally higher than the carriers' costs and improved by 20-30% in 2B. Finally, in case (2C) where bidders are assumed to be well trained, the winning bids (after premium) were considerably higher (between 25% and 40% above cost) indicating a fair and viable situation for all stakeholders as the winning prices remained below the indicated market price thus securing healthy savings for the LC as well.

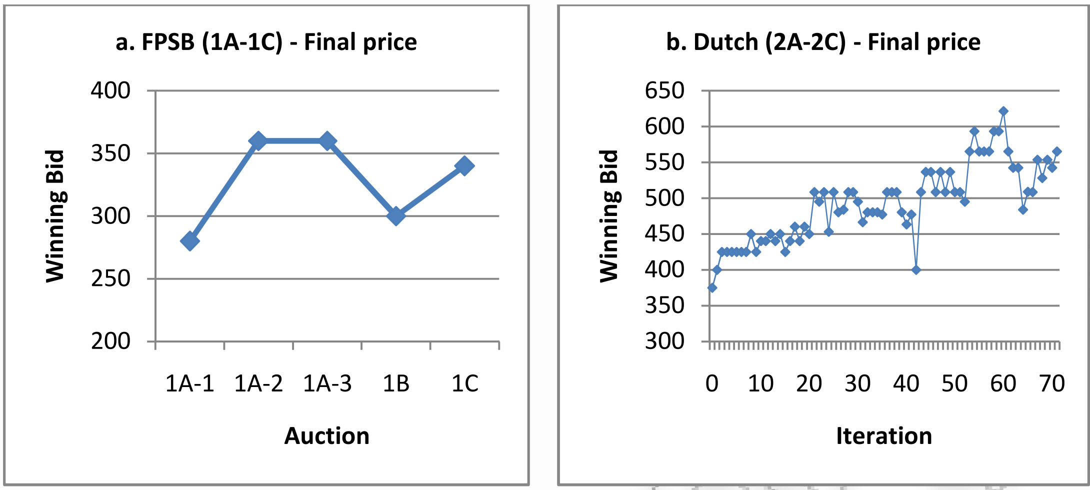

Figure 7.8: *Final Price in (i) FPSB Auctions and (ii) Dutch Auctions*

7.3.2 H2a: Impact of Bid Step and Clock Speed on the Winning Bid

In all Dutch auction experiments, four different combinations of bid step and clock speed (25MU/10’’, 10MU/10’’, 25MU/5’’ and 10MU/5’’) were employed; in experiment 2C, these correspond to 2C-1, 2C-2, 2C-3, and 2C-4, respectively. Each variation contained 10 auctions. The results depicted in Figure 7.9 indicate that the combinations 25/10 (in 2C-1) and 10/10 (in 2C-2) were the most profitable for the LC while the combinations 25/5 in 2C-3 and 10/5 (in 2C-4) were the most profitable for the winning carriers. In particular, a faster clock speed in general favors the carriers as it allows less time to the bidders to think and their strategy is mostly relying on reflexes; in the contrary, a slower clock speed allows more time to bidders to shape their strategy and leads them to place more aggressive bids which lead to higher profit for the LC. When the bid increase step is considered in conjunction to the clock speed, a bigger step at a slow ticking clock favors the LC more than a smaller step with the same clock; similarly, a bigger step at a fast ticking clock favors the carrier more than a smaller step with the same clock. Overall, when planning an auction, the auctioneer may take into account such findings in order to influence the expected bids.

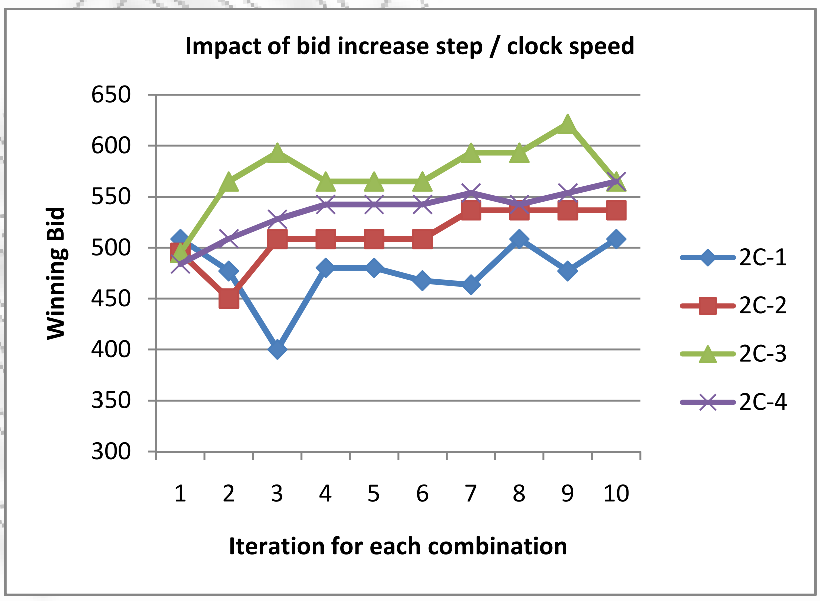

Figure 7.9: *Resulting Prices for Different Bid Increase Step / Clock Speed Combinations*

7.3.3 H2b: Impact of Location on the Winning Bid

Examining the geographical distribution of winners in auction 2C, it is observed that most of them were located in the LC (zone 0); yet a noteworthy percentage of 10% was located in zone 1, a percentage of 7.5% was located in zone 2, while even far located carriers (zones 3 and 4) won a respectable 5% of the auctions by effectively offsetting their bids with their premiums (Figure 7.10).

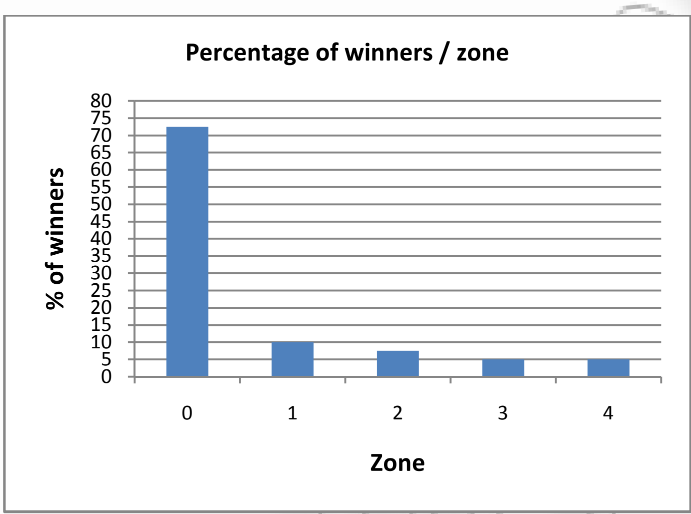

Figure 7.10: *Impact of Location on the Winning Bid*

7.3.4 Willingness to Trade (WTT)

Focusing on the 2C mature case, and particularly on the efficient, experienced bidders who won 3 or more auctions (which proves that they adopted a comparatively more rational strategy) some interesting results arise. The examination of the carriers' absolute average profits as *Willingness to Offer* (WTO) and the LC's absolute average savings as *Willingness to Pay* (WTP), the difference between the two represents an area of fair and mutually profitable trade (Figure 7.11). This price range can also be perceived as a price interval where carrier's WTO and LC's WTP converge in a common *Willingness to Trade* (WTT) conceptual instance which can be further researched under the RM context. This margin appears to become slightly "narrower" along with the number of wins for successful bidders providing evidence for the maturity of the marketplace.

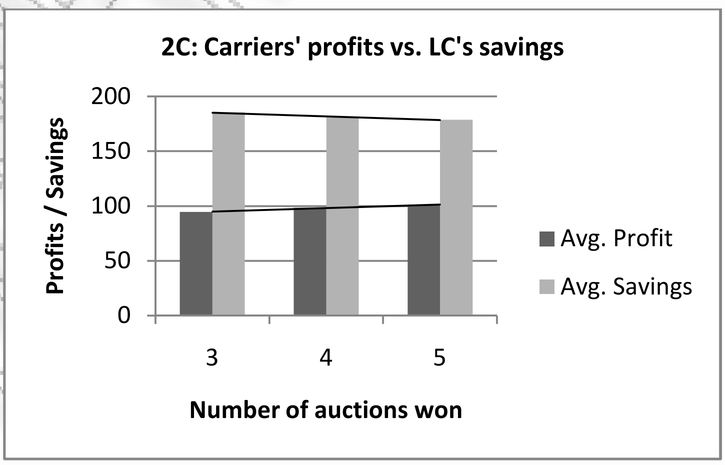

Figure 7.11: *The Willingness to Trade (WTT) Range*

7.4 Implementation of Experiments in z-Tree

*The experiment was programmed and conducted with the software Zurich Toolbox for Readymade Economic Experiments (z-Tree) (*Fischbacher, 2007) which serves as a platform for the development and implementation for economic experiments. During our research we also identified two online experimental platforms for auctions: a) *EconPort* (http://www.econport.org) supported by Experimental Economics Center, Andrew Young School of Policy Studies, Georgia State University and, b) *Vecon Lab Auctions* (http://veconlab.econ.virginia.edu/admin.htm) allowing experimentation in more than 50 particular auction types. These platforms support only the four basic auction formats and do not allow further customizing of new experimental settings. Other stand-alone experimental applications are dedicated to specific auction formats, for example HandDA for double auctions (http://faculty.cbpp.uaa.alaska.edu/jmurphy/handda/handda.html#handda). An extended overview of economic experiments in classroom can be found in http://en.wikiversity.org/wiki/Economic_Classroom_Experiments.

For our experiments we selected z-Tree (http://www.iew.uzh.ch/ztree/index.php) since it offers many options for development and customizing of any auction format. According to developers z-Tree allows the development and implementation of almost any experimental setting. Furthermore, it offers an integrated dedicated programming language which enables the communication between participants' computers, data saving, time display, calculations and design of screen layout at programmers' will. This programming language and corresponding editor is user-friendly and does not require sound previous programming knowledge.

The major entities in an experiment conducted in z-Tree are a single "*experimenter*" and a predefined number of participants called "*subjects*". Experimenter is using an *experimenter personal computer* while subjects are using *subject personal computers* serving as means for communication between them using *client-server* architecture using TCP/IP protocol. The experimenter uses a server application called *z-Tree* while subjects are using client applications called *z-Leafs*. In any experiment, the experimenter starts-up the server application and then all subjects are starting-up client applications which are establishing connections with the server application. After that, the experimenter starts the experimental program developed with the z-Tree programming language. Each single run of the experiment is called "*treatment*" entailing multiple *periods*. The interval between logging-on and out of subjects is defined as "*session*". During the treatment, z-Tree transmits all data related to the specific experiment to z-Leafs, and then z-Leafs transmit subjects' formal inputs and intentions back to z-Tree which use them for calculations according to functions and algorithms defined in its' code. Finally, the results are transmitted appropriately to subjects' clients using formal messages. The same communication workflow stands for more complex multi-step experiments formally defined as "*stages*". Communication, experimental and historical data are stored in a separate database server. Finally, z-Tree is robust and ensures reliability and integrity of transmitted data even in cases of hardware malfunction. An abstract architecture of an experimental setting is presented in Figure 7.12 (adapted from z-Tree manual: Fischbacher, U. z-Tree Tutorial 2.1. Zurich: University of Zurich, 2002.).

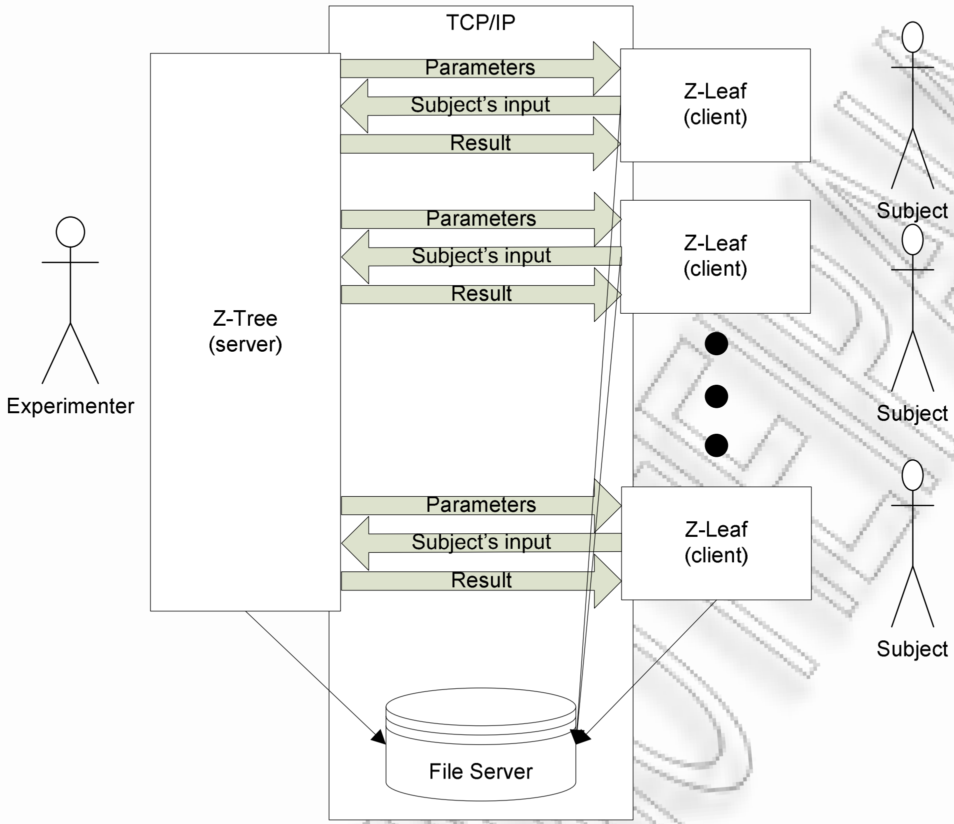

Figure 7.12: *z-Tree Experimental Setting Architecture*

Of special interest is the timing functionality; z-Tree can record the exact time of interaction between the system and the subject. This attribute is particularly useful in time-critical experiments like the experiment in Dutch auction engaged herein. In addition to the above, z-Tree offers a set of attractive functionalities for example, displaying of images, interactive graphical representations and chatting between subjects.

Experiments have been programmed on the basis of the program *background* containing global tables, programs, active screens and waiting screens. Practically, background contains all the global elements of the program. Then the program executes through a sequence of *stages* each of them containing programs, active and waiting screens for each step transaction between the system and the subject. The basic construction elements are tables which can be standard (*globals*, *subject*, *summary*, *contracts* and *session*) or experimenter-defined. *Globals* table contains variables that are common for all subjects but may change between periods, *subjects* table contains variables that may be different for each subject, *summary* table contains the same data with *subjects* but it is used for running statistics, *contracts* table contains buy/sell data of an auction and finally, *session* table contains data that may be different for different subjects but are common for all treatments.

Additional tables may be defined at programmer's will. All tables contain variables which can be built-in (e.g., number of periods, group, profit, total profit etc.) or defined by the programmer in *programs*. Programs are basically used to define functions and algorithmic calculations with the use of standard operators receiving specified inputs and providing outputs. Participants may be assigned to *groups*; z-Tree offers three different types of assignment which are *partner* (specified number of subjects in each group), *stranger* (random assignment for each period) or *absolute stranger* (each subject is never in the same group more than once).

Before and during the experiment, the experimenter may use *Clients' Table* to monitor subjects' state. After the end of the experiment, z-Tree generates several files containing experimental data. These files are: a) the *xls* file containing all tables of the experiment, b) the *sbj* file containing questionnaire responses (participants' data), c) the *pay* file containing payment data, d) the *adr* file containing participants' address and, e) the *gsf* file containing safe data of the program in binary form.

For our experiments we developed two programs for standard auction forms enhanced with specific auction attributes the most important of which being the reserve price, the participation fee, the cost/revenue calculation, and the temporal parameters for the Dutch auction. Z-Tree guarantees both fair treatment of all subjects and bidding anonymity. For more sophisticated design issues (like subsidizing patterns and bidders' location in geographic zones) we used *paper and pen* methods.

A detailed presentation of the experiments developed in Z-Tree, source code, indicative screenshots and results are presented in the Appendix of the Thesis.

7.5 Summary and Conclusion

The usefulness of the proposed methodology is summarized in the following:

- It does not require “experienced” subjects
- It may lead to more “productive” auctions
- It is less complex to implement if an auction template (e.g., ACE) is used
- It incorporates the evolution of experience, knowledge and behavior

In the area of auction mechanism design, the definition of optimal duration of each phase and the amount of service capacity being traded requires a more focused and extended research, as well as the use of alternative auction schemes (pure, hybrid or custom) in order to obtain more accurate and stable results. In the domain of behavioral analysis, it appears promising to avail effort on these knowledge management components that affect participants’ decision-making process, such as: participation or not, evaluation metrics for market information, establishment of a price-time counterbalancing bidding strategy, etc. Nevertheless, auction designer should not focus only on theoretical aspects of mechanism design; Shen and Su (2007) claim that “the choice of an appropriate auction format is a matter of practical concern”.

In the area of ICT research and applications, the integration with existing logistics operations information systems and development of software agents for carriers in order to simplify the biding process, poses a technological and systemic challenge worth investigating. Finally, the concepts, findings and propositions in this section, may well be extended, adopted and generalized in several other application areas that are currently treated with pure RM methods, such as tourism services; the present chapter establishes a solid ground towards these efforts.

The series of experiments and corresponding findings presented in this chapter are accompanying the proposed auction design and participants' training methodology. We used these experiments in order to show that there are tools for the accomplishment of the above intentions. So, our aim was not to prove efficiency of mechanisms or analysis of equilibrium, but to dig deeper in behavioral parameters and gradual learning. In the future we intend to study in depth and model participants' behavior with the use of computational intelligence tools and techniques.

Chapter 8

Conclusions and Directions for Future Research

The present chapter summarizes the findings of the thesis and illustrates answers to the research questions set in Chapter 1, in a concise form. Interesting research questions generated from the present thesis are brought to light; these highlight promising paths for further research.

This chapter is structured as follows: Section 8.1 summarizes the findings for each question set in Chapter 1. Section 8.2 describes in a crisp form the contribution of the present thesis. Finally, Section 8.3 enumerates several openings for further research.

8.1 Summary of Results

This thesis dealt with the investigation of advanced auction schemes in dynamic marketplaces, and specifically, with their classification, the technologies involved, promising applications, and behavioral aspects of the participating entities. This research was motivated and triggered by three key observations: (i) the wide diffusion of auctions as market-making and price-setting tools even for complex settings and trading items, (ii) the advances in wireless communication technologies acting as enablers for the augmentation of mobile-commerce and especially the provision of location-sensitive services and (iii) the suitability of such spatially-aware services in the reinforcement of specific emerging service markets like tourism and freight transportation.

The attempts to match these three observations brought up a series of research problems: (i) the first relates to the appropriate auction type for each application and the ways to design and develop it in a formalistic manner, (ii) the second relates to the suitability, strategic reasoning and special attributes of contemporary auctions with the addition of location-aware functionalities, and, (iii) the third deals with how to put such market mechanisms to work and achieve user acceptance by profiting of observations on the behavior of participants. The combination of these problems formulates the research essence of this thesis which can be stated as follows:

To identify and classify contemporary auction design types and parameters, and use them systematically for the development of a generic and complete auction design model. To investigate how location may affect the auction-based price definition and how may ICT developments support this in a RM context. To examine how we can approach the design of an evolutionary learning methodology that supports the gradual familiarization of market participants within the context of advanced auction formats.

The research treatment of these questions evolved through the decomposition of the overall problem into a sequence of interrelated and gradually analyzed research questions which were studied in the corresponding chapters of the thesis. In the sequel, these questions are addressed in order and the corresponding findings and contributions are concisely presented.

8.1.1 Question 1

Can we develop a generic and unified auction classification scheme containing features and mechanism parameters for the design of application-dependent auctions?

Chapter 2 of the present thesis comes to bridge the gap since the last attempt of literature organization. Due to the plethora of published works in this domain, it has been decided to focus this research in the most recent articles, specifically, those published during the last decade; although this may seem as a limitation at the first glance, more than eight hundred (800) articles have been included and referenced. The articles have been retrieved mainly from the Elsevier Science Direct, Emerald, Springer, Taylor & Francis and JSTOR databases. Wherever required, articles from earlier years have also been considered in the cases that they are fundamental for the most recent studies and are referenced. It has also been decided to limit the survey in works mostly addressing classic auction environments. Finally, this survey is extended to include works on contemporary auctions conducted over the internet and wireless networks (e- and m-auctions respectively). Based on these findings from the literature, in Chapter 3 we presented a comprehensive two-level taxonomical frame (ACE) for the classification of auction formats and an appropriate customizing language. Through a series of examples we show the applicability of ACE when aiming to develop and communicate auction mechanisms to interested stakeholders.

The contribution of research in this topic is threefold: (i) it provides an overview of basic concepts of auction theory based on fundamental works as well as on recent literature; (ii) it summarizes recent developments in auction theory and emerging auction mechanisms in a way to be comprehensive also by non-economists, giving particular emphasis on specific topics; and (iii) it constructs a coherent taxonomical frame for the classification of auction types associated to the articles that pertain to each class.

8.1.2 Question 2

How can we associate participants' decision elements for multi-dimensional auctions in order to further enhance the auction design and support participants' decisions?

As mentioned, Chapter 2 focused on auctions where bids consist of many parameters beyond price and auctions of multiple identical or complementary objects. The scope of the work is again threefold: (i) it served as an extensive review of recent literature for emerging complex auction formats; (ii) it provided a coherent analysis of these complex formats and the special design parameters that affect the decision-making process; and (iii) it is focused on the decision-making problems the auction participants face before, during and after the auction process. The aim of the study was not to evaluate the efficiency of the models that researchers have presented through the years, neither to assess the computability, convergence to the equilibrium or other mechanism characteristics in these models. Rather, the proposed analysis focused on collecting and categorizing these scientific efforts, and on decoding these models with respect to their inherent decision making attributes.

In addition to the contribution of Chapter 2, Chapter 3 culminated with the presentation of three decision models that help the auctioneer and the bidders in shaping their strategy for any multi-dimensional auction. These models are tightly integrated within the ACE-Level-1 as add-ons on specific decisions during the customizing process. Finally, a customizing language which is validated through a series of examples was also established.

8.1.3 Question 3

What are the specific properties of ICT-enabled auctions (e- and m-) and how do they differ from physical auctions?

Since ICT-enabled auctions have equivalent core mechanism characteristics with physical auctions, we extended the work of Chapter 2 to propose that ACE-Level-1& 2 may equally well apply in electronic and mobile contexts. In particular, we focused on the core structural and implementation issues which can be categorized as follows: (i) in the organization of the auction within extended electronic and mobile marketplaces with respect to their economical and marketing advantages, (ii) the appropriate existing technologies and how do they support auctions, (iii) their properties for the implementation and conduction of multi-dimensional auctions, (iv) the new functionalities for process automation offered from advances on computational intelligence and automated agents, (v) the new forms of vulnerabilities. Results from the literature survey were identified and categorized in order to highlight and organize their differences from physical auctions. The findings from this work were used as the basis for constructing the third level of our Auction Classification Ecosystem; this was performed in Chapter 5.

We, furthermore, focused on application instances which show clearly not only the resulting benefits of ICT-enabled auctions, but also the implementation of special applications which could not be supported by physical auctions. Finally, we extended our review identifying recent trends in the domain of wireless auctions.

8.1.4 Question 4

How can m-auctions successfully evolve to l-auctions?

A core difference between l-auctions and m-auctions is the ability of the former to identify spatial attributes of the auction participants (or item, or both of them) and adapt the execution attributes and the winner determination process to enhance specific aspects of the market. The development and operation of l-auctions shows some difficulties related to highly sophisticated communication networks.

Chapter 4 of the present thesis provided answers on the prerequisites for the design of l-auctions. Although the evolution process relates mostly to the technological infrastructure, special effort was given to present the material in a way easily comprehensible to non-technically literate readers. In that sense, our analysis provided a comprehensible review of the Telematics sector, the relevant communications technologies and typical architecture structures; overall, this analysis has a "business" *and* "marketing" flavor. With this in mind, we summarized the special logistical and information requirements and described how location-sensing technologies may enhance the market efficiency through surveillance technologies of items, persons and vehicles. Finally, we addressed operations efficiency and yield management issues and gave examples on how Telematics may enhance operational efficiency.

Further to the above, in Chapter 5 we expanded the ACE established in Chapter 2 to ACE-Level-3. This expansion has two functionalities: (i) it serves as guide for the tabula rasa development of a new auction marketplace ultimately including l-auctions, and (ii) it supports projects of expansion or transition from any auction context to l-auctions. Several examples of use of ACE-Level 3 provide evidence for the applicability and practicality of the proposed methodology.

8.1.5 Question 5

In which ways may l-auctions enhance the trade of location-aware services?

This research aims to motivate the shift from traditional, static and predictive ways of service offering to advanced, technology-assisted, dynamic and adaptive approaches for the same type of problems. In Chapter 6 we examined the potential that arises from the combination of auction models with ICT advances and innovations, applied in two emerging business areas, namely, the (B2C) tourism services and the (B2B) freight transport business.

Initially, we coupled the domains of m-commerce, auction-based logistics services and LBS, into a unified whole and investigated the inherent structural complexities; furthermore, we attempted to estimate the LBS communication data workload for the special auction marketplace examined. In Chapter 6, we showed that for most common scenarios, even with the use of SMS as transmitting medium, bandwidth requirements are relatively low and the execution of the l-auction is economically viable. This chapter is central in our research; indeed it bridges the operational characteristics of auctions with market-making capabilities of LBS to unfold hidden business capabilities and provides evidence for a series of applications.

Focusing on the application in tourism services, we designed a conceptual synthesis of mobile technologies, positioning technologies and auction mechanisms for the hosting of Business-to-Consumer (B2C) applications in the hospitality industry. We demonstrated and analyzed an innovative architecture and a pragmatic workflow for the application of location-aware auctions of tourism services over mobile networks; furthermore, we employed standard modeling tools to describe the core entities, participants and transactional information workflow. At the same time, we addressed and highlighted the benefits of conducting location-sensitive electronic and mobile auctions to increase capacity utilization.

We then exhibited an e-auction marketplace for freight transport services trading and expanded it so as to gain advantage of spatial attributes by deploying location-sensitive information retrieval and processing technology. The proposed marketplace can support both forward and reverse auction formats where the auction initiators are the carrier and shipper respectively. The proposed business model utilizes wireless positioning in a bi-directional way: (i) to automatically locate current users location and select which of them may act as potential bidders, and, (ii) to identify which LBS are important for each user according to carriers' trucks current location, direction and speed. Operationally, it is designed to support the three core mobility dimensions, namely: (i) Spatiality (Where), (ii) Temporality (When), and (iii) Context (What way, circumstance (e.g., available capacity), towards which actor(s)). Finally, we extended the marketplace proposed in Emiris et al., (2007) in a way to support initiation of trade either by carriers or by shippers, provision of value-added spatial services ("guide-me", "find-me", "get-together"), and co-operation of small carriers.

Technically, the proposed marketplace is based on the integration of Internet communication (wired), mobile communication (wireless) and GPS (satellite) networks. An additional property of the proposed scheme focusing on evaluation and selection of supplier of freight transport service (carrier) based on spatial and temporal characteristics. It describes how the proposed auction architecture reduces bidding complexity by converting a multi-attribute auction process to a single-attribute bidding auction.

Finally, Chapter 6 presented how l-auctions can enhance RM contexts. First, it demonstrated when and how auctions operate as complementary RM mechanism in Logistics-related services enhancing the price-setting process, secondly, it aligned RM and auctions with the recent ICT advances, and finally, it described how the use of Location Based Services (LBS) may improve the market efficiency.

8.1.6 Question 6

Can we determine auction parameters by observing participants' behavior in a way to simultaneously train them?

In Chapter 7 we spotted temporal and functional conditions for the application of m-auctions and evaluated the behavior of bidders for two distinct auction mechanisms. The benefits of incorporation of location-related premiums in the evaluation of bids were highlighted and a systemic architecture for implementation of the setting was proposed. The findings of this work strengthen the argument that m-auctions may be an efficient pricing mechanism for perishable assets and can lead to beneficial results for the involved parties; furthermore, when m-auctions are combined with LBS they may provide an ideal tool for capturing *time-critical* offers from *on-the-move* bidders and they are efficient for screening bids so as to isolate the ones that are of viable interest.

We developed an emulated marketplace as the basis for a series of behavioral experiments in a laboratory setting using a simulation research tool (z-Tree). Experimental results related to both the market efficiency and the participants' behavior were encouraging and validated the proposed methodology.

8.2 Contribution Revisited: a Summary of Business and Practical Implications

In addition to answering the above research questions, the thesis presented a series of concepts and findings which can be further expanded and utilized to enhance and develop practical applications. These are briefly presented in the sequel.

8.2.1 Auction Classification Ecosystem

The ACE-Level-1 presented in Chapter 2 is quite comprehensive even for the non-economics literate practitioner and offers a systematic representation of a wide range of auction types and mechanisms. Additionally, ACE-Level-3 zooms into market-making and ICT-related issues for the development of auction marketplaces. As a result, ACE can be used as an interfacing template between economists, market practitioners and IT developers enhancing collaboration for the realistic confrontation of design problems. Respective Chapters use examples to explain the usage of ACE to auctioneers, bidders and researchers.

Our research currently focused on collecting and categorizing these scientific efforts, and unifying them along with all primitive or advanced taxonomical parameters, in a single and complete ecosystem. It is evident from these statements that our aim is to unify all classification attempts and all taxonomical parameters in one scheme. The proposed ACE (as shown in this thesis) is an applicable tool for researchers to cope with these design problems.

8.2.2 Decision-Making Support for Multi-Dimensional Auctions

The second level in essence digs into detail the auction parameters and further crisps the taxonomy effort. In particular, the second level is valuable for the expert auction designer who wishes to shape the auction by determining mechanism parameters not evident in the first level. As a result, the benefits of the classification exposed in the second level are that: (i) it constitutes a natural extension and deepening into the study of auction design and handling, (ii) it serves as a tool to design efficient, fair, and structured (thus safer) auction schemes, and (iii) it can be used as a communication media between auction practitioners or the operational researcher. We have listed the benefits and enriched our description with paradigms on how each interested group may profit from the use of these models. Uniformity of proposed models reflects simplicity of approach and ease-of-use. Finally, special attention has been given to the usability of the models. Thus, plug-in models contain models that are useful for both the auctioneer and the bidder.

8.2.3 Revenue Management

Application of auctions in the RM context is rather limited. The present work comes to bridge this gap through the incorporation of l-auctions within a RM-based pricing scheme in a macro-temporal manner. The benefits of incorporating location-related premiums in the evaluation of bids in this auction-based pricing period are highlighted. With these application opportunities in mind, we proposed a systemic architecture for implementation of the setting in a freight transportation marketplace. From a logistical point of view, we presented appropriate pricing strategies for different classes of shippers based on service characteristics and proposed a macroscopic sequence frame presenting the timing for each pricing strategy.

8.2.4 Progressive Behavioral Auction Design

ICT serves as an ideal environment for the application of almost any auction format. Yet, the application of complex auction formats is not always successful. One of the most common mistakes in the auction design is that the designer ignores participants' knowledge and experience and assumes that they are ideally rational. In the present work we developed a *progressive design* methodology which proposes to begin from a simple mechanism and gradually enhance it with additional characteristics and parameters; furthermore, it proposes the simultaneous experimental testing utilizing z-Tree as a testbed, in order to acquire information related to potential participants' behaviour. This methodology is highly integrated with ACE formulating an important design tool for the auction practitioner.

8.2.5 Potential Applications

This thesis coins the term "*l-auction*" to denote auctions conducted over mobile networks, offering: (i) on-the-move participation and (ii) adaptation of mechanism to current spatial characteristics of participants or auctioned item (or both). We proposed that l-auctions are applicable in almost any auction instance. Yet, the most successful candidate markets are those that participants and/or items have a high location and/or time information content. We proposed two market settings (tourism and freight transportation), the complementarity in modern pricing mechanisms (RM) and four functionalities (bidders' pre-screening, automated multi-attribute bidding, collaboration/subcontracting and spatial subsidizing). Overall, the proposed applications provide synthesis of relevant research since they combine concepts, tools and methodologies from several areas for example, auctions, operations, research, ICT, RM, logistics and tourism management. We believe that the presentation structure for each proposed application leads rationally to the synthesis of hypothesis.

Based on a widely-used marketing channel (m-commerce) we propose LBS-supported auctions as a new pricing mechanism for last-hour offerings of unused capacity that acts complementarily to other methods, and specifically captures the last minute buyers or sellers. Several architectures have been proposed to highlight not only the participants and their roles, but also their ways of interaction even to the non-technically expert. The proposed models are based on the UML notation and focuses mainly on the business process instead of technical infrastructure. The use-case examples have been based on the proposed models and not vice-versa. These models are generic and several applications (including the examples described) emanate from them.

Special attention was given to the basic adoption drivers in each application; most of them represent QoS attributes of the service (fairness, low-cost, speed of transactions, easiness etc.) which are discussed separately in each proposed application. Basic ICT-related issues are discussed for integrity, focusing only on an overview and applications of ICT in price definition, allocation and capacity utilization of resources; issues like disintermediation and other side-effects are concisely stated.

Focusing on the application in tourism services, although the illustrative example refers to hotel room booking, we support that the proposed model may equally well serve any capacity-related service (car hire, bus/train/air tickets, restaurants, etc.) complementary to a revenue management policy. The Hotel case is at the core of tourism services and presents many similarities to other relevant services, such as, air-tickets. The fact that hotels are centered in the hospitality industry and at the focus of attention in research work, is also reflected in the large number of scientific publications that adopt the hotel case as a fundamental example.

8.3 Directions for Further Research

We believe that this thesis merits for further study in multiple research areas and additional examination of potential applications in several business areas. In our analysis we considered the problem from a multifaceted viewpoint and we finally identified several areas for further research which can be classified in auctions, knowledge, behavior, ICT and applications. Some of these areas/issues are currently investigated by our research team.

8.3.1 Customizing of Auctions

It is anticipated that ACE model will serve as a robust and coherent basis for future research in the area of auctions and their applications, as it encompasses a dominant portion of recent research works. It is also expected that the proposed Auctions Ecosystem will be used as the foundation of further growth in the taxonomy of auctions.

In the future, the ACE will be further expanded to incorporate the interrelationship between parameters for auction efficiency, outcomes and vulnerabilities. An ongoing effort focuses in the adaptation of the ecosystem so as to serve as the basis for the development of a knowledge base / expert system that can be integrated in DSS for auction participants. For example, in the area of auction mechanism design, the definition of optimal duration of each phase and the amount of service capacity being traded requires a more focused and extended research, as well as the use of alternative auction schemes (pure, hybrid or custom) in order to obtain more accurate and stable results.

Focusing on multi-dimensional auction plug-ins, it is expected that the results of this research will trigger further investigation in the association between auction theory, decision making and knowledge management; moreover, we presume that it will serve as the basis for the development of new tools and IT applications supporting the design and execution of multidimensional formats. It is believed that the results can be combined for the development of a knowledge base aiming to guide potential auction participants and stakeholders.

The proposed template contains the core structure and most common parameters used in multi-dimensional auctions. These templates may thus be used for an extended and more systematic literature review on multi-dimensional auctions by assigning specific research attempts and findings to proper elements, options and constraints used on the template. The models are thus useful for the representation of the evolution of literature, related findings, tools and methods. Once the core structure of the graph representations is validated, it may serve in the future for the development of classification systems for auctions. Finally, the mapping may be flourished with logical elements in order to support dependencies and interrelationships between decision elements, options and constraints and may lead on research on how to move from these templates to standard modeling and application development tools.

8.3.2 Applications

Despite the fact that the model presented for the application of l-auctions in the tourism section is still in the phase of mature systemic design, it has the potential to trigger intra-discipline research in the areas of tourism services, auction theory and mobile communications. In a nutshell, m-commerce and relevant value-adding services like LBS has many properties for all marketplace participants. Based on the literature and the concepts exposed, interesting questions may arise: How is a service provider affected by disintermediation? How easy is it to modify the model for simultaneous trading of multiple complementary services (e.g., air tickets and hotel rooms) for one stop-shopping? How are real-time transactions affecting the final market outcome? Which is the optimal duration of an auction process? Can multimedia advertising material be embedded within the marketplace or the interface? In which way the model can be expanded to allow the formation of cooperative alliances between service providers? What tools are important in order to safeguard the marketplace from vulnerabilities and ensure continuous operation? In what degree can the marketplace be customized to offer personalized services? What is the most attractive mobile and Internet interface allowing interactivity between participants? How can the model be modified to support service customization and self-building of tourism service? In which ways intelligent computing (e.g., intelligent agents) can support participants?

A future extensive research on potential stakeholders' intentions would be of great interest providing more accurate results related to business implications of the proposed conceptual markets, acceptance of innovativeness, perceived practicality, added-value, auctioned services appropriateness etc. We are currently in the process of designing an extensive and profound research to overcome the limitations (geographical and sample) and to encompass findings from the broader literature concerning managerial implications.

Subsequent research steps thus focus on the extension of the proposed LBS-based marketplace to support negotiation in characteristics beyond price like time, quality, etc. (multi-attribute auctions), and bidding on more than one complementary service (multi-item and combinatorial auctions). The process can be easily reversed with slight modifications to support *reverse* auctions allowing travelers to request service and providers to compete by offering lower prices; in this case, the hotel owners may submit bids for the lowest price for tourists located within a specific geographic area (within a radius) based on LBS. Finally, the architecture will be extended to allow trading and cooperation between tourism service providers to offer integrated services through a virtual network of enterprises forming a "holonic" enterprise.

Focusing on the analysis of potential applications of l-auctions in the freight transportation services, several opportunities for further research arise. By nature, freight transport services cannot benefit from economies of scale but they may benefit from economies of scope. Such economies may be supported via multi-dimensional auctions. A typical example is the simultaneous auctioning of a number of lines where carriers bid on bundles of complementary lines creating times more value (combinatorial auctions). Such auction mechanisms bear three important difficulties: (i) they impose additional data volume exchange in the trading process; (ii) bidding process becomes more complex especially via mobile devices, and, (iii) the winner determination problem becomes more complex therefore Operations Research methodologies and algorithms and IT support is indispensable. Extension of the proposed system to support such auctions is an area for future research. Future research steps will examine the application of LBS for automatic gathering and evaluation of other logistics attributes along with a trip temporal characteristics.

8.3.3 ICT Challenges

Having in mind that speech is the elementary and most efficient means of communication it is believed that voice interfaces development will be beneficial for any mobile electronic market. A voice interface does not have the limitations of a typical mobile device: small screen size, slow typing speed and inconvenient keyboard. From a service provider's point-of-view it offers 24/7 operation with the use of automatic voice technology. Of course voice enabled services are still not mature: first, voice recognition is not always successful and second, they are not multi-lingual. Such problems can be confronted with the use of standard messages after language selection by the user. Although hard to design and implement, it offers some critical advantages: hands-free operation and user participation while driving, less time and effort for bid submission especially for complex auction formats like multi-attribute and combinatorial. Finally, in the area of ICT research and applications, the integration with existing logistics operations information systems and development of software agents for carriers in order to simplify the bidding process, poses a technological and systemic challenge worth investigating.

8.3.4 Revenue Management

Our results in the area of application of auctions complementary to RM, opens a wide range for future research. Currently, the identification of the logic of transition between different pricing methodologies (from fixed pricing to RM pricing and then to auction-based pricing and allocation) forms a research gap which needs to be bridged. Finally, the concepts, findings and propositions in this thesis, may well be extended, adopted and generalized in several other application areas that are currently treated with pure RM methods, such as tourism services; the present thesis establishes a solid ground towards these efforts.

Advanced multidimensional auction mechanisms may also serve for specific forms of RM systems. We claim that multi-attribute auctions can support the implementation of nesting strategies based on qualitative attributes of the service while multi-item combinatorial auction formats can support network RM strategies. The case presented in this article can be further expanded to support not only a single truck but a fleet; furthermore, the LC may auction simultaneously shipments in multiple lanes. If interdependencies between these lanes exist and carriers are allowed to bid in combinations (bundles) of lanes, then a combinatorial auction format should be used. In that case, the allocation problem becomes very complex and the solution (determination of winners and corresponding allocation prices) needs the use of advanced optimization methods or heuristics. The examination of how a RM strategy may alleviate the computational effort in such problems is of particular interest.

8.3.5 Behavioral Analysis

In the domain of behavioral analysis, it appears promising to avail effort on these knowledge management components that affect participants' decision-making process, such as, participation or not, evaluation metrics for market information, establishment of a price-time counterbalancing bidding strategy, etc. Additionally, decision parameters may be further analyzed and weighted in order to identify their relative importance in specific market contexts. Then a proper sensitivity analysis may reveal how these parameters actually affect the market outcomes. Finally, one of the most exciting research areas for this analysis is the study of behavior with the use of computational intelligence tools and techniques.

In this work, we dealt with six representative cases of auction settings as last-minute RM mechanism in the context of on-the-move carriers with location sensitivity. Our results have shown that there exist interesting findings, concerning not only the operation of the pricing mechanism, but most importantly, the investigation of participants' behavior. It is obvious that multiple sibling cases may result by altering only a few parameters at a time, be experimenting with the number and the profile of the participants or with the award criteria, by considering other application areas, etc. Therefore, the present study serves as the foundation for conducting such research.

Future research will focus on more extensive and realistic experimentation with larger number of participants for this and other business cases. Finally, the concepts, findings and propositions in this article, may well be extended, adopted and generalized in several other application areas that are currently treated with pure RM methods, such as tourism services; the present article establishes a solid ground towards these efforts.

Appendix A

Experimental Setting in z-Tree

In this Appendix we present a detailed analysis of the two experimental settings developed in z-Tree programming environment. For each of the two experiments, we present a detailed analysis of the programming modules accompanied with a short description. Next, we present some indicative snapshots from the experiments and results. For each experiment we also provide the source code.

A.1. Experimental Setting of the FPSB Auction

A.1.1 Program Development

In the *General Parameters* of the program (Figure A.1) we define the number of *subjects* (participants) which for the complete set of our experiments is defined to 20 all of them assigned to a single group. We first apply 5 *practice periods* in order to train participants and make them familiar with the experimental environment. We then apply 1 *paying period* – one active experiment for each auction type. Since we use *monetary* units instead of real currency, we don't need to define specific exchange rates.

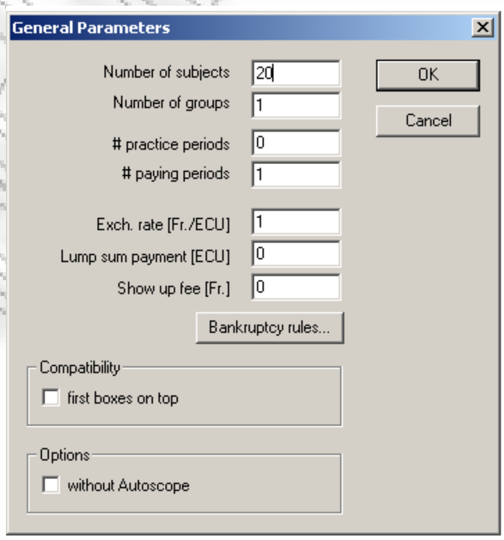

Figure A.1: *General Parameters Screen*

Next, we define the constants of our experiment which is common for all participants (Figure A.2). We define this in the *subjects* table of the *global* parameters of the program, being common for all participants. These constants are the *ParticipationFee* (defined as 20 monetary units) and the *Cost* of the project (defined as 300 monetary units).

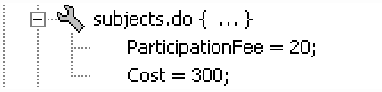

Figure A.2: *Definition of Constants for FPSB Auction*

The first stage of the program (defined as *Participation*) contains the welcome screen and asks participants whether they wish to join the experiment by pressing an "OK" button (Figure A.3). Each participant should decide and agree within 10 seconds.

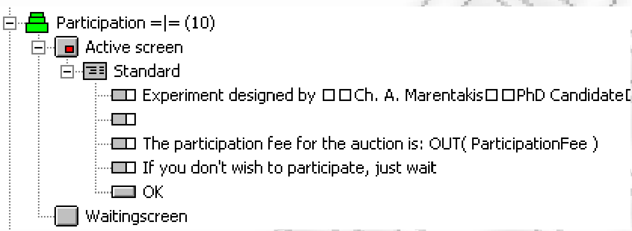

Figure A.3: *First Stage – Participation in FPSB Auction*

The second stage of the program (defined as *BidSubmission*) requests each participant to submit his bid into an appropriate field within 2 minutes (Figure A.4). Submission is confirmed by pressing an "OK" button.

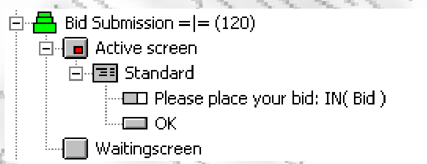

Figure A.4: *Second Stage – Bid Submission in FPSB Auction*

We have specified upper and lower bid margins which corresponds to the market price (as reserve price) and bidders' cost (as lower price) (Figure A.5). Lower price is used mainly in the training session rejecting bids below cost which are not rational.

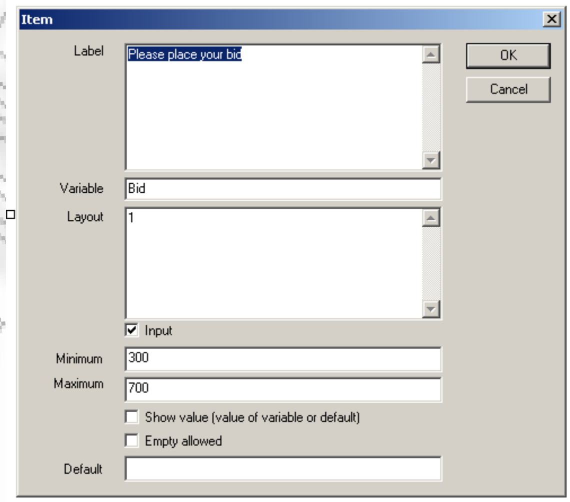

Figure A.5: *Bid Margins in FPSB Auction*

The third stage of the project calculates the winning bids and announces appropriate information to participants (Figure A.6). In the simple reverse FPSB auction the program selects the minimum submitted bid and assigns it to the variable *WinningBid*. We then count the number of participants (*N)* who joined the auction by submitting bid in order to calculate the *Fees* collected from the auction. We finally calculate the *Winner'sRevenue* based on his bid reduced by the fee he paid for the participation and the actual project cost. All participants are notified in a separate screen presenting information about the winning bid and the number of rivals (*N-1*).

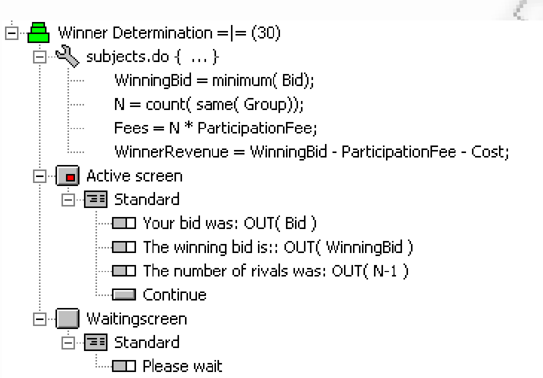

Figure A.6: *Winner Determination in FPSB Auction*

A.1.2 Execution of Experiment

We used the *Clients' Table* to monitor participants. Figure A.7 shows a typical view of the client's table before the start of the experiment.

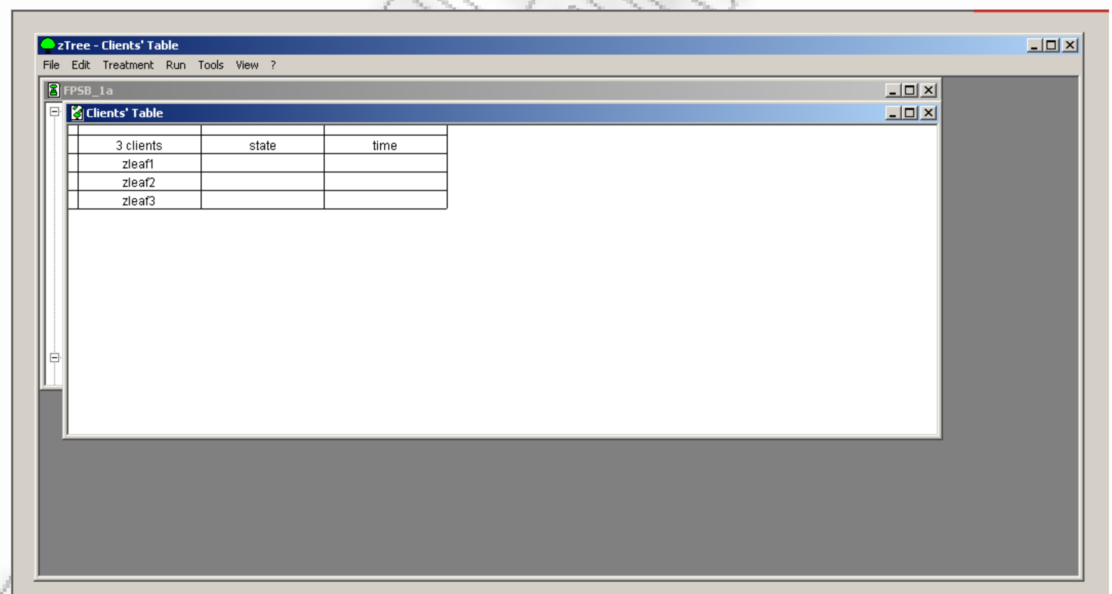

Figure A.7: *Participants Monitoring Screen in FPSB Auction*

When participants run their clients, then each client is characterized as "ready" in the *Clients' Table* (Figure A.8).

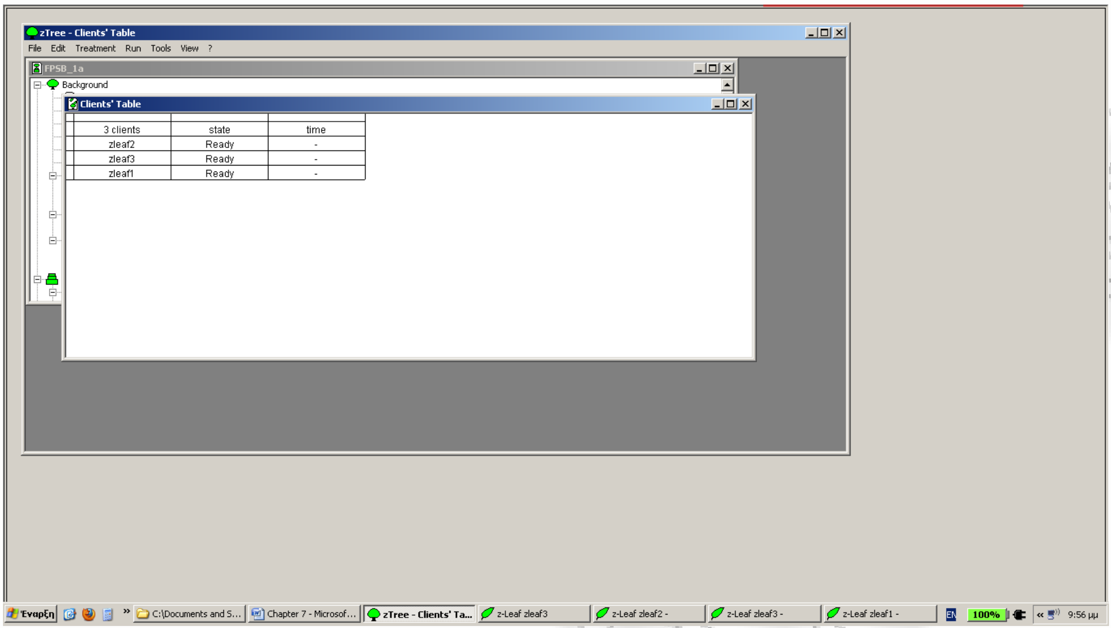

Figure A.8: *Participants Monitoring Screen – Active Participants in FPSB Auction*

All participants see simultaneously the same welcome screen of z-Leaf client presenting application-related information (Figure A.9)

Figure A.9: *Welcome Screen*

Next, each participant sees the participation screen (Figure A.10). This screen shows the current *period* (if multiple periods exists – for example in repeated experiments as we will see in the Dutch auction case) and the remaining time in seconds in order to decide whether to participate or not. The main part of the screen shows the participation fee amount (here 20 monetary units) and the OK button for participation.

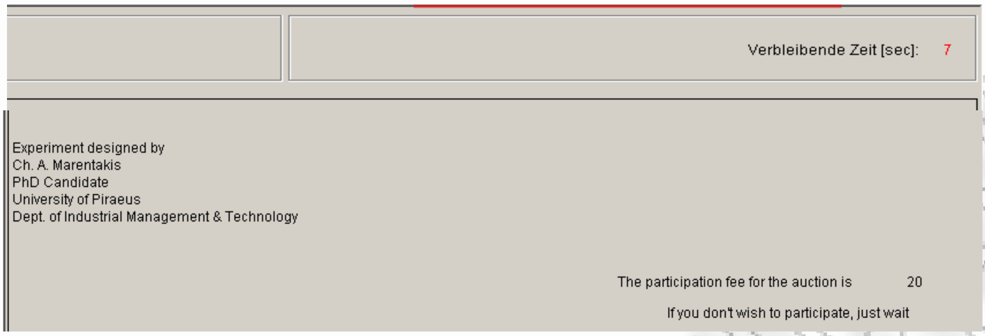

Figure A.10: *Participation Screen in FPSB Auction*

The next screen is dedicated to the submission of bid which is entered in a field in the center of the screen (Figure A.11). Bid is valid when the participant hits the OK button. Participant is allowed to validate his bid within 2 minutes – remaining time is shown in the top-right area of the screen. The restrictions related to reserve price and minimum price are active in this stage, so if the bid is outside the range defined by these parameters, an error message appears informing the bidder to modify his bid.

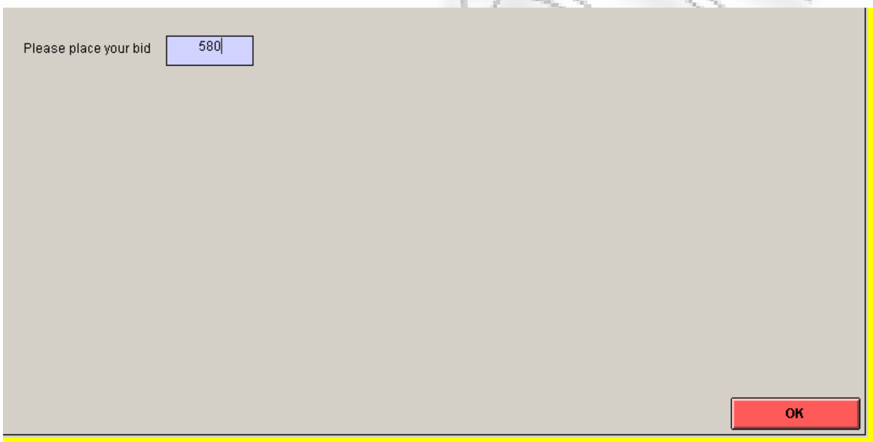

Figure A.11: *Bid Submission Screen in FPSB Auction*

When the time expires, the program calculates the current participant's bid, winning bid and number of opponents and displays them appropriately to corresponding participants (both winner and non-winners) (Figure A.12). Furthermore it calculates revenues and commissions from participation fees and stores them in an Excel table.

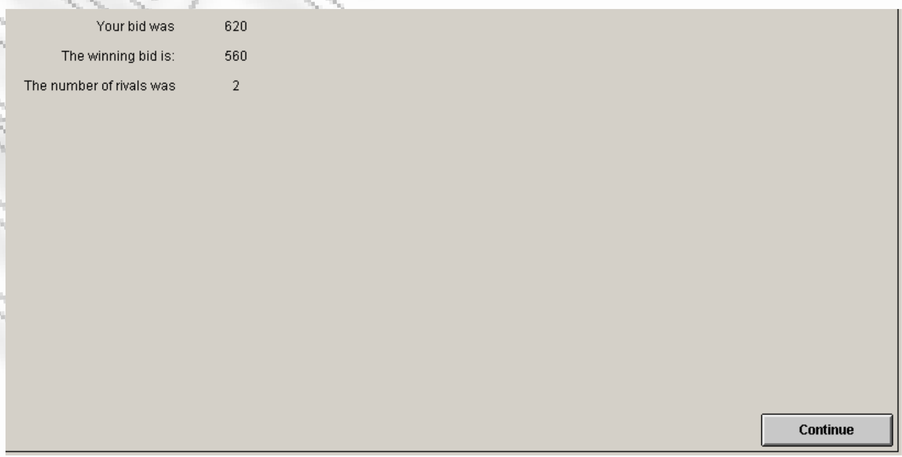

Figure A.12: *FPSB Auction Ending Screen*

A.1.3 Results

The results of the experiments are summarized in Table A.1

100825_2143	1	globals	Period	NumPeriods	RepeatTreatment													
100825_2143	1	globals	1	1	0													
100825_2143	1	subjects	Period	Subject	Group	Profit	TotalProfit	Participate	ParticipationFee	Cost	TimeOKParticipation OK	Bid	TimeOKBidSubmissio nOK	WinningBid	N	Fees	WinnerRevenue	TimeContinueWinner DeterminationOK
100825_2143	1	subjects	1	1	1	0	0	1	20	300	0	610	70	560	3	60	240	11
100825_2143	1	subjects	1	2	1	0	0	1	20	300	-	560	77	560	3	60	240	9
100825_2143	1	subjects	1	3	1	0	0	1	20	300	-	580	87	560	3	60	240	7
100825_2143	1	summary	Period															
100825_2143	1	summary	1															
100825_2143	1	session	Subject	FinalProfit	ShowUpFee	ShowUpFeeInvested	MoneyAdded	MoneyToPay	MoneyEarned									
100825_2143	1	session	1	0	0	0	0	0	0									
100825_2143	1	session	2	0	0	0	0	0	0									
100825_2143	1	session	3	0	0	0	0	0	0									

Table A.1: *Summary of Results in FPSB Auction (example)*

A.1.4 Source Code

Next, we present the source code we developed for the FPSB experiment.

```
treatment "FPSB_1a"{
    background{
      table globals{
      }
      table subjects{
      }
      table summary{
      }
      table contracts{
      }
      table session{
      }
      table logfile{
      }
      numsubjects = 3;
      numgroups = 1;
      numpracticeperiods = 0;
      numactualperiods = 1;
      exchangerate = 1;
      startendowment = 0;
      showupfee = 0;
      noAutoscope = FALSE;
      v2IntegerVars = TRUE;
      v2BooleanVars = TRUE;
```

```
      firstBoxesOnTop = FALSE;
      showupfeeawaytext = "Sie haben Verlust gemacht. Wollen Sie das Startgeld
einsetzen, um diesen Verlust zu decken?";
      showupfeeawayyestext = "Ja";
      showupfeeawaynotext = "Nein";
      moneyawaytext = "Sie haben Verlust gemacht. Wollen Sie weiterfahren?";
      moneyawayyestext = "Ja";
      moneyawaynotext = "Nein";
      bancruptwaittext = "Bitte warten Sie, bis Ihr Computer wieder freigegeben
wird.";
      program{
            table = subjects;
            do{
                  ParticipationFee = 20;
                  Cost = 300;

            }
      }
      screen action{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            headerbox "Header"{
                  hasframe = TRUE;
                  height = 10%;
                  top = 0p;
                  cuttop = TRUE;
                  showPeriods = TRUE;
                  showNumPeriods = TRUE;
                  periodtext = "Periode";
                  periodoftext = "von";
                  practiceperiodprefix = "Probe ";
                  showtime = TRUE;
                  timestr = "Verbleibende Zeit [sec]:";
                  pleasedecidetext = "Bitte entscheiden Sie sich jetzt !";
            }
      }
      screen wait{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            standardbox "Text"{
                  hasframe = TRUE;
                  buttonposition = BOTTOMRIGHT;
                  buttonsequence = HORIZONTAL;
                  item{
                        label = "Please  wait";
                  }
            }
      }
    }
    stage "Participation"{
      startwaitforall = TRUE;
      singleentry = FALSE;
      singleentrycontinuation = FALSE;
      timeouttype = ifnoinput;
      timeout = 10;
      screen action{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            standardbox "Standard"{
                  hasframe = TRUE;
                  buttonposition = BOTTOMRIGHT;
                  buttonsequence = HORIZONTAL;
                  item{
                        label = "Experiment designed by \r\nCh. A. Marentakis\r\nPhD
Candidate\r\nUniversity of Piraeus\r\nDept. of Industrial Management & Technology";
                  }
                  item{
                  }
                  item{
                        label = "The participation fee for the auction is";
                        variable = ParticipationFee;
                        format = "1";
                        input = FALSE;
```

```
                }
                item{
                      label = "If you don't wish to participate, just wait";
                }
                button "OK"{
                      clearinputafterok = FALSE;
                      norecordmadeorselected = FALSE;
                      terminatestage = FALSE;
                      donotterminatestage = FALSE;
                      specialbuttoncolor = FALSE;
                      buttoncolor = 0;
                }
          }
    }
    screen wait{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
    }
  }
  stage "Bid Submission"{
    startwaitforall = TRUE;
    singleentry = FALSE;
    singleentrycontinuation = FALSE;
    timeouttype = ifnoinput;
    timeout = 120;
    screen action{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
          standardbox "Standard"{
                hasframe = TRUE;
                buttonposition = BOTTOMRIGHT;
                buttonsequence = HORIZONTAL;
                item{
                      label = "Please place your bid";
                      variable = Bid;
                      format = "1";
                      input = TRUE;
                      showdefault = FALSE;
                      emptyallowed = FALSE;
                      min = 300;
                      max = 700;
                }
                button "OK"{
                      clearinputafterok = FALSE;
                      norecordmadeorselected = FALSE;
                      terminatestage = FALSE;
                      donotterminatestage = FALSE;
                      specialbuttoncolor = FALSE;
                      buttoncolor = 0;
                }
          }
    }
    screen wait{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
    }
  }
  stage "Winner Determination"{
    startwaitforall = TRUE;
    singleentry = FALSE;
    singleentrycontinuation = FALSE;
    timeouttype = ifnoinput;
    timeout = 30;
    program{
          table = subjects;
          do{
                WinningBid = minimum( Bid);
                N = count( same( Group));
                Fees = N * ParticipationFee;
                WinnerRevenue = WinningBid - ParticipationFee - Cost;
          }
    }
    screen action{
```

```
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            standardbox "Standard"{
                  hasframe = TRUE;
                  buttonposition = BOTTOMRIGHT;
                  buttonsequence = HORIZONTAL;
                  item{
                        label = "Your bid was";
                        variable = Bid;
                        format = "1";
                        input = FALSE;
                  }
                  item{
                        label = "The winning bid is:";
                        variable = WinningBid;
                        format = "1";
                        input = FALSE;
                  }
                  item{
                        label = "The number of rivals was";
                        variable = N-1;
                        format = "1";
                        input = FALSE;
                  }
                  button "Continue"{
                        clearinputafterok = FALSE;
                        norecordmadeorselected = FALSE;
                        terminatestage = FALSE;
                        donotterminatestage = FALSE;
                        specialbuttoncolor = FALSE;
                        buttoncolor = 0;
                  }
            }
      }
      screen wait{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            standardbox "Standard"{
                  hasframe = TRUE;
                  buttonposition = BOTTOMRIGHT;
                  buttonsequence = HORIZONTAL;
                  item{
                        label = "Please wait";
                  }
            }
      }
    }
    roles{
      role "S 1"{
      }
      role "S 2"{
      }
      role "S 3"{
      }
    }
    period "1"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
      subject 3{
            group = 1;
      }
    }
}
```

A.2. Experimental Setting of the Dutch Auction

A.2.1 Program Development

Same as in FPSB experiment, in the *General Parameters* of the program we define the number of *subjects* (participants) which for the complete set of our experiments is defined to 20 all of them assigned to a single group. We first apply 5 *practice periods* in order to train participants and make them familiar with the experimental environment. We then apply 1 *paying period* – one active experiment for each auction type. Since we use *monetary* units instead of real currency, we don't need to define specific exchange rates.

Next, we define the constants of our experiment which is common for all participants (Figure A.13). We define this in the *subjects* table of the *global* parameters of the program, being common for all participants. These constants are the *Budget* (defines as 100 monetary units) and the *Cost* of the project (defined as 400 monetary units).

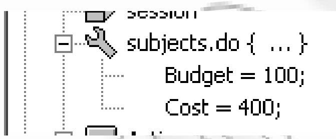

Figure A.13: *Definition of Constants for Dutch Auction*

In the main stage of the program (defined as *Auction2A*) we define the initial state of participants and the price evolution parameters (Figure A.14). More specifically, in the *subjects* table we define a dummy variable *myBid* assigning it the imaginary value -1 which represents a no-bid state (actually waiting for bid). We also initialize bidders' revenue (variable *myRevenue)*. We then define the starting price (*Price)* for the Dutch auction, the auction clock (*Delay)* and we use the command *Repeat* for the countdown increment as defined by the *delay* variable and *Later* command. We have defined two ending conditions; a) clock duration and b) a maximum price which when reached without bid submission, the auction ends. When a participant stops the auction clock the variable *WinBid* stores the current price at this time.

In Figure A.14 we have put as comments the different combinations of *Increment* and *Delay* representing Dutch auction clock parameters, each for every experiment variation.

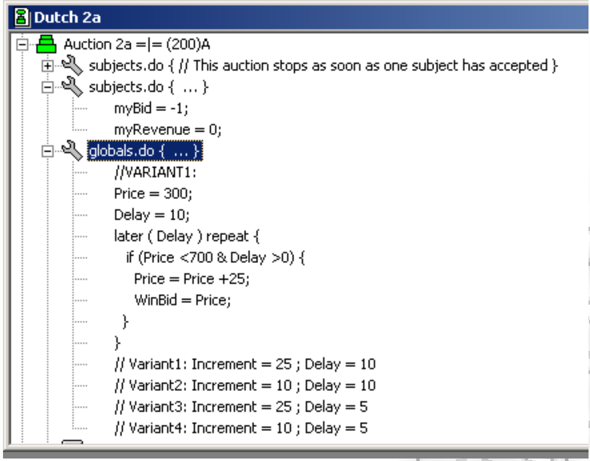

Figure A.14: *Definition of Increment and Delay Parameters in Dutch Auction*

In Figure A.15 we show additional elements of the active screen (main part) displayed during the auction evolution amongst of which is the price at each moment. Next, we define what happens when a participants accepts a price by stopping the auction clock; first we check whether more than one participants simultaneously stopped the clock. We then assign the value 0 to *myBid* variable in order to characterize the winner and we calculate winner's revenue assigning the result to *myRevenue* variable of the *subjects* table.

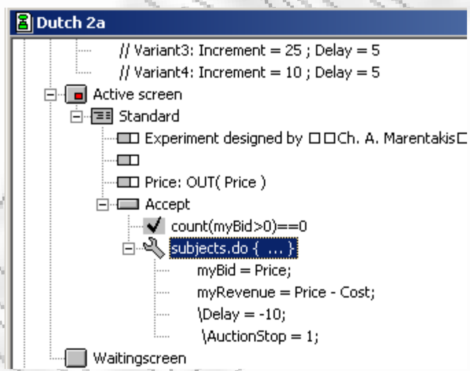

Figure A.15: *Bidding Screen and Bid Calculations*

In the final stage (Figure A.16), a new screen appears for 30 seconds to all participants presenting different types of information; non-winning bidders are informed that someone else won the auction while the winner is informed about winning price and his net revenue.

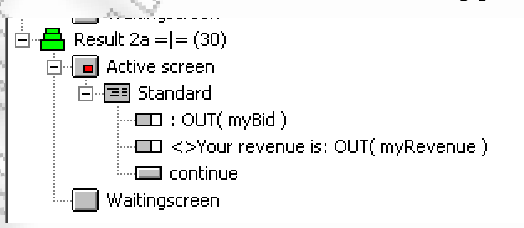

Figure A.16: *Dutch Auction Ending Results*

Different messages for winners and non-winners are displayed using the *myBid* as defined in Figure A.17.

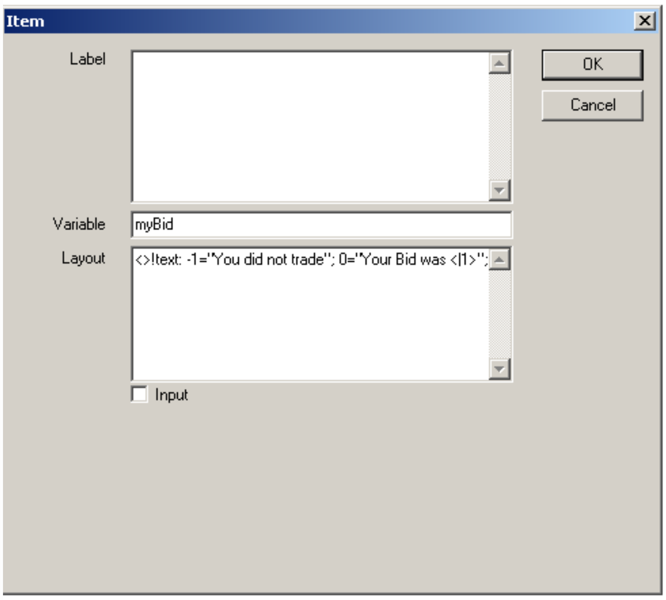

Figure A.17: *Definition of Messages for Participants in Dutch Auction*

A.2.2 Execution of Experiment

When the experiment begins, each participant sees the participation screen (Figure A.18). This screen shows the current *period* out of 10 repetitions in total for each clock speed/price step combination variant. In the top-right area of the screen a clock shows the remaining auction time in seconds. The center of the screen displays the current price which gradually increases (please remind that we experiment a reverse Dutch auction). Finally, in the bottom-right area of the screen, a button *Accept* waits for participant's action; when any of the participants his this button the auction ends.

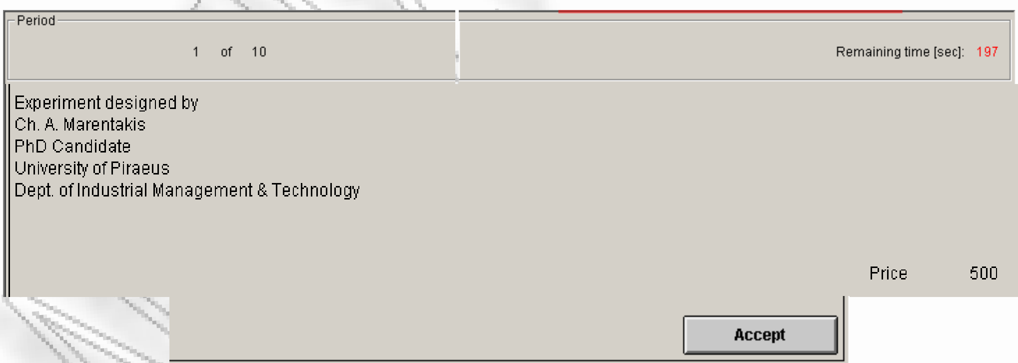

Figure A.18: *Participation Screen in Dutch Auction ("Clock" Screen)*

Immediately after the end of the auction winner's screen displays the winning bid and the net revenue after taking into account project's cost (Figure A.19)

Figure A.19: *Winner's Screen in Dutch Auction*

Remaining bidders are informed with a message "*You did not trade*" (Figure A.20) indicating also that their revenue for the current period is 0.

Figure A.20: *Losing Bidders' Screen in Dutch Auction*

If the winning bidder accepts a price which is lower than his costs, then he is informed accordingly about the final negative revenue (Figure A.21)

Figure A.21: *Winner's Message Screen when Price is Lower than Cost*

Both winner's and non-winners' screens have a "*Continue*" button in the bottom-right area of the screen. The experiment proceeds to the next period when all participants have pressed this button.

A.2.3 Results

The results of the experiments are summarized in Table A.2.

100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	1	10	0	700	-1	700	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	1	1	1	0	0	1	100	400	-1	0	0	20
100825_2224	1	subjects	1	2	1	0	0	1	100	400	700	300	186	30
100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	2	10	0	400	-1	400	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	2	1	1	0	0	1	100	400	400	0	199	18
100825_2224	1	subjects	2	2	1	0	0	1	100	400	-1	0	0	28
100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	3	10	0	550	-1	550	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	3	1	1	0	0	1	100	400	550	150	196	10
100825_2224	1	subjects	3	2	1	0	0	1	100	400	-1	0	0	12
100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	4	10	0	550	-1	550	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	4	1	1	0	0	1	100	400	550	150	196	2
100825_2224	1	subjects	4	2	1	0	0	1	100	400	-1	0	0	5
100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	5	10	0	350	-1	350	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	5	1	1	0	0	1	100	400	350	-50	200	15
100825_2224	1	subjects	5	2	1	0	0	1	100	400	-1	0	0	13
100825_2224	1	globals	Period	NumPeriods	RepeatTreatment	Price	Delay	WinBid	AuctionStop	AuctionNoStop				
100825_2224	1	globals	6	10	0	700	-1	700	1	0				
100825_2224	1	subjects	Period	Subject	Group	Profit	TotalProfi	Participate	Budget	Cost	myBid	myRevenue	TimeAcceptAu	TimeContinueResult2aOK
100825_2224	1	subjects	6	1	1	0	0	1	100	400	-1	0	0	28
100825_2224	1	subjects	6	2	1	0	0	1	100	400	700	300	192	30
100825_2224	1	summary	Period											
100825_2224	1	summary	1											
100825_2224	1	summary	2											
100825_2224	1	summary	3											
100825_2224	1	summary	4											
100825_2224	1	summary	5											
100825_2224	1	summary	6											
100825_2224	1	session	Subject	FinalProfit	ShowUpFee	ShowUpFee	MoneyAd	MoneyToPay	MoneyEarned					
100825_2224	1	session	1	0	20	0	0	20	20					
100825_2224	1	session	2	0	20	0	0	20	20					

Table A.2: *Summary of Results in Dutch Auction (example)*

A.2.4 Source Code

Finally, we present the source code we developed for the FPSB experiment.

```
treatment "Dutch 2a"{
    background{
      table globals{
      }
      table subjects{
      }
      table summary{
      }
      table contracts{
      }
      table session{
      }
      numsubjects = 2;
      numgroups = 1;
      numpracticeperiods = 0;
      numactualperiods = 10;
      exchangerate = 1;
      startendowment = 0;
      showupfee = 20;
      noAutoscope = FALSE;
      v2IntegerVars = TRUE;
      v2BooleanVars = TRUE;
      firstBoxesOnTop = FALSE;
      showupfeeawayyestext = "Yes";
      moneyawayyestext = "Yes";
      program{
            table = subjects;
            do{
                  Budget = 100;
                  Cost = 400;
            }
      }
      screen action{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            headerbox "Header"{
                  hasframe = TRUE;
                  height = 10%;
                  top = 0p;
                  cuttop = TRUE;
                  showPeriods = TRUE;
                  showNumPeriods = TRUE;
                  periodtext = "Period";
                  periodoftext = "of";
                  practiceperiodprefix = "Trial ";
                  showtime = TRUE;
                  timestr = "Remaining time [sec]:";
                  pleasedecidetext = "Please reach a decision.";
            }
      }
      screen wait{
            usesbg = TRUE;
            withalertscreen = FALSE;
            noalertscreen = FALSE;
            standardbox "Text"{
                  hasframe = TRUE;
                  buttonposition = BOTTOMRIGHT;
                  buttonsequence = HORIZONTAL;
                  item{
                        label = "Please wait until the experiment continues.";
                  }
            }
      }
    }
    stage "Auction 2a"{
```

```
	startwaitforall = TRUE;
	singleentry = FALSE;
	singleentrycontinuation = FALSE;
	timeouttype = always;
	timeout = 200;
	program{
		table = subjects;
		do{
			// This auction stops as soon as one subject has accepted
		}
	}
	program{
		table = subjects;
		do{
			myBid = -1;
			myRevenue = 0;

		}
	}
	program{
		table = globals;
		do{
			Price = 300;
			Delay = 1;
			later ( Delay ) repeat {
			   if (Price <700 & Delay >0) {
			     Price = Price +50;
			     WinBid = Price;
			   }
			}
			// Variant1: Increment = 25 ; Delay = 10
			// Variant2: Increment = 10 ; Delay = 10
			// Variant3: Increment = 25 ; Delay = 5
			// Variant4: Increment = 10 ; Delay = 5
		}
	}
	screen action{
		usesbg = TRUE;
		withalertscreen = FALSE;
		noalertscreen = FALSE;
		standardbox "Standard"{
			hasframe = TRUE;
			buttonposition = BOTTOMRIGHT;
			buttonsequence = HORIZONTAL;
			item{
				label = "Experiment designed by \r\nCh. A.
Marentakis\r\nPhD Candidate\r\nUniversity of Piraeus\r\nDept. of Industrial
Management & Technology";
			}
			item{
			}
			item{
				label = "Price";
				variable = Price;
				format = "1";
				input = FALSE;
			}
			button "Accept"{
				clearinputafterok = FALSE;
				norecordmadeorselected = FALSE;
				terminatestage = FALSE;
				donotterminatestage = FALSE;
				specialbuttoncolor = FALSE;
				buttoncolor = 0;
				checker{
					condition = count(myBid>0)==0;
					message = "Another participant was quicker";
					noButtonStr = "OK";
```

```
                    }
                    program{
                         table = subjects;
                         do{
                              myBid = Price;
                              myRevenue = Price - Cost;
                              \Delay = -1;
                               \AuctionStop = 1;

                         }
                    }
               }
          }
     }
     screen wait{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
     }
    }
    stage "Result 2a"{
     startwaitforall = TRUE;
     singleentry = FALSE;
     singleentrycontinuation = FALSE;
     timeouttype = ifnoinput;
     timeout = 30;
     screen action{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
          standardbox "Standard"{
               hasframe = TRUE;
               buttonposition = BOTTOMRIGHT;
               buttonsequence = HORIZONTAL;
               item{
                    variable = myBid;
                    format = "<>!text: -1=\"You did not trade\"; 0=\"Your
Bid was <|1>\";";
                    input = FALSE;
               }
               item{
                    label = "<>Your revenue is";
                    variable = myRevenue;
                    format = "1";
                    input = FALSE;
               }
               button "continue"{
                    clearinputafterok = FALSE;
                    norecordmadeorselected = FALSE;
                    terminatestage = FALSE;
                    donotterminatestage = FALSE;
                    specialbuttoncolor = FALSE;
                    buttoncolor = 0;
               }
          }
     }
     screen wait{
          usesbg = TRUE;
          withalertscreen = FALSE;
          noalertscreen = FALSE;
     }
    }
    roles{
     role "S 1"{
     }
     role "S 2"{
     }
    }
```

```
    period "1"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "2"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "3"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "4"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "5"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "6"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "7"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "8"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
    period "9"{
      subject 1{
            group = 1;
      }
```

```
      subject 2{
            group = 1;
      }
    }
    period "10"{
      subject 1{
            group = 1;
      }
      subject 2{
            group = 1;
      }
    }
}
```

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List of Acronyms

AA	Addaptive Attribute
AAA	Autonomous Adaptive Agents
ACE	Auction Classification Ecosystem
ACVM	Almost Common Values Model
AGPS	Assisted Global Positioning System
AHP	Analytical Hierarchy Process
AI	Artificial Intelligence
AOA	Angle of Arrival
AOP	Option Allocation Protocol
APV	Affiliated Private Value
ARM	Auction Reference Model
ASP	Application Service Provider
B2B	Business-to-Business
B2C	Business-to-Consumer
BOB	Branch-on-Bid
BVA	Binary Vickrey Auction
C2C	Consumer-to-Consumer
CA	Combinatorial Auction
CAMUS	Combinatorial Auction Multi-Search
CASS	Combinatorial Auction Structured Search
CATS	Combinatorial Auction Test Suite
CC-MAP	Closed-Cover Multi-round Auction Protocol
CDA	Continuous Double Auction
CDAs	Continuous Double Auction
COO	Cell of Origin
CPU	Central Processing Unit
CRM	Customer Relationship Management
CVA	Common Value Auctions
CVM	Common Value Model
DAB	Digital Audio Broadcasting
DAL	Descriptive Auction Language
DCFA	Decreasing Cancellation Fee Auction
DEA	Data Envelopment Analysis
DFBB	Depth First Branch and Bound
DGPS	Differential Corrected GPS
DSRC	Dedicated Short Range Communication
DSS	Decision Support System
EDI	Eectronic Data Interchange
EDT	Expectancy Disconfirmation Theory
ERP	Enterprise Resource Planning
EU	European Union
FCC	Federal Communication Commission
FM	Frequency Modulation
FPSB	First-Price Sealed-Bid
FTL	Full-Truckload
FTRs	Financial Transmission Rights
FTS	Fleet Telematics System
G2B	Government to Business
G2C	Covernment to Consumer
GEO	Geostationary Orbit
GIS	Geographic Information Systems

GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface
GVA	Generalized Vickrey Auction
H/W	Hardware
IA	Intelligent Agent
ICT	Information and Communication Technologies
IDA	Iterative Depending A*
IPO	Initial Public Offering
IPV	Independent Private Values
IPVM	Independent Private Values Model
IS	Information System
ISCA	Incompletely Specified Combinatorial Auction
IT	Information Technology
IT/IS	Information Technology / Information System
ITS	Iterative Threshold Search
KIR	Key Implementation Requirements
KP	Knapsack Problem
KPI	Key-Performance Indicators
LBS	Location-Based Services
LC	Logistics Center
LEO	Low-Earth Orbit
LP/IP	Linear Programming / Integer Programming
LTL	Less-Than-Truckload
MAGNET	Multi-Agent Negotiation Protocol
MANET	Mobile Ad Hoc Network
MAPA	Multi-Attribute Procurement Auction
MAS	Multi-Agent Systems
MC	Multi Choise
MCCA	Multi-Component Contingent Auction
MCKP	Multiple-Choice Knapsack Problem
MCS	Master Control Station
MD	Multi-Dimensional
MDKP	Multi-Dimensional Knapsack Problem
MDMCKP	Multi-Dimensional Multi-Choise Knapsack Problem
MIPEA	Multi-item Progressive Electronic Auctions
MMUCA	Mixed Multi-Unit Combinatorial Auction
MRAS	Mobile Reverse Auction System
MU	Monetary Unit
MUNCA	Multi-Unit Nondiscriminatory Combinatorial Auction
NAVSTAR	Navigation Satellite Timing and Ranging
OOAD	Object-Oriented Analysis and Design
OR	Operational Research
OS	Operation System
P2P	Peer-to-Peer
PA	Perishable Asset
PAP	Provisional Agreement Protoco
PAUSE	Progressive Adaptive User Selection Environment
PDA	Personal Data Assistant
POI	Point of Interest
PORF	Price-Oriented Rationing-Free
PPC	Pricing-Per-Column
PSP	Progressive Second Price
QUP	Quasi-Uniform-Price
R&D	Research and Development
RA	Reverse Auction
RDS	Radio Data System
RECO	Representation and Evaluation of Configurable Offers

RET	Revenue Equivalence Theorem
RFID	Radio-Frequency Identification
RFQ	Request for Quotation
RM	Revenue Management
RTFMS	Real-Time Fleet Management System
RTMA	Real-Time Multi-Auction
S/W	Software
S2S	Stakeholder to Stakeholder
SA	Selective Availability
SAA	Simultaneous Ascending Auctio
SB	Sealed-Bid
SCM	Supply Chain Management
SLS	Stochastic Local Search
SME	Small and Medium-sized Enterprise
SMS	Short Message Service
SPP	Set Packing Problem
SPSB	Second Price Sealed Bid
T&T	Track and Trace
TAC	Trading Agent Competition
TAM	Technology Acceptance Model
TBBL	Tree-Based Bidding Language
TCO	Total Cost of Ownership
TCP/IP	Transmission Control Program/Internet Protocol
TDOA	Time Difference of Arrival
TETRA	TErrestrial Trunked Radio
TL	(Full) Truckload
TTP	Trusted Third Party
UML	Unified Modeling Language
UMTS	Universal Mobile Telecommunications System
UPFR	Uniform-Price First-Rejected
UPLA	Uniform-Price Last-Accepted
VCG	Vickrey-Clarkes-Grove (mechanism)
VDA	Vickrey-Dutch Auction
VSA	Virtual Simultaneous Auction
WBR	Winning Bid Ratio
WDP	Winner Determination Problem
WOM	Word-of-Mouth
WOW	Word-of-Web
WSP	Weighted Set Packing
WTO	Willingness to Offer
WTP	Willingness To Pay
WTT	Willingness To Trade
WWW	World Wide Web
XOR	Exclusively OR
ZIP	Zero-Intelligence Plus

About the Author

Charalambos A. Marentakis was born in 1973 in Chania, Crete. He obtained a Diploma in Production Management Engineering from Technical University of Crete in 1996 specialized in Logistics Management and Operations Research. In 1997 he received a Best Diploma Thesis Award from Technical Chamber of Greece.

From 1997 to 2003 he worked as a senior Logistics and ERP consultant for many Greek and international consulting and IT companies (Planning S.A. Management Consultants, Business-Know How Ltd., SAP Hellas S.A., Accenture S.A.). Since 2004 he works for Hellenic Post S.A. From 2004 to 2009 he held the position of Head of Domestic Long-Haul and Sorting Network in Hellenic Post Courier Services (Tachymetafores EL.TA. S.A.), and from 2009 to date he is working for Hellenic Post S.A. as a Production Management Engineer involved in the implementation and operation of Telematics and GIS systems. During this period, he had also participated in two research projects related to innovative applications in fleet management and emulated vocational training respectively, and he has been involved in several professional and vocational education programs as a tutor.

In February 2004 he started as a Ph.D. student under the supervision of Associate Professor Dr. D.M. Emiris in the Department of Industrial Management and Technology at the University of Piraeus. His research resulted in several publications. He is the author or co-author in many refereed publications (4 journal research articles, 2 book chapters and more than 15 announcements in scientific conferences). During his Ph.D. studies, he has taught in several undergraduate and post-graduate semester courses in IT and Logistics areas at the University of Piraeus (post-graduate) and Technological Institute of Chalkida (undergraduate). His current research interests include revenue management, e-business, Location-based services, Logistics management and ERP systems.