

E-Business: A Review of Research Published in *Production and Operations Management* (1992–2008)

Sushil Gupta, Christos Koulamas, and George J. Kyparisis

Department of Decision Sciences and Information Systems, College of Business Administration, Florida International University, Miami, Florida 33199 guptask@fiu.edu, koulamas@fiu.edu, kyparis@fiu.edu

We review, classify, consolidate, and synthesize the contributions to the expanding field of e-business that have been published in *Production and Operations Management*. We classify e-business research in the following four categories: (1) e-auctions, (2) radio frequency identification, (3) e-business system design, and (4) competition, conflict, collaboration, and coordination (C⁴ in e-business). We identify important research themes, research methodologies, and research techniques within each of these categories. We also provide directions for future research and discuss the managerial implications of the e-business research reported in our paper.

Key words: e-business; e-auction; RFID; competition and conflict; collaboration and coordination; customer satisfaction; enablers and barriers

History: Accepted by Kalyan Singhal after 2 revisions.

1. Introduction

Developments in Internet-enabled technologies are changing the business functions, the business processes, and the structures of business organizations. Today, web-based functions span across product design, e-auction and procurement, vendor development, customer relations management, logistics and distribution, and pricing. The enabling web-based technology integrates various business functions and improves communication among business partners. Overall, the Internet has posed many challenges and has provided many opportunities to production and operations management (P/OM) researchers and practitioners. As a result, emphasis on e-business research has been growing in the academic literature.

In order to assess the current state of the research contributions in this nascent yet expanding field, we review, consolidate, and classify the recent research on e-business and provide directions for future research. Because of space constraints, we have focused on e-business papers published only in *Production and Operations Management (POM)* covering the period of 1992–2008. References to papers published in other journals are included where appropriate. In section 1.1 we propose a classification scheme for the e-business research that we have used in this paper, and in section 1.2 we present the motivation for the current survey.

1.1. Classification of E-Business Research

Primarily because of the field's infancy, there are no accepted norms in the literature for classifying

e-business research. The survey papers by Johnson and Whang (2002), Swaminathan and Tayur (2003), and Geoffrion and Krishnan (2003a, b) have documented the recent developments in e-business and their impact on the P/OM discipline. Each of the classification schemes for e-business research provided in these papers suggests slightly different categorizations of the literature. Johnson and Whang (2002) classify e-business and supply chain management research in the following three categories: (1) e-commerce, (2) e-procurement, and (3) e-collaboration. They also divide research methodologies into: (1) descriptive frameworks, (2) empirical/simulation, (3) case studies, and (4) analytical models. Swaminathan and Tayur (2003) propose the following five categories for the e-business and supply chain research: (1) procurement and supplier management, (2) visibility and information sharing, (3) pricing and distribution, (4) customization and postponement, and (5) enterprise software and decision support. Geoffrion and Krishnan (2003a, b) study e-business and management science and propose two major categories that are further subdivided into additional subcategories. These categories include: (1) information infrastructure (subdivided into [1a] from voluminous data to decisions and [1b] strategic interactions) and (2) online markets (subdivided into [2a] auctions, [2b] other price discovery mechanisms, [2c] estimating online market benefits, and [2d] e-procurement).

Based on these classification schemes and a review of the papers published in *POM* from 1992 to 2008, we have grouped the e-business research papers into the

following four categories: (1) e-auctions, (2) radio frequency identification (RFID), (3) e-business system design, and (4) C⁴ in e-business. Our reasoning for proposing the above classification scheme is as follows. The category “e-auctions” is proposed because of the increasing importance of e-auctions in procurement decisions. E-procurement has also been suggested as one of the categories in the four papers reviewed above. However, we have designated this category as e-auctions rather than e-procurement because e-auctions are used both for procurement and for selling decisions. Our decision to include RFID as a distinct category is based on its importance as an emerging web-enabling technology with potential to provide real-time and accurate data. References to RFID as an emerging research area have also been made by Kouvelis et al. (2006) and Gaimon (2008). We decided to include “e-business system design” as one of the categories because we found several papers that are primarily concerned with the design of e-business systems. The design issues include both technical issues and customer issues.

Our decision to create the fourth category, C⁴ in e-business, is grounded in the common themes found in the classification schemes of the four papers reviewed above. These themes center around the relationships between: (1) suppliers and manufacturers, which include e-procurement, e-auctions, supplier management, and bidding; (2) manufacturers and retailers, which include distribution strategies and pricing issues; and (3) retailers and customers, which primarily include pricing issues. However, these three themes do not represent an exhaustive set of relationships in an Internet-enabled supply chain. For example, in e-business, a channel conflict may arise if a manufacturer sells directly to his/her customers and competes with his/her own retailer(s). Also, collusive behavior among buyers or among suppliers presents additional important organizational and interpersonal relationships. Thus, there are many critical issues of inter-party competition, conflict, collaboration, and coordination among supply chain partners that go beyond the two-stage relationships mentioned above. Therefore, we decided to organize a category of papers that focuses on competition, conflict, collaboration, and coordination issues in e-business and coined the term “C⁴ in e-business” to refer collectively to these issues. We further classify the papers that we surveyed along two additional dimensions—within each of the four major categories listed above. These dimensions are further explained within each section at the appropriate place.

1.2. Motivation for the Current Survey

To motivate our survey paper, we first review and comment on the e-business research issues that are

included in other related survey papers. In addition to reviewing the four survey papers mentioned in section 1.1 that have a primary focus on e-business, we also reviewed several other survey papers that focused on the P/OM functions. Our objective was to identify coverage of any e-business issues in these papers. Gupta et al. (2006) divide the field of P/OM into the following broad themes: (1) operations strategy, (2) quality management, (3) supply chain management, (4) environmental issues, (5) product and service design, (6) process design/analysis, (7) scheduling, (8) production planning, (9) inventory management, and (10) other topics. Survey papers in some of these areas that are published in *POM* include the following: Kouvelis et al. (2005) surveyed the contributions in manufacturing operations that include scheduling, production planning, and inventory management; Boyer et al. (2005) surveyed the papers on operations strategy; Kleindorfer et al. (2005) surveyed the field of sustainable operations management; Krishnan and Loch (2005) surveyed the publications on new product development; Schroeder et al. (2005) reviewed the papers on quality; and Kouvelis et al. (2006) surveyed the publications on supply chain management. Other recent review papers in *POM* that include a number of *POM* references are the ones by Buhman et al. (2005) on interdisciplinary and inter-organizational research and by Gaimon (2008) on management of technology. In addition, we also reviewed two survey papers on service operations by Roth and Menor (2003) and by Smith et al. (2007).

After reviewing these survey papers we observed that only Roth and Menor (2003), Buhman et al. (2005), Kouvelis et al. (2006), Smith et al. (2007), and Gaimon (2008) provide references to some papers that deal with e-business. However, these survey papers do not create a separate category of e-business papers to highlight the importance of this emerging field. Roth and Menor (2003) include e-business under the theme of implementing service technology and e-services in the context of the future research agenda for service operations management. Buhman et al. (2005) mention e-business research in the context of dynamic pricing and e-service management. Smith et al. (2007) also refer to some of the papers concerned with e-business and service industries published in *POM*. Gaimon (2008) includes papers related to e-business in a brief discussion of RFID technology, e-auctions, and information technology (IT) process design and implementation. Kouvelis et al. (2006) divide research on supply chain management into nine areas and mention e-business-related research mostly in the sections on supply chain management practice and on multi-channel coordination. They also discuss RFID technology in the section on future research directions.

A lapse of 6–7 years after the publication of the earliest survey papers dedicated to e-business (Geofrion and Krishnan 2003a,b, Johnson and Whang 2002, Swaminathan and Tayur 2003) and the recent growth in e-business research clearly highlight the need for consolidation of the research in this field. It is interesting to note that almost 75% of the papers we review were published in the past 3 years. The purpose of our paper is, therefore, to identify any voids that may exist in the e-business literature, chart the path of the research growth in this field, take a current snapshot, provide directions for future research, and discuss the implications of e-business research for the P/OM practice.

The remainder of this paper is divided into six sections. Sections 2–5 discuss e-auctions, RFID, e-business system design, and C⁴ in e-business, respectively. In section 6, we provide an overview of the research methodologies and research techniques that have been used in the surveyed papers. In section 7, we provide directions for future research and highlight the importance of this survey for the P/OM practice.

2. E-Auctions

The term “auction” refers to the buying and selling transactions in which the price is not negotiated but is discovered through a competitive bidding process. A widely accepted definition of an auction (McAfee and McMillan 1987) reads as follows: “an auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants.” The use of auctions for commercial activity has been in existence for centuries and can be dated back to 500 BC (Krishna 2002). The Stockholm Auction House (Stockholms Auktionsverk), established in Sweden in 1674, is considered to be the oldest auction house in the world. Even though traditional auctions have long been used in commerce yet the economic theory of auctions has been developed only recently starting with the seminal paper of Vickrey (1961). More recently, the developments in IT are paving the way for an increasing use of the Internet for conducting auctions, popularly known as e-auctions. Commercial vendors like eBay and Yahoo! popularized consumer-to-consumer (C2C) and business-to-consumer (B2C) online auctions. Following the enormous success of C2C and B2C auctions, business-to-business (B2B) and e-procurement auctions have been popularized by e-commerce vendors such as FreeMarkets. The increasing use of e-auctions in practice has led to increased research on this topic and has provided fertile ground for P/OM researchers to systematically examine various issues of significance to e-auctions.

Table 1 Cross-Classification of the E-Auction Research in *Production and Operations Management (POM)*

Auction type	Research methodology			
	Frameworks and analytical models	Empirical studies	Case studies	Simulation studies
Forward auction	Feng et al. (2007)			Kwasnica and Katok (2007)
	Shen and Su (2007)			
	Sosic (2007)			
Reverse auction	Rothkopf and Whinston (2007)	Elmaghraby (2007)	Caplice (2007)	
	Peleg et al. (2002)	Mithas and Jones (2007)		
	Hazra et al. (2004)			
	Poundarikapuram and Veeramani (2004)			
	Schvartzman and Wellman (2007)			
	Chen et al. (2008)			
	Etzion and Pinker (2008)			

There are two types of auction scenarios—forward auctions and reverse auctions. In forward auctions several buyers compete and bid for one seller’s good(s) or service(s) whereas the reverse auctions involve several sellers who compete and bid to fulfill the order of one buyer. We observed that the methodologies used for e-auction research include: frameworks and analytical models, empirical studies, case studies, and simulation studies. The frameworks include conceptual and academic survey papers. We, therefore, decided to divide the papers on e-auctions using the following two dimensions—type of auctions and research methodologies. Table 1 lists the e-auction papers based on these two dimensions. A review of Table 1 shows that the reverse auction (e-procurement) is a favorite topic among P/OM researchers as compared with the forward auction. A possible reason for this disparity could be that forward auctions deal with selling scenarios and find more favor with marketing researchers. In the next two subsections, we review the e-auction papers using these two auction types as the main categories.

2.1. Forward Auctions

The research on forward auctions has received only limited attention in the studies published in *POM*. The four papers that we discuss in this category include one academic survey (Shen and Su 2007). The remaining three papers focus on three different issues in forward auctions that include: ranked items (Feng et al. 2007), collusive behavior (Sosic 2007), and impatient bidders (Kwasnica and Katok 2007). Feng et al. (2007) and Sosic (2007) use analytical models whereas Kwasnica and Katok (2007) use a simulation study.

2.1.1. Frameworks and Analytical Models in Forward Auctions. Shen and Su (2007) present an

academic survey of bidders' behavior in forward auctions and suggest the following topics for further investigation: (1) the impact of customers' entry time in the auction process, (2) evaluation of the assumptions about the distribution of customers' valuations, (3) the impact of the number of units offered in each round of bidding, (4) transparency of the information to the bidders in multiple auctions, and (5) the effect of customers' learning phenomenon in multiple auctions.

Feng et al. (2007) study auction mechanisms in which bids are invited for a set of ranked items (or positions), each bidder needs to buy only one item, and all bidders rank the items in the same way. Such problems are commonly encountered for keyword auctions in online advertising on search engines.

Sosic (2007) models the collusive behavior in forward auctions. This collusive behavior is said to occur when competing firms in a given industry participate in overt or tacit agreements to coordinate their actions in order to increase their economic gains at the expense of other market participants. Sosic (2007) investigates collusion and operation of bidding rings in online second-price sealed-bid auctions. Two important issues faced by bidding rings are the enforcement of the ring's bidding rules and the distribution of the collusive surplus among the ring members. The collusive surplus is the incremental gain realized by the ring over the non-cooperative bidding. The author proposes a strategy to distribute this collusive surplus among ring members and also shows that the proposed mechanism induces voluntary participation and enforcement of the ring rules.

2.1.2. Simulation Studies in Forward Auctions.

Kwasnica and Katok (2007) study the behavior of impatient bidders in a laboratory setting in order to investigate the impact of timing on jump bidding. A jump bid is a bid that is larger than the required bid by the auctioneer. The study uses two bidders who are assumed to be impatient in the sense that the cost of participation in the auction increases with the auction time. The total time of an auction has cost implications for the bidders, particularly when highly paid executives are involved in bidding. The size of the jump bid is an important decision in these situations and affects the auction performance.

2.2. Reverse Auctions

Reverse auctions are used in procurement decisions and account for the major share of e-auction research published in *POM*. The research methodologies used by the 10 papers in this section include frameworks and analytical models (seven papers), empirical studies (two papers), and a case study.

2.2.1. Frameworks and Analytical Models in Reverse Auctions. Among the reverse auction papers, Rothkopf and Whinston (2007) provide an academic survey while the rest of the papers develop analytical models for e-procurement as discussed below. Rothkopf and Whinston (2007), after reviewing the field of procurement auctions in general and e-procurement auctions in particular, provide the following directions for future research: (1) study of the impact of feedback policies and actual feedback to bidders on their bidding strategy, (2) inclusion of non-price factors in the design of auctions, (3) study of collusive behavior, (4) study of relative advantages of sealed bid and iterative auctions in combinatorial procurement, (5) study of tied bids in combinatorial auctions, (6) study of the impact of setting a "sell-price" on vendors' bidding strategies and on the final outcome of the bidding process, and (7) integration of both costing and bidding strategies from a bidder's view-point. The authors also suggest additional research that deals with the computational aspects of these problems.

Peleg et al. (2002) and Hazra et al. (2004) propose models to determine the optimal number of suppliers that should be contacted or selected for e-procurement to minimize total procurement costs. Peleg et al. (2002) study a two-period inventory replenishment problem with stochastic demands in both periods. In period 1, the manufacturer buys his requirements at the negotiated price from the current supplier. For period 2, the authors propose and compare the following three strategies: strategic partnership with the current supplier that locks the prices for the second period, an online search for a new supplier to meet the demand, and a combination of the above two alternatives. Hazra et al. (2004) study electronic markets in a "build-to-order" environment and propose models to decide the number of suppliers who are invited to participate in the bid process, the number of bidders who are finally awarded the contract, and the amount allocated to each winner.

The next two papers focus on procurement decisions involving multi-unit auctions. Schwartzman and Wellman (2007) consider two-sided (double) multi-unit auctions for a single product with standard auctions (with divisible bids) and "all-or-none" (AON) auctions (with indivisible bids) and study the effect of various price-quote policies on the efficiency of market-based allocations in the AON auctions. The paper identifies factors that influence the use of the AON auctions in preference to standard auctions. Chen et al. (2008) study multi-unit auctions in which a buyer purchases a package of goods or services with multiple characteristics and propose an auction and audit mechanism that integrates the

auction process, the post-award audits, and the profit-sharing schemes. An audit is defined as the after-the-fact verifiable estimate of the actual cost incurred by the supplier. The objective is to minimize the dependence of the auction mechanism on the suppliers' cost functions and buyer's revenue functions.

Poundarikapuram and Veeramani (2004) assume that the sourcing decisions have already been made by the manufacturer in a supply chain and develop a procurement model in which the suppliers and the manufacturer adopt a collaborative planning approach. A master optimization problem common to all participants is formulated in a collaborative manner at the upper level. Local optimization problems unique to individual participants are formulated and solved at the lower levels. The efficiency of the proposed distributed decision-making method is compared with the traditional centralized approach based on the solution of a single large-scale optimization problem.

Etzion and Pinker (2008) model the competitive behavior of two types of suppliers in electronic B2B markets, a traditional supplier (Type 1 supplier) with long-term contracts who only occasionally sells in spot markets (through auctions), and a supplier who has no long-term contracts and sells exclusively in spot markets (Type 2 supplier). The model shows that the production and profits of the Type 2 supplier increase with more participation of the Type 1 supplier when the demands in the two channels are either independent or positively correlated. These results do not necessarily hold when the demands in the two channels are negatively correlated. The industries with negative correlation between the two demand types are more suitable for suppliers who use forward contracts to sell their products.

2.2.2. Empirical Studies in Reverse Auctions.

Elmaghraby (2007) interviews the leading procurement software vendors and then identifies potential research issues for e-procurement. The author concludes that the auction formats used in practice include decisions on: (1) item bundling and selection of the bidding lots, (2) sequencing of the bidding lots for auctions, (3) feedback mechanism—rank versus full disclosure, and (4) selection of the bid format. The paper emphasizes the importance of identifying qualified suppliers in the sourcing process. A diminishing emphasis on price-alone auctions is also observed, thus paving the way for multi-attribute auctions. The findings also suggest that the popularity of rank feedback as opposed to full-disclosure feedback is increasing. We came across several papers in our survey that advance the understanding of some of the topics identified by Elmaghraby (2007) as important in

the e-auction practice. For example, Peleg et al. (2002) and Hazra et al. (2004) focus on identifying qualified bidders and determining the optimal number of bidders. Schwartzman and Wellman (2007) develop an auction algorithm for multi-unit auctions of a single good with indivisible bids. Chen et al. (2008) study auctions in which a buyer has to procure an item with multiple characteristics. These papers are reviewed in section 2.2.1.

Mithas and Jones (2007) establish relationships between buyer surplus and the following auction design parameters: (1) bidding competition, (2) bid decrement, (3) reserve price, (4) auction duration, and (5) information transparency. The buyer surplus is measured by calculating the price of the lowest winning bid as a percentage of the historical price. A related paper (Chen et al. 2008), which proposes an analytical model for auction design using audits and analyzes its impact on buyer profits, was reviewed in section 2.2.1.

2.2.3. Case Studies in Reverse Auctions. Caplice (2007) studies electronic marketplaces that use combinatorial auctions, private and public exchanges, and electronic catalogs in the transportation industry for truckload operations. The bid winner is determined by solving the winner determination problem (WDP) through a mixed integer program to minimize the transportation costs for the shipper. The solution of the WDP problem is the assignment of shipping lanes to various carriers.

2.3. Future Research Directions for E-auctions

The surveyed papers on e-auctions included forward and reverse auctions, a variety of methodologies, several industries, and numerous e-procurement scenarios. Based on the future research directions provided in these papers, some important research themes emerge that include: communication in auctions, non-price factors, collusion, combinatorial auctions, reserve prices, bid increments, pre-qualifying bidders, taxonomy, post-auction audits, technology support, and assumptions about the cost and revenue functions. Important issues within each of these themes and the papers that highlight the importance of these themes are identified below.

Communication in Auctions. The transparency of communication among various parties involved in an auction is an important research topic. Communication covers selection criteria, details of the product to be procured, and a clear description of the business terms. The information and feedback that is provided by the buyer to suppliers in e-procurement (reverse auctions) influence the bidders' bidding strategies and the outcome of an auction. The need

for more research on this topic has been highlighted by Rothkopf and Whinston (2007), Elmaghraby (2007), Mithas and Jones (2007), and Schwartzman and Wellman (2007).

Non-Price Factors. The importance of the study of non-price factors in auction design has been stressed by Rothkopf and Whinston (2007) and Elmaghraby (2007).

Collusion. The study of collusive behavior and bidding ring formation has been emphasized by Rothkopf and Whinston (2007), Chen et al. (2008), Kwasnica and Katok (2007), and Susic (2007). The possibility of the existence of collusive behavior needs to be studied among suppliers, and between the buyer and the winning supplier (Chen et al. 2008). Other topics related to the study of collusion include the optimal ring size and the mechanism to distribute collusive surplus (Susic 2007). The differences between collusion and signaling also need to be investigated (Kwasnica and Katok 2007).

Combinatorial Auctions. Rothkopf and Whinston (2007), Elmaghraby (2007), and Feng et al. (2007) have suggested that combinatorial auctions is an important research topic. Some of the research issues in combinatorial auctions include: (1) finding the optimal number of items in a single auction (Feng et al. 2007), (2) studying the bundling process (Elmaghraby 2007), (3) the sequencing rules to auction various bundles (Elmaghraby 2007), and (4) the advantages of sealed bid and iterative auctions in combinatorial procurement (Rothkopf and Whinston 2007). The problems of tied bids in combinatorial auctions also need to be studied (Rothkopf and Whinston 2007). Combinatorial auctions need to be supported by appropriate computer systems, requiring work from a computer science perspective (Rothkopf and Whinston 2007). Additional research work is needed to deploy IT in reverse auctions. Also, IT deployment can help mitigate various costs associated with the procurement activity (Mithas and Jones 2007).

Reserve Price and Bid Increment. Additional research is needed to appropriately set the reserve price (Mithas and Jones 2007) and study the impact of setting a reserve price on vendors' bidding strategies and on the final outcome of the bidding process (Rothkopf and Whinston 2007). The optimal level of increment to be set also needs additional investigation (Kwasnica and Katok 2007).

Number and Type of Pre-qualifiers. Elmaghraby (2007) and Hazra et al. (2004) point out the importance of research that focuses on identifying pre-qualified

bidders who are invited to bid in an e-auction. The impact of participation by non-qualified bidders also needs to be studied (Elmaghraby 2007). Hazra et al. (2004) point out that the cost of pre-qualifying bidders should be considered in designing the auction mechanism.

Taxonomy. Boyer and Olson (2002) and Mithas and Jones (2007) propose the development of a knowledge base for e-auctions. The analysis and cataloging of various issues that relate to Internet usage has been suggested by Boyer and Olson (2002). Mithas and Jones (2007) propose that development of a taxonomy of bidder heterogeneity in B2B auctions is necessary.

Use of Audits. Chen et al. (2008) provide several directions for future research in designing contracts that use post-bid audit data. These include contracts with multiple suppliers, sourcing through multiple channels, and coordination in multisourcing. They also point out the need for additional research to determine the required information about suppliers to be collected by the buyer and the differences in the design of incentive contracts from single versus repeat procurement situations. Also more research is needed on the process, the industry norms, and on the influence of bargaining power in designing the structure of profit-sharing contracts.

Technology Support. Additional research is needed to support and integrate the various aspects of e-business including technology (Boyer and Olson 2002). The study of visual design parameters on e-auction effectiveness and on buyer behavior is another important area of research (Mithas and Jones 2007). Caplice (2007) suggests the development of better and more flexible systems at the execution stage after the auction has been conducted.

Cost and Revenue Functions. Assessing the buyer's revenue function is an important research topic for the future (Hazra et al. 2004). The impact of different valuation functions for different bidders needs to be investigated (Feng et al. 2007). Additional research is needed for integrating the costing and bidding strategies from a bidder's view point (Rothkopf and Whinston 2007). Auction scenarios in which suppliers have different production costs need to be investigated (Etzion and Pinker 2008).

3. RFID

RFID is an enabling technology for real-time data collection and has a great potential to support and promote e-business activities. RFID tracks the movement and flow of items in a supply chain and provides visibility to managers about the location and condition of the tracked items. The real-time

Table 2 Cross-Classification of the Radio Frequency Identification (RFID) Research in *Production and Operations Management (POM)*

Research theme	Research methodology			
	Frameworks and analytical models	Empirical studies	Case studies	Simulation studies
Business value of RFID	Lee and Ozer (2007) Karaer and Lee (2007) Dutta et al. (2007)		Amini et al. (2007) Delen et al. (2007)	
Adoption and implementation of RFID	Dutta et al. (2007) Gaukler et al. (2007) Heese (2007)	Whitaker et al. (2007)	Barratt and Choi (2007) Ngai et al. (2007)	

information is valuable because it helps to increase asset utilization and to minimize inventory- and logistics-related costs. RFID also minimizes delays in information transmission leading to improved information sharing among the partners in a supply chain. The design of RFID systems is critical because installing RFID technology infrastructure entails a large initial investment and significant potential risks in technology adoption.

We observed that the underlying themes of most of the RFID research reviewed in our paper are the assessment of business value (benefits and costs) of RFID technology, and the implementation/adoption issues. Therefore, we have mapped the papers on RFID in two dimensions—research themes and research methodologies. Table 2 lists the RFID papers across these two dimensions. We also observed that frameworks and analytical models as well as case studies are the two major research methodologies used in these papers. Only one paper used empirical studies; and none of the papers used simulation studies. We review the contributions of the RFID papers by using the research themes as the major categories in the following sections.

3.1. Business Value of RFID

The business value of RFID comes primarily from the visibility it provides to managers about the items tracked. RFID also provides the visibility across partners in a supply chain and has an impact on reducing information asymmetries. We first review the frameworks and analytical models (three papers) followed by the two case studies.

3.1.1. Frameworks and Analytical Models for Business Value of RFID. Dutta et al. (2007) identify the following three stages in the evolution of RFID business value: technology deployment and integration, integration with business processes, and development of new business architectures for employees, policies,

and organizational structures. They propose three dimensions for an RFID value proposition that include RFID technology, the quantification of the RFID business value, and the incentives for RFID adoption and implementation. The business value of RFID emanates from labor cost savings, shrinkage reduction, and inventory visibility. According to Lee and Ozer (2007), the estimates of the value of RFID due to labor cost savings are relatively more reliable as compared with other claims because they are derived from detailed time-and-motion studies. However, the estimates of the value of RFID resulting from inventory savings, shrinkage reduction, out-of-stock reduction, and/or sales increases lack academic rigor because these estimates are invariably based on the unreliable guesses of technology consultants and vendors. Lee and Ozer (2007) posit that the claims regarding the business value of RFID are not supported by analytical models. They observe the existence of a credibility gap and suggest building analytical models to quantify the gains due to RFID.

Karaer and Lee (2007) model a reverse supply chain for the distribution center of a manufacturer and show that the value of visibility provided by RFID is a function of system parameters that include the probability distributions of the regular demand and returns, the probabilities of returns being discarded or reworked or used as is, the lead times for different steps in the supply chain, the length of the reverse supply chain, and the shortage and inventory holding costs. The authors derive conditions under which the value of the RFID information is attractive to the manufacturer.

3.1.2. Case Studies on Business Value of RFID.

Amini et al. (2007) and Delen et al. (2007) analyze the business value of RFID in two different industrial contexts. Amini et al. (2007) used RFID to track trauma patients in a hospital and used the data collected in a simulation model. RFID improved the tracking of patients' time from about 25% to 80% in the trauma center where patients spent about 10–12 hours for their treatment. RFID technology's ability to collect data in a passive manner avoids interference with medical procedures. RFID-based simulation models help in analyzing health care processes more thoroughly based on the data collected for process cycle time, patient throughput rate, and equipment and personnel utilization.

Delen et al. (2007) establish the business value of RFID for a retailer by analyzing the movement of RFID-tagged cases between distribution centers and retail stores. The analysis provides insights into the distribution of lead times among different products and different combinations of distribution centers and retail stores. The RFID-generated information

also helps in tracking recalls, delivering products to the stores as per schedule, and in studying the back-room process that involves moving the products to the sales floor. In addition to providing immediate visibility, RFID data utilization leads to gains due to limited process changes first and then to the major modifications in the logistics system.

3.2. Adoption and Implementation of RFID

The papers in this section study cost sharing issues, identify critical success factors for RFID implementation, and highlight the deployment issues that impede RFID implementation. The return on investment, the business value, and the selection of partners are important considerations at the strategic level in RFID investment projects (Ngai et al. 2007). We first study the frameworks and analytical models (three papers) followed by an empirical study and then two case studies.

3.2.1. Frameworks and Analytical Models for Adoption and Implementation of RFID. Dutta et al. (2007), as discussed in section 3.1.1, identify the incentives for RFID adoption and implementation as one of the three dimensions of the RFID value proposition. The authors highlight the issues of cost sharing and double marginalization by referring to the contributions of Gaukler et al. (2007) and Heese (2007). They also use Cisco's operations during the Internet's boom as an example to show that a supply chain operating in a near real-time due to RFID implementation may experience nervousness.

Gaukler et al. (2007) and Heese (2007) propose analytical models for RFID adoption and implementation. Gaukler et al. (2007) develop a newsvendor inventory model for a manufacturer who implements an RFID system at the case/pallet level and makes an offer to the retailer to implement item-level RFID and share the cost of the tags required. Two scenarios are studied—one with a dominant manufacturer and one with a dominant retailer. Heese (2007) develops a newsvendor inventory model and studies the impact of RFID adoption on minimizing inventory record inaccuracy in a supply chain with one manufacturer and one retailer. They compare the RFID adoption decision in a decentralized supply chain with a similar decision in an integrated supply chain.

3.2.2. Empirical Studies of Adoption and Implementation of RFID. Whitaker et al. (2007) study the relationships between RFID adoption and factors involving financial and IT resources of an organization, the partner mandates, and the data standards. They develop a theoretical model for RFID implementation and expected investment returns and test their

model using data from a diverse set of US firms. According to the authors, an organization can enjoy more RFID benefits by partner mandate, increased RFID spending, and IT application upgrade.

3.2.3. Case Studies of Adoption and Implementation of RFID. Barratt and Choi (2007) investigate RFID adoption issues and use institutional theory as the conceptual framework for organizational responses to institutional pressures. They investigate organizational responses to RFID mandates through a case study of a large defense contractor and conclude that the responses of four different business units of the contractor ranged from full compliance to non-compliance or unwillingness to comply. The drivers for the different levels of responses included each unit's perception of institutional rationalization, technical rationalization, perceived uncertainty, and internal coupling within the organization.

Ngai et al. (2007) present a case study of the design, development, and implementation of an RFID-based traceability system to increase inventory visibility during the maintenance cycle in order to minimize delays, and item misplacements in the maintenance department of an aircraft engineering company. The critical success factors for RFID implementation include: (1) high organizational motivation, (2) implementation process efficiency, (3) effective cost control, and (4) RFID skills and knowledge transfer. Several deployment issues that impede RFID implementation include: (1) lack of in-house RFID expertise, (2) inadequate technology support from local RFID vendors, (3) existence of different sets of industry standards, (4) unreliable hardware performance, and (5) underdeveloped RFID middleware. Overall, the study reports that the RFID-based traceability system has resulted in improved lead times, competitive differentiation, savings from reusing RFID tags, breakthrough productivity by automation, reduction of human errors in handling the repairable parts, improved inventory management, reduced manpower and manual data recording, real-time monitoring and access to detailed information, reduction of repairable parts loss, and improved customer relationships.

3.3. Future Research Directions for RFID

RFID provides valuable real-time data by tracking the movement and flow of materials in a supply chain and even patients in a hospital (Amini et al. 2007). The research reviewed in this paper can be replicated in other organizational settings and in other operational areas of an organization (Barratt and Choi 2007, Dutta et al. 2007, Lee and Ozer 2007, Whitaker et al. 2007). Our review of the RFID literature highlights several important themes that relate to the business value of

RFID, and to the RFID adoption and implementation. We have grouped these research themes in the following categories: design and configuration issues, taxonomy, extensions of analytical models, and RFID mandates. These are discussed below.

Design and Configuration Issues: The design and development of more effective and efficient RFID systems (including technology improvement) that span from the data collection stage to the implementation of decisions (based on collected data) are suggested by Amini et al. (2007), Delen et al. (2007), and Lee and Ozer (2007). The sustainability of the effectiveness of an RFID system after implementation is also an important issue that needs to be investigated (Ngai et al. 2007).

Taxonomy: The standardization of business data used by RFID systems and the development of taxonomies are important issues in the design of RFID systems (Amini et al. 2007, Dutta et al. 2007, Ngai et al. 2007). The empirical determination of the RFID system characteristics and parameters has been proposed by Lee and Ozer (2007). Empirical research is also suggested by Heese (2007) to establish (or deny) whether RFID is more beneficial to decentralized supply chains in practice.

Extensions of Analytical Models: The analytical models reviewed in this paper can be extended to more complex supply chains consisting of multiple competing manufacturers and/or retailers and to problems involving substitute products (Gaukler et al. 2007). The incentive and coordination problem, the appropriate sharing of costs, and the distribution of benefits need to be assessed and modeled (Dutta et al. 2007, Lee and Ozer 2007). The development of benchmark systems without RFID to identify the incremental gains in the business value of RFID is stressed by Lee and Ozer (2007).

RFID Mandates: The mandates to implement RFID by a dominant partner in a supply chain or by a parent organization are suggested as a mechanism to implement RFID initiatives. An analysis of the views of the parent organization that mandates RFID (particularly in situations of non-compliance) needs to be performed (Barratt and Choi 2007). Heese (2007) suggests the modeling of the problem in a setting in which a dominant retailer mandates RFID adoption.

4. E-Business System Design

The design of e-business systems has become an important and major organizational endeavor. P/OM can make significant contributions to the profitability of the Internet-based businesses (Starr 2003). Designing a user-friendly web interface has become crucial in order to improve customer satisfaction and ensure the ultimate success of e-business activities.

The design, development, implementation, and evaluation of an e-business system are multi-dimensional tasks that involve technological considerations, customers' attitudes and expectations, and the internal organizational environment. The important themes that emerge from a review of the papers on e-business system design include customer satisfaction, and the enablers/barriers of e-adoption and implementation. We also observed that the primary research foci of the papers on e-business system design are either the business customers (B2B) or the individual customers (B2C). Following the mapping schemes used in the earlier sections, we have mapped the papers on e-business system design on two dimensions—research themes and research methodologies. Table 3 lists the e-business system design papers across these two dimensions. Most of the papers in this section have used empirical studies as the research methodology. Only one paper used frameworks and analytical models. Similarly, case study was used by only one paper. None of the papers used simulation studies. We, therefore, discuss the contributions of these papers using the research themes as the major categories. The B2B and B2C have been used as subcategories within the two research themes.

4.1. Customer Satisfaction

Customer satisfaction is an important key success factor for e-business. An e-business system consists of many components (each having its own quality dimensions) that influence customer satisfaction. These components and their quality measures need to be identified for any new e-business system being developed, and these may differ between the B2B and B2C systems as discussed below.

4.1.1. Customer Satisfaction in B2B Systems. We identified two papers that study issues related to customer satisfaction in the B2B systems as discussed below.

Boyer and Olson (2002) empirically establish relationships between the performance of the purchasing function of an organization and its Internet strategy, its employee work environment, and its website design. The purchasing performance is measured through an assessment of general purchasing costs, personnel training costs, billing accuracy, and availability of supplies and materials. The authors point out that higher customer satisfaction can be achieved if the web interface is easy to use, provides accurate information, and guarantees reliable transactions.

Field et al. (2004) develop a conceptual process model for an e-service system with a focus on measuring and managing e-service quality. They propose the identification and use of the e-service system

Table 3 Cross-Classification of the E-Business System Design Research in *Production and Operations Management (POM)*

Research theme	Customer type	Research methodology			
		Frameworks and analytical models	Empirical studies	Case studies	Simulation studies
Customer satisfaction	B2B	Field et al. (2004)	Boyer and Olson (2002)		
	B2C	Field et al. (2004)	Heim and Sinha (2002) Boyer and Frohlich (2006) Ba and Johansson (2008) Rabinovich et al. (2008)		
Enablers of and barriers to e-adoption and implementation	B2B		Boyer and Olson (2002) Tsiriktsis et al. (2004)	Tatsiopoulos et al. (2002)	
	B2C				

B2B, business-to-business; B2C, business-to-consumer.

components to locate sources of lower quality and to determine e-service quality dimensions. The proposed model links service quality dimensions to components of the e-service system that include entities, transactions, and product flows. The quality dimensions include four major categories: (1) website design, (2) fulfillment and reliability, (3) security and privacy, and (4) customer service. The model can be used to identify quality dimensions of a particular system component or to map a particular quality dimension to the appropriate entities. The proposed approach can be tailored to any specific class of customers and to any component of the e-service system. For example, Boyer and Frohlich (2006) study the effects of operational execution on repeat purchasing behavior of heterogeneous customer segments and Rabinovich et al. (2008) analyze the influence of service quality and product attributes on retail markups in Internet CD retailing. These two studies are discussed in the next subsection.

4.1.2. Customer Satisfaction in B2C Systems. The papers surveyed in this subsection study the impact of e-business system design on customer acceptance, satisfaction, and loyalty; they also highlight the importance of numerous factors (in addition to pricing) in online purchasing. The conceptual paper of Field et al. (2004), discussed in section 4.1.1, also contributes to the design of B2C systems. Next, we review four more papers in this section.

Heim and Sinha (2002) study electronic retailing in the food industry and Boyer and Frohlich (2006) focus on the home delivery grocery business. Both papers study the determinants of customer satisfaction and customer loyalty. Heim and Sinha (2002) use system flexibility as a design parameter and propose a taxonomy of service processes that is based on a continuum of low to high process flexibility. The authors observed that increased flexibility in e-processes leads to more customer loyalty

and satisfaction with website aesthetics, website navigation, product selection, product information, customer support, and ease of return. Unlike Heim and Sinha (2002), Boyer and Frohlich (2006) classify customers into four categories and use operational execution as a determinant of the system design. They determine the relationship between the categories of the customers and the operational execution parameters. The four categories of customers include: convenience sensitive, price sensitive, Internet acceptors, and delivery insensitive. Their operational execution indicators include the quality of service, the quality of the product, and the website quality.

Ba and Johansson (2008) use the classification of the four service process categories in electronic retailing developed by Heim and Sinha (2002) to examine the relationships between customer satisfaction and the following measures of electronic service delivery system: perceived e-service process, service value, perceived ease of use, perceived control, and interactivity.

Rabinovich et al. (2008) empirically analyze the relationship between retail markups, service quality, and product attributes in Internet CD retailing. Fulfillment reliability, product availability, and delivery execution are used as measures of quality. The constructs used in the study include: vintage, popularity, efficiency, privacy, functionality of the pre-purchase process, retailer mark-up during the purchase process, fulfillment at the post-purchase stage, interactive fairness, and outcome fairness at the post-purchase recovery stage.

4.2. Enablers of and Barriers to E-Adoption and Implementation

The perceived business value of an e-process by an organization facilitates and enables the adoption of Internet technology. The organizational environment may act as an enabler of or barrier to e-adoption and implementation. The papers reviewed in this

section identify and discuss these issues. We note that there are no papers that deal with enablers of and barriers to e-adoption and implementation in B2C systems. For individual customers, the issues of e-adoption are primarily concerned with customer satisfaction.

4.2.1. Enablers and Barriers of B2B Systems. Boyer and Olson (2002) mention that the environmental factors affecting e-business operations include the employees' comfort level with using computers, the presence of a technology champion in the company, the amount of technical support available to the users, and the intensity of computer usage. Cost reduction, convenience/delivery improvement, improved administration of purchase transactions, and improvements in delivery accuracy, service, and security add business value to the purchasing function of an organization and promote acceptance of Internet-based purchasing.

According to Tsikriktsis et al. (2004), the enablers of an e-adoption process include the expected improvement in performance, access to new markets, and the bandwagon effect—the external pressure. The e-adoption barriers stem from the internal operational environment and the behavior and expectations of customers. The e-processes include e-transactions and an electronic customer relations management (e-CRM) process. Their study shows that both e-CRM and e-transactions are significantly driven by expected performance benefits and external pressures whereas e-CRM is not driven by the potential access to new markets. Access to new markets is, however, a major driver for the adoption of e-transaction processes. They also observe that both e-CRM and e-transactions have the same adoption barriers. However, internal barriers, as compared with customer barriers, play a significantly major negative role in the adoption of these e-processes. They also observe that the adoption enablers are more influential than the barriers to adoption of e-processes. The complexity of operations hinders the adoption of the e-processes. On the other hand, ease of digitization of the products and services offered by an organization encourages the adoption of e-processes.

Tatsiopoulos et al. (2002) analyze the design and implementation of e-business software systems and present a case study for a firm in the clothing industry. The proposed system led the company to improve monitoring of the partner companies in the virtual enterprise, improve the business dialogue processes, decrease the lead time of business transactions, improve the speed and agility of response to market changes, and improve the management of available resources.

4.3. Future Research Directions for E-Business System Design

The papers reviewed in this section show that system flexibility, quality of service, product attributes, and perceived ease of using the e-business systems are important factors that influence customer satisfaction and loyalty. The design of e-business systems should also take into account the customer characteristics in case of heterogeneous customers. We also observe that e-process adoption is easier if the internal organizational environment supports the e-process and the e-process leads to improved organizational performance. The following themes emerge as topics for future research on e-business system design based on our observations discussed above and on the future research directions mentioned in the reviewed papers.

Taxonomy: Developing a taxonomy and cataloguing various issues in e-business have been suggested by Boyer and Olson (2002) and Heim and Sinha (2002).

Design and Configuration: Several issues related to e-business system design that need investigation include the integration of technology, operational and promotional issues (Boyer and Olson 2002), cost/flexibility tradeoffs (Heim and Sinha 2002), the effect of fulfillment and the returns on business value (Ba and Johansson 2008), the identification of an objective measure of the technological capabilities of an e-service website (Ba and Johansson 2008), and the development of sets of quality measures for individual components of the e-service system (Field et al. 2004).

Enablers and Barriers: The future research related to enablers and barriers includes the impact of customer barriers in the adoption of e-processes in the service industry (Tsikriktsis et al. 2004), the relative dominance of external pressure, and the perceived business value of e-business implementation (Tsikriktsis et al. 2004).

Pricing: Pricing is an important issue in e-business. The setting of markups is a potential area for research. Various issues that need investigation include: the markup-service quality link in a service industry, the impact of product information and retailer guarantees for less-standardized goods or high-end items, and a longitudinal study of markups for an individual retailer (Rabinovich et al. 2008).

Future researchers in this area should also note that the design of e-business systems primarily deals with the technical issues and/or the consumer issues. This observation emphasizes the need for more collaborative research among P/OM, information systems, and marketing researchers to develop efficient and effective e-business systems. There is a plethora of literature on issues related to customer satisfaction in the marketing journals. An excellent exposure to customer satisfaction issues can be found in the following papers: Boulding et al. (2005) and Mithas et al. (2005).

5. The C⁴ in E-Business

Table 4 maps the papers on C⁴ in e-business across the research themes and the research methodologies. In this table, we have grouped competition and conflict together as one research theme and collaboration and coordination as the second research theme because the issues found in these two groups are interrelated. The research themes emanating from the C⁴ issues span across all stages of a supply chain. However, we have grouped the papers surveyed in this section in the following two stages of the supply chain: (1) *distribution* that involves interaction between manufacturers and retailers and (2) *retailing* that involves interaction between retailers and customers. The papers on procurement, another important stage in the supply chain involving interaction between suppliers and manufacturers, have been discussed in the section on e-auctions. The distribution and retailing stages have been used as the subcategories of the two major research themes in Table 4. A review of Table 4 shows that competition and conflict are primarily studied at the distribution stage whereas collaboration and coordination form the core of the research issues at the retailing stage. Table 4 also shows that frameworks and analytical models is the only research methodology used by the C⁴ in e-business papers. We discuss the details of the papers in this section under the two research theme categories.

5.1. Competition and Conflict

In any business environment, more so in e-business, competition and conflict are inevitable between partners at different stages of the supply chain and among multiple partners at a given stage. For example, suppliers compete for winning the manufacturer's supply orders

(the case of e-procurement) and retailers compete among themselves for increasing their market share at the retailing stage. With the advent of e-business, the manufacturers have started competing with their own retailers by opening parallel Internet channels to sell their products—a situation most prevalent at the distribution stage. In this section, we review three papers that study competition and conflict at the distribution stage and one paper that focuses at the retailing stage.

5.1.1. Competition and Conflict at the Distribution Stage. The advent of the Internet has paved the way for the emergence of mixed-channel supply chains in which a manufacturer, through a direct (Internet) channel, competes with his/her own traditional brick-and-mortar retailer for the same consumer market. This creates a situation of conflict. The three papers that propose models to resolve the channel conflicts include the following: Tsay and Agrawal (2004), Cattani et al. (2006), and Mukhopadhyay et al. (2008).

Tsay and Agrawal (2004) study the channel conflict resulting from using both the direct and the traditional reseller channels simultaneously by a manufacturer and analyze the relationship of the manufacturer's and the retailer's prices and profits. Some alternative options to influence the relationship between the manufacturer and the reseller are also examined. These options include revisions in the wholesale prices, diversion of customers to the direct channel by the reseller for a commission, and fulfilling the demand only through the reseller. Such options are based on the competitive advantage of each channel for different functions. The authors conclude that the reseller channel is not necessarily adversely affected by the addition of a direct channel and that the choice of selecting a channel is not always the same for both the manufacturer and the retailer. Some counterintuitive situations were identified in which the manufacturer preferred only the reseller and the reseller prefers that the manufacturer opens a direct channel.

Cattani et al. (2006) consider a mixed-channel situation similar to that of Tsay and Agrawal (2004) and propose the following three strategies to avoid channel conflicts: (1) the wholesale prices remain unchanged and the retailer sets his/her prices, (2) the wholesale prices are adjusted to maintain the retail prices at the previous level, and (3) the wholesale price is determined to maximize the wholesaler's profit with no guarantee of maintaining the base wholesale or retail prices. In each of these strategies, the manufacturer decides the wholesale prices and also agrees not to undercut the retailer's selling price to minimize conflict and maintain harmony. It is concluded that the third strategy is preferred both by the retailers and the customers—a somewhat

Table 4 Cross-Classification of the C⁴ in E-Business Research in *Production and Operations Management (POM)*

Research theme	Stages of supply chain	Research methodology			
		Frameworks and analytical models	Empirical studies	Case studies	Simulation studies
Competition and conflict	Distribution	Tsay and Agrawal (2004) Cattani et al. (2006) Mukhopadhyay et al. (2008)			
	Retailing	Sun et al. (2008)			
Collaboration and coordination	Distribution				
	Retailing	Cattani and Souza (2002) Chen et al. (2007) Xia and Dube (2007)			

counterintuitive finding. It is also shown that the manufacturer's profits can be increased substantially by reducing the retail price in the direct channel below the one in the traditional channel when the web channel convenience is on par with that of the traditional channel. This tactic may lead the manufacturer to abandon the equal retail price policy that may adversely affect the retailer's profits.

Mukhopadhyay et al. (2008) also consider the mixed-channel scenario and suggest that the retailer may be allowed to add other features and value to differentiate his/her product and offering from the one sold through a direct channel by the manufacturer. The retailer sets the price of the modified product. The manufacturer may also make a side payment to the retailer to reduce conflict. The profits for both supply chain partners are functions of the wholesale price, the respective channel retail prices, and the respective channel demands. The contracts are modeled under full information and under asymmetric information. Closed-form formulas are derived for optimal policies for both types of contracts to maximize retailer's and manufacturer's profit functions.

5.1.2. Competition and Conflict at the Retailing Stage. Sun et al. (2008) model a duopoly competition between two online retailers selling the same product. The two retailers can choose either an in-stock policy or a stockless policy to meet customer demand. These two policies affect the customer's waiting time to receive the product. The customer chooses a firm based on the prices and on the average waiting time for the order. Each firm maximizes its own profit by setting its optimal prices and its average waiting time. The proposed model determines the feasibility of using a stockless policy and the criteria for selecting one of the two policies.

5.2. Collaboration and Coordination

Competition results in conflict, which in turn leads the competing entities to collaborate and coordinate to arrive at a win-win situation for everyone. However, we did not find any paper that fits into this framework of collaboration and coordination either at the distribution or at the retailing stage. The three papers that we have included in this section focus primarily on optimizing an organization's own retailing decisions.

Cattani and Souza (2002) model continuous-review inventory systems for two classes of customers who are characterized as (1) higher price–shorter lead time customers and (2) lower price–longer lead time customers. The customers' responses to unmet demand include lost sales, backlogging of orders, and a combination of lost sales and backlogging of orders. For each one of these customer responses, the first-come-first-serve (FCFS) policy and a rationing policy (in

conjunction with FCFS) to fulfill customer orders are analyzed. It is shown that the firm's profitability can be increased by an appropriate choice of the rationing policy. The issue of customer sensitivity to waiting times in online sales has also been studied by Sun et al. (2008) as discussed earlier.

Chen et al. (2007) analyze the channel choices available to online retailers (e-tailers) who sell seasonal products through a primary channel (the e-tailer's own website) and a secondary channel (the websites of third-party vendors). The e-tailer has to pay the third-party vendors based on cost-per-click that reduces the revenue per unit in the secondary channel. The e-tailer has to sell a certain number of identical products within a finite time horizon with no replenishment. A dynamic stochastic rationing model is proposed to maximize the e-tailer's expected revenue over the given time interval by optimally controlling the timing of the periods during which the secondary channel should be opened and closed.

Xia and Dube (2007) model the selection of the best set of service offerings that maximizes a provider's long-run discounted reward revenue. A service offering is uniquely represented by its price, its service level, and the amount of resources required to offer the service. The provider's profit for the service offering is a function of demand, price, service level, and the resource cost. Numerical experiments are conducted to show the calculation of the optimal average reward in the long run.

5.3. Future Research Directions for C⁴ in E-Business

The papers reviewed in this section primarily propose analytical models and suggest the following future research directions: (1) the inclusion of the demand uncertainty and more general demand functions (Mukhopadhyay et al. 2008, Sun et al. 2008, Tsay and Agrawal 2004, Xia and Dube 2007), (2) the inclusion of more generalized probability distributions for customers' sensitivity to waiting time (Sun et al. 2008), and (3) the use of general functions instead of the quadratic functions for the costs of the sales efforts (Tsay and Agrawal 2004). In addition, Tsay and Agrawal (2004) recommend the following research directions: (1) the investigation of image control, flexibility, and brand loyalty, and (2) impact of product customization, delivery lead times, and ease of returns.

6. Research Methodologies and Techniques

In this section, we provide an overview of the research methodologies and techniques that were used in the reviewed research papers. The paper counts in the four major categories of e-business research that we defined in this paper are as follows: e-auctions (14 papers),

Table 5 Cross-Classification of the E-Business Papers in *Production and Operations Management (POM)*

	Research method						Research technique				
	Frameworks and analytical models						Game theory	Stochastic models	Deterministic models	Statistical methods	
	Total	Analytical models	Conceptual papers	Academic surveys	Empirical studies	Case studies					Simulation studies
E-auctions	14	8		2	2	1	1	8	6	7	2
Radio frequency identification	10	3		2	1	4		2	3		2
E-business system design	8		1		6	1					6
C ⁴ in e-business	7	7						4	6	4	
Total number of papers	39	18	1	4	9	6	1	14	15	11	10

RFID (10 papers), e-business system design (eight papers), and C⁴ in e-business (seven papers). Following Johnson and Whang (2002), we classify these papers (based on the research methods used) as frameworks and analytical models, empirical studies, case studies, and simulation studies. The frameworks category includes conceptual papers and academic surveys. We also specify the research techniques utilized as game theory, stochastic models, deterministic models, and/or statistical methods. Table 5 cross-lists the paper counts within each of the four major categories against the two additional dimensions mentioned above (research methods and research techniques).

We observe that analytical models (18 papers) is the major research methodology used in e-business research followed by empirical studies (nine papers) and case studies (six papers). E-auctions used analytical models in eight out of the 14 papers whereas all seven papers in the C⁴ in e-business group used analytical models. The empirical studies are primarily used for the e-business system design research—six out of the eight papers. Four out of the six case studies were used in the RFID research.

We also observe that both game theory and stochastic models are the primary research techniques for e-business research. Game theory was used in eight papers in the e-auction research followed by four papers in C⁴ in e-business and by two papers in RFID. The stochastic models were used in e-auctions (six papers), C⁴ in e-business (six papers) and RFID (three papers). The deterministic models were primarily used in e-auctions (seven papers) followed by four papers in C⁴ in e-business. The statistical methods were used mainly in the e-business system design research (six papers) followed by two papers each in e-auctions and RFID, respectively. Table 6 gives a cross-classification of the research methods vs. research techniques. The sum of the entries under each technique in a row is not equal to the entry under the total column because a paper might have used multiple techniques.

The above analysis shows a paucity of case studies in e-business research. We also notice an absence of

real-life examples in the analytical papers. The empirical studies help in developing causal relationships and can identify modeling opportunities. Mithas and Krishnan (2009) provide an excellent exposure to research techniques to establish causality.

7. Conclusions, Future Research Directions, and Managerial Implications

E-business is a multi-dimensional discipline involving the application of technology, the study of customers' attitudes, expectations, and satisfaction, the identification of internal organizational environment, the study of the relationships among partners in the supply chain, the development of collaborative strategies and coordination mechanisms, and the development of analytical models for operating (e.g., inventory and pricing) decisions. The research in the e-business area has been influenced by the developments in many academic fields that include but are not limited to the following: behavioral sciences, computer science, economics, information systems, marketing, operations management, OR/MS, and technology management. Collaboration among researchers in these disciplines is, therefore, crucial for a uniform and robust devel-

Table 6 Cross-Classification-Research Methods vs. Research Techniques

Research method	Research technique				
	Total	Game theory	Stochastic models	Deterministic models	Statistical methods
Frameworks and analytical models					
Analytical models	18	13	15	10	
Conceptual papers	1				
Academic surveys	4				
Empirical studies	9				8
Case studies	6			1	1
Simulation studies	1	1			1
Total	39	14	15	11	10

opment of the e-business research field. The literature on e-business can be found in many journals in the disciplines listed above. We limited our review to the papers published only in *POM*. However, in our review, we are inclusive of a broad variety of research topics related to e-business as compared with some of the earlier surveys that provided only a partial coverage of e-business issues. In particular, RFID and e-business system design did not get their fair share of attention in the earlier review papers.

In this paper, we have grouped each e-business research paper in only one of the following four categories: e-auctions, RFID, e-business system design, and C⁴ in e-business. These four categories, however, are not mutually exclusive. We have tried to include all papers in which the “e” dimension was a major focus of research and which belong to the four e-business categories conceptualized in this paper. However, we excluded papers with primary emphasis on IT. Based on the review of the papers published in *POM* and our assessment of the e-business field, we make the following specific recommendations to the P/OM researchers for future research:

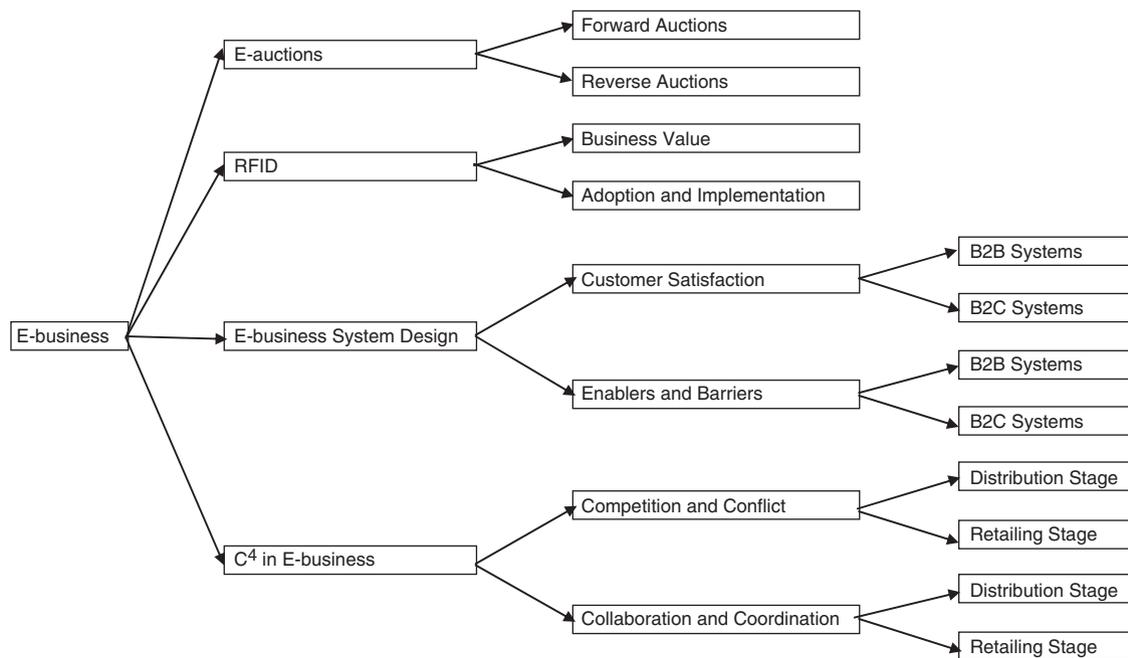
- The managerial relevance of the rigor of analytical models can be enhanced by incorporating real-life examples.
- Analytical models should be developed for specific organizations or industries.
- Analytical modeling can be extended to the study of multi-stage supply chain issues as compared with the current emphasis on the two-stage supply chains in the e-business environment.
- There is a paucity of benchmark systems to compare new models and new developments in the e-business area because this field is new and evolving. We suggest the development of taxonomy and benchmark systems for use in future e-business research. This observation has also been made in some of the reviewed papers.
- We found modeling of collusive behavior very intriguing. In our opinion, this is an important research topic because a collusive ring may form at any stage or between stages of a supply chain. For example, what kind of a collusive behavior, if any, may develop between the suppliers and retailers of a manufacturer? How would the manufacturer respond to this collusion? The study of collusion may require collaborative research efforts among experts in economics, operations management, game theory, and organizational behavior.
- The developments in RFID technology are taking place primarily in the engineering and technology disciplines. However, the review of RFID literature underscores the importance of the business value of RFID, and of the issues related to

RFID adoption and implementation. P/OM researchers need to find ways to use this important emerging technology in the most efficient way, which may require building analytical models and finding novel applications. For example, RFID technology could help to avoid serious inadvertent mistakes such as a surgeon leaving instruments and sponges in a patient’s body after a medical procedure (ScienceDaily 2006).

- There is a need for more empirical and simulation studies to identify RFID issues that warrant investigation, e.g., privacy and reliability issues.
- More empirical research is needed to identify the issues that give rise to the conflicts in e-business supply chains and to better understand the factors contributing to customer satisfaction in an e-business environment. Collaboration between researchers in the P/OM, marketing, information system, and organizational behavior disciplines may be needed to research these topics.
- Design of effective and efficient e-business systems for B2B scenarios needs more attention from researchers in the fields of P/OM and information systems.
- We found very few papers that study the enablers/barriers and their roles in e-business adoption. In order for an e-business endeavor to be successful, it is important to understand these issues. There is a need for more empirical as well as analytical research on understanding the enablers and barriers in an e-business environment.
- The use of the Internet in support of the traditional P/OM functions is conspicuously absent in the research papers we reviewed. Most of the reviewed papers focus on the supply chain issues. The developments in e-business research can be used to improve internal linkages and operations within an organization. For example, Bardhan et al. (2007) discuss the applications of IT for outsourcing decisions. An important research issue concerns how the Internet (or Intranet) can be used to improve internal P/OM functions such as product development, process development, quality control, scheduling, assembly operations, and flexible manufacturing systems.
- The findings of the e-business research could be extended to other emerging areas that are drawing the attention of P/OM researchers. For example, these areas include, but are not limited, to e-government, environmental management, and disaster management.

We conclude this paper hoping that P/OM practitioners will find this survey very informative and useful. We have identified the major themes of e-business research that in most instances focus on

Figure 1 Roadmap of Research Themes in E-Business



solving practical problems. Figure 1 provides a roadmap for practitioners to familiarize them with the research streams in e-business. A manager will be able to identify the research findings that relate to his/her problem. It is, however, understood that each real-life problem is unique with its own intricacies. The research findings reported in this paper can serve as a stimulus to the managers to explore the research related to their problems in more detail and develop implementable solutions. The development of solutions for real-life problems may promote and open avenues for joint research studies between the academicians and practitioners. All the issues discussed in the four major categories in this paper have practical importance. In fact, these issues have emanated from the developments in e-business practice.

Acknowledgments

We thank the editor-in-chief and the two anonymous referees for providing detailed and useful suggestions that improved the presentation of this paper.

References

- Amini, M., R. F. Otondo, B. D. Janz, M. G. Pitts. 2007. Simulation modeling and analysis: A collateral application and exposition of RFID technology. *Prod. Oper. Manag.* **16**(5): 586–598.
- Ba, S., W. C. Johansson. 2008. An exploratory study of the impact of e-service process on online customer satisfaction. *Prod. Oper. Manag.* **17**(1): 107–119.
- Bardhan, I. R., S. Mithas, S. Lin. 2007. Performance impacts of strategy, information technology applications, and business process outsourcing in US manufacturing plants. *Prod. Oper. Manag.* **16**(6): 747–762.
- Barratt, M., T. Choi. 2007. Mandated RFID and institutional responses: Cases of decentralized business units. *Prod. Oper. Manag.* **16**(5): 569–585.
- Boulding, W., R. Staelin, M. Ehret, W. J. Johnston. 2005. A customer relationship management roadmap: What is known, potential pitfalls, and where to go. *J. Mark.* **69**(4): 155–166.
- Boyer, K. K., M. Swink, E. D. Rosenzweig. 2005. Operations strategy research in the POMS Journal. *Prod. Oper. Manag.* **14**(4): 442–449.
- Boyer, K. K., M. T. Frohlich. 2006. Analysis of effects of operational execution on repeat purchasing for heterogeneous customer segments. *Prod. Oper. Manag.* **15**(2): 229–242.
- Boyer, K. K., J. R. Olson. 2002. Drivers of internet purchasing success. *Prod. Oper. Manag.* **11**(4): 480–498.
- Buhman, C., S. Kekre, J. Singhal. 2005. Interdisciplinary and inter-organizational research: Establishing the science of enterprise networks. *Prod. Oper. Manag.* **14**(4): 493–513.
- Caplice, C. 2007. Electronic markets for truckload transportation. *Prod. Oper. Manag.* **16**(4): 423–436.
- Cattani, K., W. Gilland, H. S. Heese, J. Swaminathan. 2006. Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Prod. Oper. Manag.* **15**(1): 40–56.
- Cattani, K. D., G. C. Souza. 2002. Inventory rationing and shipment flexibility alternatives for direct market firms. *Prod. Oper. Manag.* **11**(4): 441–457.
- Chen, F. Y., J. Chen, Y. Xiao. 2007. Optimal control of selling channels for an online retailer with cost-per-click payments and seasonal products. *Prod. Oper. Manag.* **16**(3): 292–305.
- Chen, Y.-J., S. Seshadri, E. Zemel. 2008. Sourcing through auctions and audits. *Prod. Oper. Manag.* **17**(2): 121–138.
- Delen, D., B. C. Hardgrave, R. Sharda. 2007. RFID for better supply-chain management through enhanced information visibility. *Prod. Oper. Manag.* **16**(5): 613–624.
- Dutta, A., H. L. Lee, S. Whang. 2007. RFID and operations management: Technology, value, and incentives. *Prod. Oper. Manag.* **16**(5): 646–655.

- Elmaghraby, W. 2007. Auctions within e-sourcing events. *Prod. Oper. Manag.* 16(4): 409–422.
- Etzion, H., E. J. Pinker. 2008. Asymmetric competition in B2B spot markets. *Prod. Oper. Manag.* 17(2): 150–161.
- Feng, J., Z.-J. M. Shen, R. L. Zhan. 2007. Ranked items auctions and online advertisement. *Prod. Oper. Manag.* 16(4): 510–522.
- Field, J. M., G. R. Heim, K. K. Sinha. 2004. Managing quality in the e-service system: Development and application of a process model. *Prod. Oper. Manag.* 13(4): 291–306.
- Gaimon, C. 2008. The management of technology: A production and operations management perspective. *Prod. Oper. Manag.* 17(1): 1–11.
- Gaukler, G. M., R. W. Seifert, W. H. Hausman. 2007. Item-level RFID in the retail supply chain. *Prod. Oper. Manag.* 16(1): 65–76.
- Geoffrion, A. M., R. Krishnan. 2003a. E-business and management science: Mutual impacts (Part 1 of 2). *Manage. Sci.* 49(10): 1275–1286.
- Geoffrion, A. M., R. Krishnan. 2003b. E-business and management science: Mutual impacts (Part 2 of 2). *Manage. Sci.* 49(11): 1445–1456.
- Gupta, S., R. Verma, L. Victorino. 2006. Empirical research published in *Production and Operations Management* (1992–2005): Trends and future directions. *Prod. Oper. Manag.* 15(3): 432–448.
- Hazra, J., B. Mahadevan, S. Seshadri. 2004. Capacity allocation among multiple suppliers in an electronic market. *Prod. Oper. Manag.* 13(2): 161–170.
- Heese, H. S. 2007. Inventory record inaccuracy, double marginalization, and RFID adoption. *Prod. Oper. Manag.* 16(5): 542–553.
- Heim, G. R., K. K. Sinha. 2002. Service process configurations in electronic retailing: A taxonomic analysis of electronic food retailers. *Prod. Oper. Manag.* 11(1): 54–74.
- Johnson, M. E., S. Whang. 2002. E-Business and supply chain management: An overview and framework. *Prod. Oper. Manag.* 11(4): 413–423.
- Karaer, O., H. L. Lee. 2007. Managing the reverse channel with RFID-enabled negative demand information. *Prod. Oper. Manag.* 16(5): 625–645.
- Kleindorfer, P. R., K. Singhal, L. N. Van Wassenhove. 2005. Sustainable operations management. *Prod. Oper. Manag.* 14(4): 482–492.
- Kouvelis, P., C. Chambers, H. Wang. 2006. Supply chain management research and *Production and Operations Management*: Review, trends, and opportunities. *Prod. Oper. Manag.* 15(3): 449–469.
- Kouvelis, P., C. Chambers, D. Z. Yu. 2005. Manufacturing operations manuscripts published in the first 52 issues of *POM*: Review, trends, and opportunities. *Prod. Oper. Manag.* 14(4): 450–467.
- Krishna, V. 2002. *Auction Theory*. Academic Press, San Diego.
- Krishnan, V., C. H. Loch. 2005. A retrospective look at *Production and Operations Management* articles on new product development. *Prod. Oper. Manag.* 14(4): 433–441.
- Kwasnica, A. M., E. Katok. 2007. The effect of timing on jump bidding in ascending auctions. *Prod. Oper. Manag.* 16(4): 483–494.
- Lee, H. L., O. Ozer. 2007. Unlocking the value of RFID. *Prod. Oper. Manag.* 16(1): 40–64.
- McAfee, R. P., J. McMillan. 1987. Auctions and bidding. *J. Econ. Lit.* 25(2): 699–738.
- Mithas, S., J. L. Jones. 2007. Do auction parameters affect buyer surplus in e-auctions for procurement? *Prod. Oper. Manag.* 16(4): 455–470.
- Mithas, S., M. S. Krishnan. 2009. From association to causation via a potential outcomes approach. *Inf. Syst. Res.* 20(2): 295–313.
- Mithas, S., M. S. Krishnan, C. Fornell. 2005. Why do customer relationship management applications affect customer satisfaction? *J. Mark.* 69(4): 201–209.
- Mukhopadhyay, S. K., X. Zhu, X. Yue. 2008. Optimal contract design for mixed channels under information asymmetry. *Prod. Oper. Manag.* 17(6): 641–650.
- Ngai, E. W. T., T. C. E. Cheng, K.-H. Lai, P. Y. F. Chai, Y. S. Choi, R. K. Y. Sin. 2007. Development of an RFID-based traceability system: Experiences and lessons learned from an aircraft engineering company. *Prod. Oper. Manag.* 16(5): 554–568.
- Peleg, B., H. L. Lee, W. Hausman. 2002. Short-term e-procurement strategies versus long-term contracts. *Prod. Oper. Manag.* 11(4): 458–479.
- Poundarikapuram, S., D. Veeramani. 2004. Distributed decision-making in supply chains and private e-marketplaces. *Prod. Oper. Manag.* 13(1): 111–121.
- Rabinovich, E., A. Maltz, R. K. Sinha. 2008. Assessing markups, service quality, and product attributes in music CD's internet retailing. *Prod. Oper. Manag.* 17(3): 320–337.
- Roth, A. R., L. J. Menor. 2003. Insights into service operations management: A research agenda. *Prod. Oper. Manag.* 12(2): 145–164.
- Rothkopf, M. H., A. B. Whinston. 2007. On e-auctions for procurement operations. *Prod. Oper. Manag.* 16(4): 404–408.
- Stockholms Auktionsverk (Stockholms Auktionsverk). Available at <http://www.auktionsverket.se/stadsauktion> (accessed June 19, 2009).
- Schroeder, R. G., K. Linderman, D. Zhang. 2005. Evolution of quality: First fifty issues of *Production and Operations Management*. *Prod. Oper. Manag.* 14(4): 468–481.
- Schwartzman, L. J., M. P. Wellman. 2007. Market-based allocation with indivisible bids. *Prod. Oper. Manag.* 16(4): 495–509.
- ScienceDaily*. 2006. RFID chips could help surgeons avoid leaving sponges in patients. *ScienceDaily*, July 18.
- Shen, Z.-J. M., X. Su. 2007. Customer behavior modeling in revenue management and auctions: A review and new research opportunities. *Prod. Oper. Manag.* 16(6): 713–728.
- Smith, J. S., K. R. Karwan, R. E. Markland. 2007. A note on the growth of research in service operations management. *Prod. Oper. Manag.* 16(6): 780–790.
- Sosic, G. 2007. Collusion in second-price auctions under minimax regret criterion. *Prod. Oper. Manag.* 16(4): 471–482.
- Starr, M. 2003. Application of POM to e-business: B2C e-shopping. *Int. J. Oper. Prod. Manage.* 23(1): 105–124.
- Sun, D., J. K. Ryan, H. Shin. 2008. Why do we observe stockless operations on the Internet? Stockless operations under competition. *Prod. Oper. Manag.* 17(2): 139–149.
- Swaminathan, J. M., S. R. Tayur. 2003. Models for supply chains in e-business. *Manage. Sci.* 49(10): 1387–1406.
- Tatsiopoulos, I. P., S. T. Ponis, E. A. Hadziliadis, N. A. Panayiotou. 2002. Realization of the virtual enterprise paradigm in the clothing industry through e-business technology. *Prod. Oper. Manag.* 11(4): 516–530.
- Tsay, A. A., N. Agrawal. 2004. Channel conflict and coordination in the e-commerce age. *Prod. Oper. Manag.* 13(1): 93–110.
- Tsikriktsis, N., G. Lanzolla, M. Frohlich. 2004. Adoption of e-processes by service firms: An empirical study of antecedents. *Prod. Oper. Manag.* 13(3): 216–229.
- Vickrey, W. 1961. Counterspeculation, auctions, and competitive sealed tenders. *J. Finance* 16(1): 8–37.
- Whitaker, J., S. Mithas, M. S. Krishnan. 2007. A field study of RFID deployment and return expectations. *Prod. Oper. Manag.* 16(5): 599–612.
- Xia, C. H., P. Dube. 2007. Dynamic pricing in e-services under demand uncertainty. *Prod. Oper. Manag.* 16(6): 701–771.