Pierluigi Argoneto · Paolo Renna

Innovative Tools for Business Coalitions in B2B Applications

How Negotiation, Auction and Game Theory Can Support Small- and Medium-sized Business in E-business

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Preface

One of the most debated consequences regarding the increased availability and use of information and communication technologies (ICTs), especially since the early 1990s, have been their impact on economic growth. Generally speaking, ICT can serve to reduce transaction costs at all levels of a commercial transaction. With the emergence and spread of the Internet in the developed world, it was expected that it would change the way that companies in developing countries—big and small—would transact, connecting them to international markets, reducing costs and improving competitiveness, propelling growth and development. There are various types of ICT-based applications, which can be grouped under the generic term "e-marketplace" including auctions, trade leads, e-retail and direct buyer/seller links. However, this generalization could imply that all applications support on-line buying and selling, and that transactions are actually completed on-line. Today, e-marketplaces have a significant role to play in business and continue to be a vibrant research topic and they are surely the most common e-business application within the manufacturing industry. At the same time globalization is pushing manufacturing companies toward a more distributed production approach. Indeed, corporate manufacturing firms are spreading their production all over the world in order to stay close to the customers, while medium manufacturing firms organize themselves in networks in order to scale their production to a global level. This tendency is putting a lot of stress on production planning. Indeed, the more distributed production facilities are, the more difficult and complex production planning becomes. An evolution of the consolidated use of this virtual interaction among customers and suppliers is the increasing of the e-marketplaces profitability by an integration of production planning, negotiation and coalition support tools. Production planning tools allow to create a link between commercialization and production activities, supplying a better service for customer, negotiation tools allow to make transactions taking into account both buyers and sellers' goals and, finally, coalition represents the proposed course of action for small and medium suppliers not able to fully respond to the customer requests. The book presents a study that has been conducted about the opportunity to utilize a set of innovative methodologies to face all the issues coming from the interaction of customers and suppliers in an e-marketplaces environment. The first methodology to this end is the use of a Multi-Agent Architecture to support the automatic interaction among the actors of an e-marketplace. The second one concerns the bargaining model based on the negotiation mechanism and, lastly, the production planning to support the agents during the bargaining phase. The fourth tool developed to support the e-marketplace is the possibility to make coalition among the suppliers: to this end two different approaches have been proposed. The first regards the application of Nash equilibrium to select the partners of a potential seller's coalition, while the other is a centralized approach with a profit sharing mechanism based on Shapley value. In order to test the proposed models, a simulation environment based on the elaborated Multi-Agent architecture has been developed. All the innovative approaches reported in this book have been statistically tested in different market conditions.

Very briefly, the book is organized as follows: Chap. 1 introduces the research problem and the research context with reference to the state of the art; Chap. 2 presents an overview of the Multi-Agent System that is, the technological tool suggested to support the automatic interaction among the involved actors. Chapter 3 provides an overview of Game Theory: the methodological tools used to build coalition and to face the related profit sharing issue. Chapter 4 presents an overview of the bargaining models, while the models for coalition management are reported in Chap. 5. Chapters 6 and 7, respectively present the simulation environment and the simulation results. Finally, Chap. 8 presents the conclusions of the research developed in the book.

Potenza, 5 Marzo 2011

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Contents

Chapter 1
Business-to-Business E-Marketplaces: A Literature Overview and Motivations

1.1 Introduction

One of the most debated consequences regarding the increased availability and use of information and communications technologies (ICTs), especially since the early 1990s, has been their impact on economic growth. This relationship has been widely analyzed and though with some controversies, the majority of the literature has supported that ICT investments explain a relevant part of economic growth, even in more recent years (Romero and Rodriguez 2010). For example, Jorgenson et al. (2008) obtain that the contribution of information technologies to total factor productivity for the US economy in 2000–2004 was 31%. Such a contribution would be smaller for EU countries, which is likely related to lower weight of investments in new information technologies in total gross capital formation (Van Bark et al. 2003). The positive link between telecommunication infrastructure and economic growth is also well-established in the literature that adopts an inter-country perspective. The work by Thompson and Garbacz (2007), who obtained a significant effect of information networks on the productive efficiency, is a recent example.

Generally speaking, ICT can serve to reduce transaction costs at all levels of a commercial transaction. With the emergence and spread of the Internet in the developed world, it was expected that it would change the way that companies in developing countries—big and small—would transact, connecting them to international markets, reducing costs and improving competitiveness and propelling growth and development. However, this was based on the premise that all such companies would have access to ICTs, including cost-effective and reliable ICT infrastructure (Standing et al. 2010). There are various types of ICT-based applications, which can be grouped under the generic term “e-marketplace” including auctions, trade leads, e-retail and direct buyer/seller links. However, this generalization could imply that all applications support on-line buying and selling, and that transactions are actually completed online. Today, e-marketplaces have a significant

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role to play in business and continue to be a vibrant research topic. From a research perspective, electronic marketplaces are examples of mechanisms, which instantiate the concepts related to economic market theory (Grover et al. 1999; Williamson 1975) and relational theory in terms of arm's length relationships (Uzzi 1997). These theories and the actual implementations of e-marketplaces are in contrast to the supply chain hierarchies: therefore, from a theoretical perspective, the study of e-marketplaces is significant because it presents an alternative line of enquiry related to efficiencies created through information technology. In its simplest form an e-marketplace, sometimes referred to as exchange, auction and catalogue aggregator, can be defined as an inter-organizational information system that allows the participating buyers and sellers in some market to exchange information about prices and product offerings (Bakos 1997). An e-marketplace should enable potential trading partners to be identified and a transaction to be executed (Choudhury et al. 1998). The distinction between Business-to-Business (B2B) e-marketplaces and Business-to-Consumer (B2C) or Consumer-to-Consumer e-marketplaces is blurring as increasing number of firms procure and sell via e-marketplaces.

1.2 Electronic Markets

A major category of literature in electronic marketplace research is investigating the theoretical foundations of markets and market efficiencies. This includes research that examines the transaction cost theory, pricing, efficient markets principles and relational theory. The development of IT has been viewed as a primary factor in the reduction of transaction costs and one which allows for a greater number of suppliers in electronic markets (Malone et al. 1987). Transaction costs are the costs associated with finding someone with whom to do business, reaching an agreement about the price and other aspects of the exchange, and ensuring that the terms of the agreement are fulfilled (Williamson 1975). Electronic markets have the potential to streamline and manage these activities and reduce the transaction costs associated with conducting business compared with hierarchies where a company has to manage its suppliers and procurement processes (Malone et al. 1987). However, it has been acknowledged that market efficiencies may be related to certain types of non-recurrent transactions (Williamson 1979). Efficiency in electronic marketplaces takes many forms. Significant work has been conducted on the theoretical aspects of matching the buyer and seller through various algorithms to select, classify and rank matches. Another major focus is related to efficiencies related to transaction costs. Although market environments are thought to reduce transaction costs, new transaction costs are incurred through the use of e-marketplaces because they engender a more complex environment where there are interdependent transaction risk factors, such as environmental uncertainty, information asymmetry and asset specificity. Lee and Clark (1996) found that most risks, and uncertainties are associated with social and economic barriers rather than with IT.

1.2.1 Adoption and Implementation of E-Marketplaces

Connection to a B2B e-marketplace may involve a significant investment in hardware, software and employee training (Damsgaard 1999) and this can impose significant switching costs for participants. Related to the adoption are the challenges of assessing risk associated with the selection of an e-marketplace and possible implementation problems with suppliers. Dewan et al. (2000) examined early adoption benefits such as increased profit and market share that results from the reduction in the sellers' costs associated with collecting buyer preference information and managing multiple prices. Those firms that customize products can gain a temporary advantage through e-marketplaces using discriminatory pricing to increase market share and also increased prices. However, the benefits of customization disappear when competing sellers adopt the same method as it tends to lead to over customizing to the detriment of profits. Barriers to adoption are often related to the differences between expected benefits and realized ones when adopting e-hubs due to factors such as problems of systems integration with the e-hubs and increases in supplier–buyer mistrust. Further barriers to the benefits realization include technological compatibility and operational capacity (Kaefera and Bendoly 2004). A particular issue related to the adoption of an e-marketplace by firms is the system perspective and their information systems which create the opportunity for the organization to concretely operate in an e-marketplace. Studies of auction mechanisms are included here when their focus is the negotiation and the execution of the transaction. Different e-marketplaces have different technological and information standards and e-marketplace standards may not be compatible with EDI and an organization's extranet standards. Business models examine auction structures and sub-systems and their evolution over time. They are included under "system" rather than organizational issues as their focus is the e-marketplace structure rather than the organizational implications of the structures. The private versus public feature of e-marketplaces has been investigated by Cousins and Robey (2005) who found that private metal exchanges were more successful than public metal exchanges because they allowed existing traditional relationships involving trust and privacy to continue while public exchanges did not.

Developing e-marketplace systems that share knowledge is a topic that is under represented in the information systems literature. Gosain (2003) researched the need to accommodate the tacit, situated and complex nature of knowledge and the challenges associated with its transfer and assimilation within e-marketplaces. Although considerable research has been conducted on the technical features of e-marketplaces, there are some areas that appear under researched. Areas with research potential that require further investigation include mobile access to e-marketplaces, usability of e-marketplace systems and future technical and system developments. Because of the large number of articles focusing on auction mechanisms it has been included as a separate category. The most common topic of research within electronic marketplaces is the actual auction process itself: the focus is on the type of auction process, associated algorithms and the efficiency of auction types. In particular, the functionality of the system is emphasized in terms of pricing of goods, features to provide support to buyer and seller related to bid strategies, feedback and reputation mechanisms and trust issues related to auction features. Classifying bidders and how the auction mechanism facilitates bidding have implications for the design and effective use of the mechanism. The development of bidder taxonomies has been linked to the idea of designing bidding agents that are aligned with the buyer's strategies (Bapna et al. 2004).

1.2.2 Electronic Commerce and E-Marketplaces

E-marketplaces can serve to provide several benefits to buyers and sellers alike. On the buyer side, applications such as reduce in buyers' search costs in terms of time and money; with the simple click of a button, information on a variety of sellers and goods and services for sale are made available. This leads to an increase in demand for goods and services. The improved information reduces the ability of sellers to attract monopoly profits and thus improves a market's ability to optimal allocate resources. On the seller side, e-marketplaces also reduce seller costs by allowing sellers, particularly micro businesses that lack the necessary resources to run brick-and-mortar shops (rent, employee salaries) to market their wares over their mobile or through a computer; this is especially relevant to low-income users in the developing world. It also opens up markets for the sale of less-popular, or long-tail products, since the cost of selling them is considerably reduced (Anderson 2006). However, exploitation of the long-tail requires sophisticated information processing and logistical capabilities that small and medium enterprises may not readily have. Nevertheless, the increase in supply of goods and services (and associated outward shift of the supply curve), together with the outward movement of the demand curve leads to a fall in prices and an expansion of the market. The impact of the perhaps unjustly maligned middlemen, or intermediaries, can be reduced through e-marketplaces (Wigand and Benjamin 1995; Picot et al. 1997) as more informed sellers have a chance to gain (more) direct access to markets, a process known as disintermediation. Many have argued that the lack of reliable information in developing countries gives opportunity to the intermediaries (sometimes more than one) to extract monopoly profits from the seller, and charge consumers exorbitant prices. However, much of the criticism of middlemen fails to take into account the services they provide such as transportation and aggregation into larger lots. When the information flows improve, the intermediaries do not disappear; the functions they perform change.

Summarizing the sourcing of goods or services via electronic means, usually through the internet, is an opportunity. Precursors of EP can be seen as early as the 1980s, with the evolution of Material Requirements Planning (MRP) systems into Manufacturing Resource Planning (MRP II) and then into Enterprise Resource Planning (ERP) systems in the mid 1990s. Moreover, Electronic Data Interchange

(EDI) can also be regarded as a form of electronic procurement. Although numerous papers have been published on this topic, no comprehensive literature review was found that tries to structure this research. It is thus the goal of the present paper to do just that, and to provide a starting point for a classification scheme. For this purpose, we consider usefully the following macro groups of e-marketplaces:

- e-MRO and web-based ERP—the processes of creating and approving purchasing requisitions, placing purchase orders and receiving the goods or services ordered via a software system based on internet technology; e-MRO deals with indirect items (MRO), web-based ERP deals with product-related items;
- e-sourcing—the process of identifying new suppliers for a specific category of purchasing requirements using internet technology;
- e-tendering—the process of sending requests for information and prices to suppliers and receiving the responses using internet technology;
- e-reverse auctioning—enables a purchaser to buy goods and services needed from a number of known or unknown suppliers;
- e-informing—the process of gathering and distributing purchasing information both from and to internal and external parties using internet technology.

It is important to note that we are only looking at the Business-to-Business (B2B) sector, thus excluding the Business-to-Consumer (B2C) side of it, which is the interest of this book. In the following two paragraphs, we focus the attention on the business models related to the e-marketplace, in particular the macro sector of negotiation mechanisms, and on the possibility and motivation to create coalitions in the considered B2B context.

1.3 Negotiation in Economics

The variety of involved disciplines and perspectives in the conflict resolutions field has created different terminologies, definitions, notations and formulations about the concept of negotiation. As a result, interdisciplinary cooperation among concerned fields of study suffers from inconsistencies and contradictions (Gulliver 1979). Yet, negotiations require an interdisciplinary approach because of their psychological, social and cultural character; economic, legal and political considerations; quantitative and qualitative aspects and strategic, tactical and managerial perspectives. Clearly, interdisciplinary approaches provide richer and more comprehensive models of negotiators and negotiations. Computer science and information systems contributions include construction of electronic negotiation tables, decision and negotiation support systems (DSS, NSS), artificial negotiating software agents (NSA) and software platforms for bidding and auctioning (Holsapple and Lai 1998; Kersten 1997; Maes and Guttman 1999; Rosenschein and Zlotkin 1994). Most traditional negotiations have been conducted face-to-face; others have been conducted using mail, fax and telephone. Mail-based and e-mail-based negotiations share many similarities in that they are difficult to manage, time-consuming and prone to misunderstanding (Thompson 2001). Yet, the impact of information technologies on negotiations is not limited to the use of electronic communication. Information technology changes the way a negotiation problem can be represented, and a negotiation process can be structured. The use of Internet-based information systems allows for many more activities undertaken in negotiations, including, efficient matching of potential negotiators; exchange, comparison and categorization of rich data; the use of tools for data collection, problem structuring and analysis and interpretation of offers. These new possibilities have led to the emergence of formal negotiation procedures and protocols, which are necessary for the use of rich and expressive information technologies in various stages of negotiation processes rather than solely for the exchange of messages. Initiated by the commercial exploration of the Internet as a global communication and "negotiation" infrastructure (Raisch 2000), electronic varieties of negotiations have started to gain momentum in manifold shapes—from web-based NSS, to on-line auctions, to automated agent-based negotiations, in both research studies and business applications (Edwards 2001). Examples of new negotiation protocols include auction protocols with combinatorial bids on product bundles, automated negotiations among software agents as well as protocols supporting bi- and multi-lateral negotiations among human negotiators. Electronic negotiations promise higher levels of process efficiency and effectiveness, and most importantly, a higher quality and faster emergence of agreements. The potential monetary impact leads to an increased demand for appropriate electronic negotiations for specific negotiation situations. Yet, both the design of suitable electronic negotiation protocols and the implementation of relevant electronic negotiation media largely lack systematic, traceable and reproducible approaches and thus they remain more an art than a science. Recent developments created an opportunity for mutual fertilization of research studies and approaches, and for integration of different perspectives on negotiations into an interdisciplinary research effort to develop an engineering approach to electronic negotiations, similar to, for example, system or process engineering, which brings together the findings about negotiators and negotiation processes from the different research areas.

1.3.1 Underlying Principle for Electronic Negotiation

The computerization of negotiation processes increasingly affects the way businesses interact with their customers, suppliers and other business partners. Traditionally, firms conducted negotiations with a counterpart in a bilateral manner: face-to-face, in writing or via telephone and facsimile. Such negotiations are difficult to manage, time-consuming, prone to misunderstanding and require significant cognitive efforts. Traditional negotiations suffer from limited transparency of the negotiated, meagre liquidity, an ex ante restricted number of potential counterparts and high transaction costs (Weinhardt and Gomber 1999). Those negotiation processes are rarely efficient and often lead to inefficient compromises (Kersten and Mallory 1999). The rationale for e-negotiations is, therefore, the possibility of higher levels of process efficiency and effectiveness, including the exchange of quantitatively and qualitatively improved information during the negotiation process. The design of e-negotiation media, support systems and software agents that matches the diversity of users, and the richness and complexity of negotiation situations, requires categorization and structuring of the latter, and, also, specification of concepts and constructs. This effort led to the creation of a taxonomy of electronic negotiations comprising types of processes and terms used to describe different types in detail. Raiffa (1982) in his seminal work discourages "devising a taxonomy of disputes, in which the listing would be reasonably exhaustive and in which overlaps among categories would be rare. This was possible, I found, only after developing a host of abstract constructs—and even then the taxonomy was not very useful". Noting this caveat, it is obvious that such efforts need to be made. This is because new information technologies are increasingly being used to construct media for engagement in social and economic processes such as negotiation in parallel and independently of the behavioural and normative models of these processes. Results of social sciences should be taken into account in the design of these media and as well as their implications for the processes themselves. In addition, a taxonomy allows for the establishment of a common, unique terminology across disciplines, classification of models and systems, identification of their possible extensions and for the identification of new constructs and negotiation protocols.

1.3.2 Electronic Negotiation Protocols

The implementation of every model in an information system brings forth certain rules of interaction that those who use this medium must follow. These rules need to be specified so that agents (human or artificial) know the permissible set of actions. An *e-negotiation protocol* is a model of the negotiation process in which at least some activities are supported or performed by information systems and the negotiations are conducted with an electronic medium. The e-negotiation protocol may be complex and with many rules governing the parties as they move through different stages and phases of the negotiation process. For example, an e-negotiation may begin with an auction and, after three winning bidders have been identified, move on to a bilateral bargaining protocol among the three winners. Typically, designers try to achieve certain goals for the outcome of a negotiation and for the negotiation process itself, such as, Pareto optimality of the result, maximization of the bid taker's revenue/ utility, stability and speed of convergence (Jackson 2000). These objectives are achieved through:

- Specification of the structure of the negotiation problem and process;
- Specification of rules of feasible activities and their sequencing and timing; and
- Imposition of limitations on the form and content of information exchange.

Every e-negotiation protocol restricts the negotiators' freedom in order to meet one or more of the above objectives. A *closed e-negotiation protocol* is one that is defined and fixed prior to the negotiation process so that new rules cannot be added throughout the negotiation. A closed negotiation protocol can cover various negotiation situations but the set of rules is fixed and the rules cannot be modified. Implementations of traditional auction formats such as the Dutch or English auction are good examples of a closed e-negotiation protocol. An *open e-negotiation protocol* does not contain all rules required for the negotiation; they may be constructed by the participants or by mechanisms during the negotiation process. In both cases, this involves learning about the participants, problem and process; the results of learning are new rules that were not present prior to the e-negotiation. Complex electronic negotiation protocols often involve a combination of two or more different classes of negotiation protocols and thus exhibit the characteristics of multiple negotiation models in either sequential or parallel execution. For example, in financial markets continuous double auction protocols have been combined with bilateral chat markets (Budimir and Holtmann 2001) where a trader can select an offer and engage in a bilateral chat with the respective counterpart.

1.3.3 Characteristic that Differentiates Negotiations Protocols

Evaluation of the results of negotiations is not easy. Since the agents are self-interested, when a negotiation is said to be successful we must ask "successful for whom?" since each agent is concerned only with its own benefits or looses from the resolution of the negotiation. Nevertheless, there are some parameters that can be used to evaluate different protocols:

- *Distribution*: the decision-making process should be distributed. There should be no central unit or agent required to manage the process.
- *Symmetry*: the coordination mechanism should not treat agents differently in light of non-relevant attributes. In the situations considered, the agents' utility functions and their role in the encounter are the relevant attributes. All other attributes, such as an agent's name, characteristic, or manufacturer, are not relevant.

That is, symmetry implies that given a specific situation, the replacement of an agent with another that is identical with respect to the above attributes will not change the outcome of the negotiation. The following parameters can be used to evaluate the results of the negotiation:

- *Negotiation time*: negotiations that end without delay are preferable to negotiations that are time-consuming. It will be assumed that a delay in reaching an agreement causes an increase in the cost of communication and computation time spent on the negotiation. We want to prevent the agents from spending too much time on negotiation resulting in not keeping to their timetables for satisfying their goals.

- *Efficiency*: it is preferred that the outcome of the negotiations will be efficient. It increases the number of agents that will be satisfied by the negotiation results and the agents' satisfaction levels from the negotiation results. Thus it is preferable that the agents reach Pareto optimal agreements.
- *Simplicity*: negotiation processes that are simple and efficient are preferable to complex processes. Being a "simple strategy" means that it is feasible to build it into an automated agent. A "simple strategy" is also one that an agent will be able to compute in a reasonable amount of time.
- *Stability*: A set of negotiation strategies for a given set of agents is stable if, given that all the other agents included in the set are following their strategies, it is beneficial to an agent to follow its strategy too. Negotiation protocols that have stable strategies are more useful in multi-agent environments than protocols that are unstable. If there are stable strategies, we can recommend to all agent designers to build the relevant strategies into their agents.

1.4 Multi-Attribute Negotiation in Economics

The study on multi-attribute negotiation in economics is mainly conducted by game theory and, it can be divided into two branches: non-cooperative and cooperative multi-attribute negotiation (Lai et al. 2004).

1.4.1 Non-Cooperative Negotiation

The models and theorems in this branch are concerned with the situations in which the sets of possible actions of individual players are the primitives (Osborne and Rubinstein 1994). Thus, the research in this branch mainly focuses on the analysis of equilibrium outcomes of a negotiation game. Players are in equilibrium if a unilateral change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy (Nash 1951). The pioneering work in this field is Rubinstein's alternating-offer bargaining solution (Rubinstein 1982). Further, within different contexts, researchers studied the bargaining game with asymmetric information, incomplete information, outside options etc. (Fishburn and Rubinstein 1982; Rubinstein 1985; Fudenberg and Tirole 1983; Ordover and Rubinstein 1986; Muthoo 1995; Chatterjee and Lee 1998). But most of them focus on one single issue and simultaneous negotiation with multiple issues is too complicated for non-cooperative alternating-offer game. Faced with multiple issues, agents need to decide two things before the negotiation: one is what kind of negotiation procedure they will take and the other is the type of agreement implementation. We call these two negotiation procedure and agreement implementation: together they form a negotiation framework of multi-attribute negotiation. There usually exist three types of negotiation procedures: separate, simultaneous and sequential. Separate negotiation means agents negotiate with each issue separately (independently and simultaneously). We can view it, as if there are n pairs of representatives for the two agents, and each pair of them independently negotiates one issue. Simultaneous negotiation means two agents negotiate a complete package on all issues simultaneously. The last one is that two agents negotiate issue-by-issue sequentially, i.e., issue-by-issue negotiation. Here, with issue-by-issue negotiation, agents also need to decide the order to negotiate each issue. For agreement implementation, there can be two types: sequential and simultaneous. Sequential implementation means the agreement on each issue is implemented once it is reached, while simultaneous implementation means that agreements are implemented together when all issues are settled. Usually, agreement implementation might be determined by the negotiation problem. Research on issue-by-issue negotiation is mostly based on Rubinstein's bargaining model by introducing another issue (pie) into the system. By different assumptions, the two issues may have different values and be differentially preferred by the agents. Besides, the two issues can either be simultaneously available or arrived at in a sequential order.

The idea of negotiating issue-by-issue and some challenges it presents is illustrated by an example from the American Automobile Association (Bac and Raff 1996). They recommended that buyers should first focus on negotiating the price of the car and only discuss financing, factory rebates and the trade-in allowance once the price has been agreed upon. 'However, the thing somehow seems to be puzzling as those issues are almost perfect substitutes, i.e., all ultimately determining how much money will change hands. Why shouldn't the buyers negotiate on them simultaneously and reach an agreement right way?' One reason, as Bac and Raff say (1996), is bounded rationality, simultaneously negotiating a complete package might be too complex for individual buyers. However, this reason provides only an intuitive idea on issue-by-issue negotiation. More theoretical explanation or signaling might be the first and only reason that researchers mention, why issue-by-issue negotiation arises under incomplete information. Bac and Raff (1996) study a case with two simultaneous and identical pies where agents can either choose sequential negotiation with sequential implementation or simultaneous negotiation with simultaneous implementation. The authors show that in the context of complete information agents will take simultaneous negotiation and reach an agreement without delay. But in the context of asymmetric information (assume two players A and B, A is informed, but B is uncertain of A's time discount, which can take one of the values: δH with probability π and δL with $1 - \pi$), the authors argue that when B's time discount is in some interval (not so strong and also not so weak), the "*strong*" type of the informed agent (A with δH) may make a single offer on one pie and leave it to the opponent (B) to make an offer on the second pie, while a "*weak*" type of informed player (A with δL) only makes a combined offer. So if issue-by-issue negotiation arises, it is because the "*strong*" and informed agent, by a single (signaling) offer, wants to let her opponent know she is strong and makes her concede. Busch and Horstmann (1999) similarly but more strictly study the signaling factor with an incomplete information model that allows for different sized pies and each kind of agreement implementation. By setting some parameter configurations, they show that issue-by-issue negotiation may arise with signaling reason and they prove under such configurations that signaling does not arise if agents can only bargain a complete package. So the authors argue it is purely because some favorable endogenous agenda for issue-by-issue bargaining is available. Besides, they also show that if issue-by-issue bargaining arises from agents it will negotiate the "large" pie first. However, multi-attribute negotiation under the context of incomplete information is complicated for analysis, and the results are also not so intuitive.

1.4.2 Complete Information

As mentioned above, under complete information agents will negotiate a complete package if it is with simultaneous and identical pies. But when assumptions are changed, issue-by-issue negotiation could possibly arise under complete information. In real-life, we know with sequential issues some people might like to decide all issues at once, while others prefer to decide one by one. Busch and Horstmann (1997b) study the difference between incomplete contract (issue-by-issue) and complete contract (simultaneous) negotiation with sequential pies on which agents have different preferences. From the equilibrium outcomes of the two procedures, we see if agents are heterogeneous, they might have conflicting favors on the two procedures, which means one prefers incomplete contract procedure but the other may prefer complete contract procedure. Further, Busch and Horstmann also show when time is costless agents will agree to negotiate complete contract, while if time is very valuable agents will take incomplete contract. With different perspective Lang and Rosenthal (2001) argue joint concavity of two agents' payoffs can eliminate the possibility of non-fully bundled (issue-by-issue) equilibrium offers, but in realistic settings, the property of joint concavity is usually not true so that partial bundled offer on a subset of unsettled issues may be superior over fully bundled offer. Commonly people only consider the time issue in negotiation research. But the factor of breakdown can also impact a multi-attribute negotiation. We know sometimes agents insisting on some issue may lead the whole negotiation to breakdown. Chen (2002) is one researcher who studied issue-by-issue negotiation with breakdown factor. Chen applies a probability setting that a negotiation on some issue breaks down if a proposal on it is rejected. However, he assumes agents' utility functions are linear additive so that one negotiation breaking down does not affect others. By comparing the equilibrium outcomes between issue-by-issue negotiation and simultaneous negotiation, Chen argues that when the probability of breakdown is low, agents prefer to negotiate a complete package because intuitively we know that the bargaining can last long enough so that agents can get to a "Win–Win" solution with inter-issue trade-offs. However, when the breakdown probability is high, agents weakly prefer issue-by-issue negotiation. Chen also shows that if agents are sufficiently heterogeneous, issue-by-issue negotiation may also be superior over simultaneous negotiation. In and Serrano (2004) assume that one, agents will prefer to bargain simultaneously over all issues. Negotiation breakdown can make the whole procedure fail, and agents are restricted to make an offer on only one of the remaining issues each round. They show that when the probability of breakdown goes to zero, there is a large multiplicity of equilibrium agreements and inefficiency arises. But it does not happen for simultaneous negotiation. However, if agents are not restricted to make offers on only one issue at each round (i.e., agents can make partially or fully-bundled offers), the outcome turns to be Pareto-efficient (In and Serrano 2003). Thus, their work indicates strict issue-by-issue negotiation may raise inefficiency. Inderst (2000) might be the only person who compares those three different negotiation procedures in one paper. On a set of unrelated issues, Inderst argues that the issues are mutually beneficial. Besides the work above, Weinberger (2000) studies the multi-attribute negotiation problem within a specific context allowing "Selective Acceptance". In such a context, the offer initially needs to be a complete package including all issues, but agents can accept or reject the whole package as well as selectively accept part of the package on some issues. But if agents accept a part on some issues, these issues cannot be reopened again. The author indicates that in some situations this leads to good solutions. Weinberger shows "Selective Acceptance" can lead to inefficient equilibrium outcomes if some issues are indivisible or agents have opposing valuations on issues. For comparison, Weinberger shows that inefficient outcomes do not arise under the rule only to accept or reject the whole package. However, the equilibrium outcomes with "Selective Acceptance" are not dominated by the efficient outcome. It means there must be some agent who is better off by the rule of "Selective Acceptance" and will not agree on the efficient outcome. The research results under complete information, compared to those under incomplete information, are more intuitive. However, from the results we see inefficiency may arise in issue-by-issue negotiation except when negotiation friction is big. It indicates only when time is a profitable or breakdown probability is high, agents might be better off by issue-by-issue negotiation. Especially, if agents are also sufficiently heterogeneous, issue-by-issue negotiation might be an appropriate approach.

1.4.3 Agreement Implementation

People are usually not so patient to wait until all agreements are reached and then to enjoy their gains. So agreement implementation is also an important issue agents need to decide. Further, we know agreement implementation can also impact the order of negotiation on issues. If the implementation is sequential, it is usually true that people will negotiate the easier issues first; but if it is simultaneous implementation, it becomes indifferent between hard issues or easy issues if there are no other factors (Raiffa 1982). Busch and Horstmann (2002) formally study this problem. First, they define two kinds of issues, "*easy issue*" and "*hard issue*". An "*easy*" issue is one on which the agents' time discounts are public information so that agreement will be reached without delay; a "*hard*" issue is one where there will be delay to reach agreement because of incomplete information. Then they show that if the implementation is sequential agents will negotiate the "*easy*" issue first, while if it is simultaneous they will settle large surplus issue first no matter whether it is "*easy*" or "*hard*". And of course agents will apply sequential implementation under issue-by-issue negotiation because by simultaneous implementation the achievements on the firstly settled issues would be depreciated when all agreements are reached.

1.4.4 Cooperative Negotiation

Research in cooperative game theory deals with the situations in which the sets of possible joint actions of *groups* of players are the negotiation primitives (Osborne and Rubinstein 1994). The term "cooperative" here does not mean that players cooperate, but they are supposed to be able to discuss the situations with perfect information, agree on some rational joint plan and the agreement is assumed to be enforceable (Nash 1953). Research on multi-attribute negotiation, in this field, is concerned with finding a solution when given some possible outcomes, which is required to satisfy a set of axioms such as Nash axioms. Below, we first discuss Nash solution and some other axiom work that are applicable in cooperative multi-attribute negotiation; then the methodology to find out Pareto-optimal frontier is introduced. Finally, we discuss some methods named as "fair negotiations" that are applicable in some specific situations. Herrero (1989), Busch and Horstmann (1997a) study the differences between negotiation procedures and agreement implementations by exogenous agendas. Herrero (1989) points out that the equilibrium outcomes differ under these procedures even when discount factors go to one. Busch and Horstmann (1997a) compare the results under the agendas of simultaneous bargaining with simultaneous implementation and issue-by-issue bargaining with sequential implementation. Busch and Horstmann argue that agents prefer the latter agenda if the higher value issue is negotiated first, otherwise agents will take the former agenda. Besides, Chen (2002) characterizes an equilibrium agenda, which lets agents first negotiate the most important ones among the remaining issues. In and Serrano (2003, 2004), and Inderst (2000) also study negotiations based on exogenous agendas. Up to now, we mentioned most of the existing work in the field of non-cooperative game theory. We see that although issue-by-issue approach is much simpler than simultaneous negotiation, it may encounter the difficulties of agenda selection and inefficiency. Besides, the implicit assumptions to take issue-by-issue negotiation are that agents' utility functions are linear or additive, and reservation price on each issue is independent.

Specifically, research in Cooperative game theory deals with the situations in which the sets of possible joint actions of *groups* of players are the negotiation primitives. The term of "cooperative" here does not mean that players cooperate, but they are supposed to be able to discuss the situations with perfect information, agree on some rational joint plan and the agreement is assumed to be enforceable. Research on multi-attribute negotiation in this field is concerned with finding a solution when given some possible outcomes, which is required to satisfy a set of axioms such as Nash axioms. Below, we first discuss Nash solution and some other axiom work that are applicable in cooperative multi-attribute negotiation; then the methodology to find out Pareto-optimal frontier is introduced. Finally, we discuss some methods named as "fair negotiations" that are applicable in some specific situations (market positions) because it is already assumed in Nash's approach that two agents are sufficiently intelligent and rational, and information is perfect.

Nash's approach is also applicable even when there are multiple issues as long as the assumptions can be maintained that include: strategy space of each agent is compact, convex and metrizable, corresponding solution space is compact and convex, information is perfect and agents are sufficiently intelligent and rational. Following Nash's methodology, for two-person negotiation game on n issues, the first thing is to construct the mapping from strategy space (*n-dimensional*) to solution space (2-*dimensional*). From Nash's approach, we say the problem can be simplified in most of the situations where the disagreement payoff pair is fixed such that agents cannot choose disagreement strategy as a threat, for instance, or some undetermined punishments. In other words, agents' reservation utilities are certain. Usually this assumption is reasonable for a negotiation game as Nash assumes in (Nash 1953); if there is no agreement, agents get zero utilities. So now to solve the negotiation problem it is not necessary to reach the whole space or even the whole frontier but the Pareto-frontier because it is assumed that agents are sufficiently intelligent and rational such that the outcome is Pareto-efficient.

1.5 Multi-Agent System and Negotiation

Negotiation has been one of the central subjects in the research area of multi-agent systems (MAS) (Kraus 2001; Braun et al. 2006). For MAS-based SCM applications, agents act on behalf of supply chain members by making use of autonomous characteristics and decision-making capabilities. Over the last decade, there has been an increasing trend toward the use of MAS in industrial and commerce applications. Typically, agents in a MAS have to negotiate and coordinate their activities to come to mutually acceptable agreements. For instance, agent-based negotiations have been established to support applications including Supply chain Management (Tewari et al. 2003), shopfloor control, holonic manufacturing systems, process planning and scheduling integration, e-commerce, supply chain integration and virtual enterprise formation.

In the last few years, there have been several attempts to define an agent. For example, Etzioni and Weld (1995) require an agent to be goal-oriented, collaborative, flexible and capable of making independent decisions on when to act. In addition, they determined that an agent should be a continuously running process and be able to engage in complex communication with other agents, including people. It should automatically customize itself to the preferences of its user and to environment changes. Subrahmanian et al. (2000) concentrate on the interaction of an agent with other agents and the environment. They define a software agent as a body of software that:

- Provides one or more useful services that other agents may use under specified conditions;
- Includes a description of the service offered by the software, which may be accessed and understood by agents;
- Includes the ability to act autonomously without requiring explicit direction from a human being;
- Includes the ability to describe succinctly and declaratively how an agent determines what actions to take even though this description may be kept hidden from other agents, and
- Includes the ability to interact with other agents either in a cooperative or in a adverse manner, as appropriate.

There are two aspects to the development of agents: what is the architecture of each agent, and how do they interconnect, coordinate their activities and cooperate. There are many approaches to the development of a single agent. These approaches can be divided into three many categories (Wooldrige and Jennings 1995): *deliberative*, *reactive* and *hybrid architectures.* A *deliberative architecture* is one that contains an explicitly represented, symbolic model of the world, and one in which decisions (e.g., about what actions to perform) are made via logical reasoning, based on a pattern matching and symbol manipulation. The main criticism of this approach is that the computational complexity of symbol manipulation is very high, and some key problems appear to be intractable. A *reactive architecture* is usually defined as one that does not include any kind of central symbolic world model and does not use any complex symbolic reasoning. These types of agents work efficiently when they are faced with many “routine” activities. Many researchers suggest that neither a completely deliberate nor a completely reactive approach is suitable for buildings agents. They use *hybrid systems*, which attempt to combine the deliberate and the reactive approaches.

1.5.1 Negotiation Models

Negotiations were used in DAI both in Distributed Problem Solving (DPS), where the agents are cooperative, and in Multi-Agent Systems (MAS), where the agents are self-interested. Several works in DPS use negotiation for distributed planning and distributed search for possible solutions for hard problems. For example, Conry et al. (1991) suggests multi-stage negotiation to solve distributed constraint satisfaction problems when no central planner exists. Moehlman et al. (1992) use negotiation as a tool for distributed planning: each agent has certain important constraints, and it tries to find a feasible solution using a negotiation process. They applied this approach in the Phoenix fireman array. Lander and Lesser (1992) use a negotiation search, which is a multi-stage negotiation as a means of cooperation while searching and solving conflicts among the agents. For the MAS environments, Rosenschein and Zlotkin (1994) identified three distinct domains where negotiation is applicable and found a different strategy for each domain:

- *Task-Oriented Domain*: finding ways in which agents can negotiate to come to an agreement, and allocating their tasks in a way that is beneficial to everyone;
- *State-Oriented Domain*: finding actions which change the state of the "world" and serve the agents' goals; and
- *Worth-Oriented Domain*: same as State-Oriented Domain above, but, in this domain, the decision is taken according to the maximum utility the agents gain from the states.

Sycara (1987) presented a model of negotiation that combines case-based reasoning and optimization of multi-attribute utilities. In her work agents try to influence the goals and intentions of their opponents. Zeng and Sycara (1998) consider negotiation in a marketing environment with a learning process in which the buyer and the seller update their beliefs about the opponent's reservation price using the Bayesian rule.

1.5.2 Mobile Agent-Based Negotiation System

Mobile agents (MA) are software agents that have the basic capability to move themselves from host to host and continue execution from the point they stopped on the previous host. They may interact with computer hosts and then return to their users after completing their duties, and they are well-suited for negotiations because of their distinctive features. Other authors handle the multi-tier supply chain, where a supplier may need to contact further suppliers of sub-components. It simply puts mobile agents in a serial working pattern and virtually connects with suppliers in a ring topology. However, these systems act as mediators between buyers and suppliers. Buyers and suppliers must travel to or log on to these auction sites and negotiate inside the auction sites.

1.5.3 Negotiation Protocol

For MAS applications, the negotiation protocol comprises a set of rules to govern the interactions of agents. The protocol sets stages for the negotiation process, covering:

- The permissible types of participants (e.g., the negotiators and relevant third parties);
- The negotiation states (e.g., accepting bids, negotiation closed, etc.);
- The events that cause state transitions (e.g., no more bidders, bid accepted, etc.); and
- The valid actions of participants, in particular, states (e.g., sent by whom, to whom, and when).

Depending on the protocol types, negotiations can be categorized as bidding, auction and bargaining.

1.5.4 Bidding

Bidding is the simplest but powerful negotiation protocol for MAS applications. The contract net protocol (CNP) is a good example of bidding. The original CNP has been applied to different kinds of SCM negotiation problems. Some researchers have extended the CNP to competitive agents with conflicting goals as the CNP was originally designed for agents with non-conflicting goals. The extended CNP based on a marginal cost-based contract provides a formal model of the decision process of bidding and awarding to solve a vehicle routing problem.

1.5.5 Auction

Auctions have been widely studied and applied. In general, the auctioneer in an auction is the seller, while in a reverse auction the auctioneer is a buyer. The auctioneer initiates an auction with an initial offer and monitors the auction process while bidders send their own bids in response to the initial offer or bids from other offers. The auctioneer follows a certain auction protocol to pick up the final partner. Different types of auction protocols, such as English auction (first-price ascending), Japanese auction (second-price ascending), first-price sealed-bid auction, Vickrey auction (second-price sealed-bid) and Dutch auction (first-price descending), etc., are different in the way prices are quoted and in the manner in which bids are tendered. With the proliferation and success of internet-based auction sites such as eBay, the auction has been very common in on-line retailing. Many auction systems have also been designed and implemented. Despite their advantages, researchers realize that auction is not well-suited for cooperative or semi-competitive negotiation. They show several limitations. Firstly, auctions only allow negotiation for price and thus many other relevant attributes (e.g., delivery and after-sales service) are ignored. Secondly, auctions are usually scheduled in advance and with time restrictions. Some buyers/sellers may not want to wait until an auction opens or finalizes. Thirdly, auctions fail to support two-way communication of offers and counter-offers. One side is allowed to propose counter-offers but the other side can only accept/reject the opponent's counter-offers. Lastly, in auctions, it is impossible to exercise different negotiation strategies with different partners.

1.5.6 Bargaining

Bargaining allows the bargainers to solve the conflicts by alternating-offer and counter-offer round by round until an agreement is reached. During the bargaining process, concessions by either side or both sides are required. A bargaining protocol involves multi-round negotiations, its process is more complex than that of a bidding protocol, and the strategy used is more complex than that of auctions. One significant difference between bargaining and auction is: in an auction, only one side (either buyer or seller) is making the concession, while in bargaining, both sides can offer concessions. The other major difference between auction and bargaining is that multiple issues can be involved in bargaining. There are several variations of bargaining: bi-lateral bargaining (one-to-one), multi-lateral bargaining (one-to-many, many-to-one and many-to-many), single-issue bargaining and multi-issue bargaining. Different policies and strategies are often applied in different bargaining situations. For multi-issue bargaining protocols, according to the order of issues bargained, it is further divided into two categories: bargaining in-bundle over multiple issues and bargaining issues one-by-one. The former protocol can bargain multiple issues simultaneously, and it allows the negotiators to exploit the trade-offs among different issues, but the negotiation space is complex and difficult to search. The issue-by-issue approach has a simpler computation, but an important question that arises is the order in which the issues are bargained. Based on the order of exchanging offers, some bargaining protocols allow agents to submit offers simultaneously, for example, the monotonic concession protocol (MCP). In contrast, other protocols allow for iterative exchange of offers, for example the iterative negotiation protocol. Generally, most bargaining models in agent-based systems adopt Rubinstein's alternating sequential offers protocol, with which a framework of two agents, the buyer and the seller, bargain over an item (bilateral negotiation). Players alternatively take it in turns to make an action which can be either (i) accepting the offer (counter-offer) from the opponent or (ii) proposing its counter-offer until agreement or disagreement is reached (as well as the time is reached). This approach is simple to understand and implement but it is confined to the bi-lateral bargaining process with limited negotiation primitives. Many modifications of the traditional alternating-offer models have been proposed to improve the bargaining mechanism.

1.5.7 Multi-Lateral Negotiation

Multi-lateral negotiation involves various complex issues and it is one of the challenging problems in MAS research. Endriss and Maudet (2005) examined the complexity of multi-lateral negotiation and they proposed the adoption of monotonic concession protocols in the multi-lateral scenario (Endriss 2006). For multi-lateral bargaining, there are multiple providers of the product or service. In this case, there are two alternative ways of bargaining: negotiate sequentially with all the providers or negotiate concurrently. To negotiate sequentially, the outcome of one negotiation will be used to dictate the behavior in subsequent negotiations. It is comparatively easy to use but it may result in lengthy negotiation encounters.

1.6 Coalition Formation

The study of business cooperation from an economic point of view can be approached from the theory of transaction costs, the aim of which is to search for hiring efficiency on the basis of a comparative analysis of the cost of planning, adapting and supervising the performance of economic activities. Transaction costs arise from the defects of the market due to the fact that the exchanges take place in conditions, which substantially differ from those which are implicit in the neoclassical economic model which describes the functioning of markets. Thus, the economic agents are subject to limited rationality (restrictions on their capability to make forecasts, to determine contingencies and to evaluate them correctly so as to confidently determine the price and the other conditions of exchange), which explains why the hypotheses about their behavior attributes selfish (aimed at maximizing their individual benefit) and opportunistic (derived from the unverifiable nature of certain information and from the incompleteness of certain contracts) behavior to them. Consequently, the use of market implies certain costs—transaction costs—which are those resources that are consumed during the process of regulating the conditions in which the transfer of goods and services takes place prior to the actual exchange which derives from said transfer.

Coase (1937) was the first to point out that within the framework of the market economy and due to the initiative of private agents, new formulas of collective action appear—companies—which substitute the market in its organizational and allocation functions when the latter incurs high transaction costs in order to carry them out. However, his argument does not specify the circumstances that must converge in an exchange in order to decide whether the market or the company is the most appropriate organizational model. Arrow (1969) and in particular Williamson (1986) goes deeper in the analysis of transaction costs derived from the use of the market. The latter introduces the distinction between ex-ante transaction costs (which includes costs involved in drawing up, renegotiating and safeguarding the agreement) and ex-post costs (which include the costs involved in changing plans, re-negotiating the terms of the agreement, those involved in the creation and functioning of proceedings for the purpose of settling disagreements, and in ensuring that the parties fulfill the obligations undertaken). In short, the company emerges as an organization that produces goods and services and as a mechanism for the allocation of resources which is an alternative to the market; therefore, on the basis of the comparison between the transaction costs and the costs of internalizing an activity, the market and the company's sphere of activity can be determined. Although the distinction between market and company has been clearly stated, reality shows that the dividing line between them is not as clear as it may seem at first. The company and the market, as alternative mechanisms for governing transactions, compete for the control over them and decision to regulate a transaction with one or the other depends on efficiency criteria, and therefore it will be necessary to determine the transaction costs in each case. In this sense, Walker and Weber (1984) suggest that the company, taking into account the specific nature of the asset, compares the administrative costs involved in putting an internal production system into operation with the transaction costs which its acquisition in the market entails. In view of both aspects, one can see, on the basis of a certain specificity of the assets it is preferable to internalize the activity. If the transaction has a high frequency, the assets which are exchanged are very specific and the level of uncertainty is high, internalization appears to be the best alternative to the market (since the costs deriving from the contracts and their regulation will be very high). However, internalization also entails significant disadvantages with regard to costs, not only those which derive from the acquisition of assets, but also those which result from the complexity of organizing and administrating a larger company. Furthermore, the division of activities between market and company gives rise to numerous contractual alternatives among companies although, as Menguzzato (1995) points out, a *continuum* exists between these two extremes. Thus, the company and the market possess management structures for carrying out transactions, but there are also a number of intermediate possibilities which materialize in a wide variety of contracts which create a web of complex relations among economic agents: within the scope of the market with independent units, it is possible to establish agreements and relations which involve assuming authority principles characteristic of an organizational behavior and, on the contrary, within the internal sphere of the company, it is possible to establish performance guidelines which simulate the market's rules of conduct (e.g., when profit centers and independent business units are defined). The concept of business cooperation, from this perspective, is considered as either a hybrid between the market and the company or as an intermediate form of organization between the externalization (or pure market) and the internalization of production activities (or pure company). The underlying criterion in choosing from among the different possibilities is the search for economic efficiency through the minimization of transaction costs.

Coalition formation has been also studied intensively by game theorists. A primary motivation for players in a game to form coalitions is to obtain more profit. There are three basic problems in coalition formation in a given game: how to share profit among the participants, who should be in which coalition (coalition generation) and whether a stable coalition exists. Among various theoretic developments, the core introduced by Gillies (1953) is the earliest and the most well-accepted concept for coalition formation problems. For the detailed discussion on core, please refer to Kannai (1992).

1.6.1 The Aims of Cooperation from the Economic Point of View

We have already mentioned that the neoclassical economic model does not consider the existence of transaction costs, since it assumes the rationality of the economic agents, i.e., they act without restrictions when it comes to making decisions. Nevertheless, these assumptions do not coincide with real life because:

a. When the economic agents make economic transactions, they find themselves in a changing environment with limited and asymmetrical information which leads to the existence of *uncertainty* about the results of their actions.
b. There are few offers and demands for certain goods or services, which means they have a greater *bargaining power* in the market.
c. There are certain *specific assets* due to their location or their qualities, which are not easily replaceable or accessible.

These circumstances mean that we encounter a decision-maker who acts with *limited rationality*, and they lead us away from the economic functioning of perfect markets—in the neoclassical sense—as the most efficient mechanisms for allocating resources by introducing certain costs, the transaction costs, which derive from the circumstances mentioned above. Business cooperation attempts to transform the traditional markets into arranged or *quasi-integrated* markets. Such markets consist of a set of relations and contracts between legally independent companies based on fairly complex and specific cooperation agreements. It is not the competition which sustains the functioning of these markets, but rather the privileged or agreed relations established either between the company and its competitors or between the company and other companies in its sphere. The final objective is to minimize the transaction costs through the cooperation agreements. Faced with the increase in *uncertainty*, the company may choose to search for an agreement or to internalize the tasks. For example, entering a new geographic market is a decision which involves a high level of uncertainty due to: the possible difference in the preferences of the consumers and the difficulty in identifying them, lack of knowledge about the competitors and the response of the market to the product and its adaptation, etc. In this situation, establishing certain agreements with the local agents (for example, the creation of a joint-venture) allows the company to have more information, which therefore, reduces the level of uncertainty. Moreover, considering the existence of a limited number of economic agents (offerers and demandants) which take part in the transaction may imply that there are companies in the market who exert some power over it—*bargaining power* with customers and suppliers—which allows such companies to generate economies of scale by obtaining cheaper prices and achieving lower costs. This leads to be technically more efficient internal processes and better prices in the market due to a greater concentration with respect to their competitors. In these markets, in which the logic of volume is a critical variable, greater presence or concentration is a fundamental competitive quality. The larger size can be obtained through internal growth (internalization of activities) or external growth (merger or takeover of companies). Internal growth implies an increase in administration and management costs, whereas in the second case, the administrative and management costs may be increased by both the increase in uncertainty due to the acquisition of an external company and, logically, the cost of the investment itself. Cooperation among companies represents a third option for the acquisition of volume, although this also entails certain costs which derive from organizing and administrating the cooperation contract. In short, making one decision or another involves an assessment of the different costs. Finally, the *specificity* of certain assets entails an increase in the transaction costs and, as has been mentioned before, choosing between internalization and cooperation depends on the level of specificity: for a very high specificity, internalization is preferable because, apart from the fact that it ensures the supply—especially when it is essential to the production process—it eliminates the dependence on external factors and involves a lower cost than that which would be produced by entering into a very detailed negotiation process. On the contrary, when the assets involved in the transaction have a certain degree of specificity but do not determine the competitive position of the company in the market—the supplementary goods—cooperation may be the best way to reduce market costs. To sum up, we could specify the objectives of business cooperation as follows:

- To reduce the transaction costs, which increase as uncertainty in the economic markets increases;
- To obtain a greater volume and presence in the market by establishing agreements with competitors, suppliers or customers;
- To seek efficiency in certain activities carried out by the company through externalization, when the internal costs involved in carrying out an activity are higher than if said activity is carried out in the market with a competitive logic; and finally,
- To gain access to specific goods which the company does not have but which are complementary to its activity.

Depending on the specificity of the assets, cooperation may turn out to be more efficient than acquisition in the market, given that the uncertainty relating to their obtainment decreases without the costs of internalization being incurred.

1.6.2 Business Cooperation Approached from the Theory of Organization

The different approaches within the theory of organization have made a decisive contribution to the improvement of the organizational bases of the company. Each school of thought (classical school, the school of human relations, the school of social systems) makes useful but limited and to some extent biased contributions to the study of the organizations. The contingent approach, inspired by the theory of systems, tries to overcome these limitations and tries to provide a conceptual and overall analysis framework. The contingent theory attempts to establish and understand how an organization works under different sets of conditions (or contingencies) and, in view of this, to establish the structural designs and the managerial actions most suited to each case. The initial hypothesis is that various types of organization can co-exist successfully depending on the different conditions. These conditions arise not only from the internal characteristics of the company, but also from the environment in which it operates. Therefore, each company should search for congruence between its structure and internal processes and the contingencies or specific circumstances which characterize the environment in which its activities are carried out. Thus, from the point of view of the contingent approach, the organizational structure should respond appropriately to the levels of uncertainty: the more unknown an environment is—due to its level of dynamism and complexity—the more flexible and less structured the internal organization will have to be order to rapidly adapt to the different conditions. On the contrary, an organization which operates in a relatively well-known environment will be able to preserve a fixed and stable structure on a long-term basis. The contingent approach covers a wide variety of studies that can be placed in one of the following groups:

a. Studies based on the determinism of the business environment, which relate the design of the organizational structure to a set of external or contingent factors, and therefore, the structure and organizational processes should respond appropriately to these factors.
b. Studies which, based on the discretion of the management, make the organizational structure depend on the decisions of the managerial team. In this sense, the decisions about objectives pursued and the strategy chosen to achieve them entail the choice of the environment in which the company is going to carry out its activity.

Between these two undoubtedly extreme solutions, a third option emerges, one which involves the determinism of the environment and the discretion of the management in a process of interaction and mutual adaptation: this is what is known as the ecological approach. From this point of view, the environment is a restriction to which the organization adapts by various means. The interaction between the organization and the environment is resolved through strategy: within a more or less turbulent environment, the company chooses a strategy which adapts to these circumstances and ensures its success. Given the great number of limitations that make it difficult for organizations to adapt to the environment and the enormous pressures which are exerted to maintain a state of structural inertia, it is assumed that the organization's adaptation to the environment through the choice of a strategy is not enough to explain the behavior of organizations, which is why the isomorphism principle is introduced. On the basis of this principle, two ways of adapting to the environment are suggested: through learning (the decision-makers analyze the optimum responses and adjust the behavior of the organization according to this learning), and through selection, i.e., it is the environment that positively selects the optimum combinations of organizations.

1.7 Motivation

Early work by Malone et al. (1987) discussed the benefits and potential of electronic markets, stating their superiority over hierarchies in terms of transaction costs. It also predicted the rise of electronic marketplaces. However, after a period of consolidation many viable e-marketplaces increased in profitability and offered a competitive option for firms procuring goods and services and for consumers making purchases. The classification of e-marketplace, negotiation and cooperation among firms literature presented in this chapter has proposed some significant consideration starting from which we continue the rest of the work. Although there have been a considerable number of articles published in leading journals on e-marketplaces there are still many unanswered questions and areas that lack clarity. Many articles have focused on auction mechanisms in relation to their efficiency and effectiveness. In comparison, relatively few articles have investigated the organization implications of e-marketplace participation and the issues involved in adoption and implementation. In addition, the fundamental questions related to the debate over the relative merits of electronic markets versus electronic hierarchies still need further research. The above two areas (organizational and electronic markets theory) are examples of macro level studies in which this book will contribute. Moreover, in the nowadays business environment, also characterized by an economic dynamic subjected to constant changes, it is necessary for the company to possess certain strategies, which allow it to anticipate change, to adapt to the new market rules of play and to achieve a strong position with respect to the competition. There are two types of strategic options within the reach of any business decision-maker: those relating to the search for a stronger competitive position for the product (looking for new markets for the product, developing new products or through diversification), and those which refer to the possibilities of growth available to the company. With regard to the latter, business growth has traditionally been a concept which is interlinked with the search for competitive advantages. There is a great deal of literature connected with this theme, and it is generally agreed that two of the most common strategic objectives of the business growth are:

- To acquire greater control over the market, in those markets in which the logic of volume is critical (economies of scale, of learning, of scope, etc.), allowing the company to have a strong and defendable position;
- To acquire complementary and synergic resources, to form a coalition with other enterprises to stay competitive on the market.

The latter offers a wide variety of possibilities through cooperation among companies and a number of different types of agreement may be reached—depending on the objectives pursued, the characteristics and the number of partners, the level of commitment, etc.—and these, in a complex and often unpredictable environment, consolidating external growth based on association agreements implies a strategic decision which entails a lower level of structural involvement for the company than another type of decision. The association agreements among companies may be regarded as the origin of what is known as cooperation. Cooperation, as has already been mentioned, involves a strategic decision which allows growth both when what is sought is a *logic of volume* (greater presence in the market) and when the aim is to search for *complementary aspects or synergic effects*—obtained by grouping together or combining qualitatively complementary assets—providing, in turn, the flexibility necessary for reacting to the volatility of the environment. The special characteristic of these actions is the existence of more or less long-term agreement among different companies, which do not give up either their legal independence or their power to make decisions independently. Among the various forms of cooperation, the agreements between competitors occupy a special position due to their ambiguity and complexity, since they also create the most distrust. It seems logical to wonder whether the allied competitors really do put aside the idea of confrontation, since the study of the cooperation among competitors makes it clear that there are numerous strategic reasons, which justify the conclusion of cooperation agreements although, a priori, they may seem to be paradoxical. The theory of competitive advantage affirms that cooperation makes it possible to optimize the respective chains of value of the companies linked by the agreement. In this sense, cooperation agreements are keeping in with the logic complementary aspects, since the creation of value reinforces the competitive advantages of the participants in the agreement. In short, cooperation is considered to be a strategic option which allows competitive advantages to be obtained in exchange for a renunciation of direct confrontation. This type of cooperation, also known as symbiotic cooperation or differentiated cooperation, associates complementary companies, which share or exchange resources, each of them contributing a different force. This combination of efforts allows a more complete or more intense use of the different assets that each one of the companies possesses in an unequal proportion. The explanations of cooperation based on the search for effects of growth or effects of market power are supported by the theories of competitive positioning and by industrial economics. Thus, if the maximization of profits in a particular activity depends on improving the competitive positioning of the company with respect to its rivals and if the necessary resources or risks undertaken exceed the company's means, a cooperative approach makes it possible to obtain economies of scale, the effects of the experience or a diversification of the risk; at the same time, the power of the companies associated within their sector increases. This type of cooperation, also called similitude alliances of scale or joint-venture with accumulation of resources associates companies which may be comparable within a related field and which have identical problems, a meeting point of resources of the same nature (technological, human, etc.) being created. The authors, starting from this perspective, in order to recover profitability in e-marketplaces, propose an innovative software integration of production planning, negotiation and coalition support tools. Undeniably, production planning tools allow creating a link between commercialization and production activities providing a better service for the customer, which can gain reliable information about order availability and timing, and for the supplier, that can correctly plan resources utilization in order to achieve lower costs. On the other hand, negotiation tools allow making transactions able to take into account both buyers' and sellers' identities and goals, providing a better global satisfaction. Furthermore, coalition may be a big chance for small and medium suppliers not able to fully respond to the customer request: collaboration among different agents is a basic issue in a stay-together economy. The specific focus of the research presented in this paper is, on one hand, to propose a MAS architecture for enabling automatic trading in manufacturing e-marketplaces and, on the other hand, to test different types of VAS models that the MAS architecture is able to support.

1.8 Book Outline

The book is organized in eight chapters.

Chapter 2 presents the Agent-Based Architecture developed to support the "added value tools" in neutral linear e-marketplaces. The architecture will be described from three points of view. The first prospective is the interaction between the e-marketplace with external actors by the use case diagram formalism. The second prospective is the functional context described by the use of IDEF0 formalism. Finally, the last prospective is the dynamic point of view illustrated by UML activity diagrams. The design activities of the multi-agent architecture presented in this chapter allow to support the development of the architecture independently from the ICT tool use.

Chapter 3 reports an overview of the Game Theory that is the more relevant topic for the research presented in this book. In this chapter, the main issues of the game theory are discussed. Specifically, the methodology used to support the approaches proposed in this research are explained: NASH equilibrium and the SHAPLEY value approaches.

Chapter 4 describes the bargaining models adopted by the buyers and sellers in the agent-based architecture described in Chap. 2. The approaches proposed can be classified in three categories: negotiation, auction and one shot. Moreover, the bargaining approaches are based on the information provided by production planning tool. Production planning tools allow to create a link between commercialization and production activities improving the satisfaction of the performance of the bargaining protocol.

Chapter 5 presents the methodologies to support the entire life cycle of a coalition. All the proposed approaches are based on game theory, except the considered benchmark. In particular, an innovative methodology has been developed for each problem regarding the life cycle of the coalition. Each one is formalized and developed within the multi-agent architecture discussed in Chap. 2.

Chapter 6 presents the simulation environment proper developed to test the proposed innovative methodologies. The first part of the chapter describes the discrete event simulator developed by the use of JAVA and LINGO package for the optimization problem. Instead, the second part of the chapter presents the parameters to define the case study investigated. Finally, in the third part, the performance measures in order to evaluate the value added by the proposed tools are illustrated.

Chapter 7 shows the results of experimental classes designed in the previous chapter. The aim of the simulations is to understand, what kind of real advantages e-marketplace participants can achieve from added values services. The simulations have been conducted in order to evaluate the performance measures in different environmental conditions. This allows to investigate the robustness of the approaches proposed. A statistical analysis is conducted to evaluate models and input impact parameters on the estimated performance measures. The simulation results will be deeply discussed to highlight the main features of the proposed approaches.

Chapter 8 illustrates the conclusions of the research. The chapter highlights the major contributions of the developed research. Moreover, the future development paths are drawn.

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Chapter 2
Multi-Agent Architecture

2.1 Introduction

Multi-Agent Systems (MAS) seem to be the most promising approach to support Business-to-Business activities. In the scientific literature several applications based on agent technologies are proposed to support e-marketplace (Xu and Wang 2002; Hee et al. 2003; Perrone et al. 2003; Chen et al. 2008; Renna 2009).

MAS architectures can be categorized into: centralized, distributed and hybrid architectures that are a sort of combination of the first two. The centralized multi-agent architectures share many of limitations of the master–slave ones, while the distributed are much more complex because of their huge information flow and their related more complicated information management. The hybrid architecture, instead, seems to combine the advantages of these two (Zhang and Xie 2007): that is the motivation why the methodology proposed in this book uses a hybrid approach, where some agents are in charge to coordinate the activities among all the agents of the architecture.

Often, the process modeling of multi-agent structure is focused on one main aspect. Workflow analysis tools, based on several views, seem to be the most useful methodology to engineering e-business Value Added Services (VAS) design (Presley et al. 2001). In this research the authors use an integrated methodology starting from the existing technologies, rather than creating a new design technique.

Specifically, the used methodologies are based on IDEF0 and UML formalisms by three different points of view. The first is the functional aspect described by the IDEF0 formalism. The second is the formalization of the interaction with external actors by the use case diagram and, finally, the dynamics point of view is described by using an UML activity diagrams. With these three steps of description, the design of the multi architecture proposed in this chapter could surely be a valid support for a concrete development of e-marketplace dedicated to B2B applications.

P. Argoneto and P. Renna, *Innovative Tools for Business Coalitions in B2B Applications*, DOI: 10.1007/978-0-85729-707-5_2,

Kim et al. (2003) considered similarities and differences between IDEF and UML modeling approaches. They observed that the combined development and reuse of IDEF and UML models has the potential to place information technology (IT) systems engineering projects into a wider context of enterprise engineering. Also Hernandez-Matias et al. (2008) proposed an integrated modeling framework can increase the capacity of modeling tools for rapidly creating a structured database. A specific decision-making support tool for managing performance indicators has been developed to use this data structure establishing a standard interface that can be used by any modeler and simulator.

The opportune process modeling can support both the development of real application of the e-marketplace and the development of the simulation environment.

The chapter is structured as follows. Section 2.2 discusses the e-marketplace context in this research, while in Sect. 2.3 the agent-based architecture is introduced. Section 2.4 describes the static structure of the multi-agent architecture; while Sect. 2.5 explains the dynamic point of view of the architecture proposed. In Sect. 2.6, the production planning activities are formalized and in Sect. 2.7 the coalition activities are described. Finally, Sect. 2.8 explains the conclusions of this chapter.

2.2 E-Marketplace Context

According to the classification of the business models of Barrat and Rosdhal (2002), the classification of the e-marketplaces can depend on the following characteristics: buyer behavior; centricity; accessibility.

The main characteristic for the research presented in this book is the centricity of the e-marketplace. The "centricity" of the e-marketplaces can be classified in the following categories:

- *Buyer centric e-marketplace*: in this case, the e-marketplace is established by larger buyers. The buyers manage the e-marketplace and invite the suppliers to participate. Examples of buyer centric e-markets are: FreeMarkets, FOB and Covisint.
- *Seller centric e-marketplace*: this case is the contrary of the buyer centric e-marketplace. The e-marketplace is established by larger sellers. The sellers manage the e-marketplace and invite the buyers to participate. Examples of buyer centric e-markets are: e.g., Ingram Micro, Echemicals, Dell Corporation and Deutsche Telekom MarketPlace.
- *Neutral e-marketplace*: these e-marketplaces are suitable for small and medium enterprises that operate both as sellers or buyers. Generally, these e-marketplaces are established by third independent party who sets-up the e-marketplace and gets a fee from e-marketplace transactions and services offered to e-marketplace participant (Perrone et al. 2005). Examples of buyer centric e-markets are: CPGmarket, Tribon Marketplace and ChemConnect.

Wise and Morrison (2000) have located the following reasons of low profitability of the e-marketplaces in the following reasons:

- Most of the e-marketplaces, especially those seller or buyer oriented, put respectively buyers and sellers in a price competitions that bring advantages only for the e-marketplace owner (the buyer and the seller), but not for the other participants;
- Sellers get very little advantage in staying in an e-marketplace because the possibility to spread the business is in part neglected by the price reduction;
- E-marketplace owner do not seem to provide their customer (e-marketplace participants) with distinctive offering and services that allow to improve profitability.

However, the e-marketplaces described above have encountered problems in terms of growth and profit capabilities (Ordanini et al. 2004; Sawhney and Di Maria 2003) and lack of appropriate pricing models and competition (Ordanini 2006).

The e-marketplace profitability can be achieved by the following characteristics (Argoneto et al. 2004):

- Developing a closed loop between the client order and the production planning activity of the supplier in order to integrate the customer–supplier chain;
- Providing the e-marketplace with a set of real VAS able to bring advantages both to the suppliers and the customers;
- Measuring, through a performance-based approach, the amount of the advantage that suppliers and customers might obtain by staying together in an e-marketplace; indeed, this “stay-together economy” should represent the reason for suppliers and customer to come into an e-marketplace.

For the above reasons, in this book the VAS proposed regard a private neutral e-marketplace. Private means that the participants need to be registered to access the e-marketplace and use the offered services. Neutral means that each actor behaves as a seller or as a buyer and has the same importance.

This approach realizes a full integration between the customer order and the supplier planning activity. The customer and the supplier system interact through an agent-based network. Furthermore, a set of VAS are proposed in the e-marketplace and specifically negotiation and coalition support services.

Figure 2.1 shows the structure of a neutral lineal e-marketplace.

2.3 The Agent-Based Architecture

The objective of this chapter is to develop a distributed architecture based on a multi-agent system able to face with the above e-marketplace context.

The agent-based framework is described in Fig. 2.2 which consists of a neutral linear e-marketplace owned by a third independent part. The suppliers and

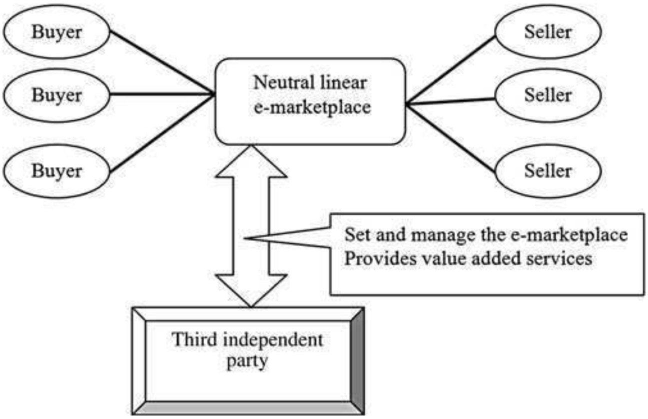

Fig. 2.1 Private neutral e-marketplace

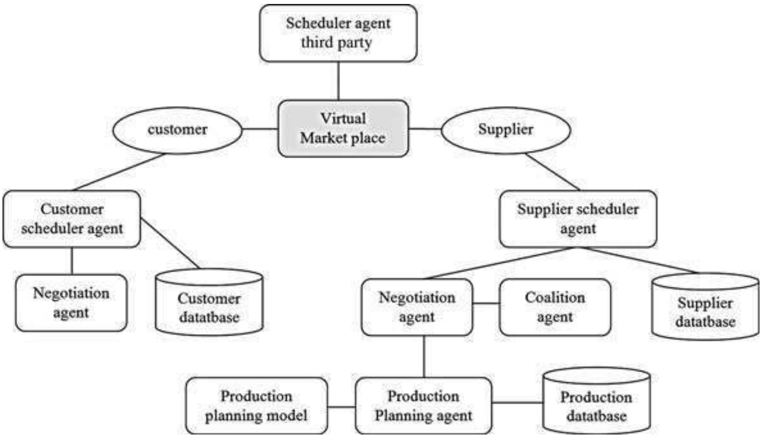

Fig. 2.2 The agent-based architecture

customers interact by an electronic network to exchange information and to reach agreements. The scheduler agent of this third independent part is in charge for managing the activities among customers and suppliers of the e-marketplace.

The generic customer is implemented by the following *objects*:

- The *Scheduler Customer Agent* (SCA) synchronizes the activities of the customer *objects* and the disciplines the activities with the virtual marketplace;
- The *Customer Negotiation Agent* (CNA) puts the orders characterized by the information of volume, due date, price and the typology product. Moreover, it negotiates with the suppliers using opportune negotiation strategies;
- The customer database that provides, to the CNA, the information on the suppliers and the past negotiation process.

Differently, the generic supplier consists of the following *objects*:

- The *Scheduler Supplier Agent* (SSA) synchronizes the activities of the supplier *objects* and disciplines the activities with the virtual marketplace;
- The *Supplier Negotiation Agent* (SNA) negotiates with the customers using opportune strategies and the information provided by the production planning agent;
- The *Production Planning Agent* (PPA) receives the information on the customer orders by the SNA and plans the activities in order to determine all the production planning alternatives. It uses a proper production planning model (described in Chap. 4) to plan the orders and provides the information to the SNA for the negotiation activities.
- The *Supplier Coalition Agent* (SCoA) receives the information by the SNA and evaluates the possibility to make coalition with other suppliers. It uses opportune strategies to support the SNA in the coalitional issues;
- The *production planning model* implements the mathematical model to obtain the production planning alternatives;
- The *production database* manages all the information concerning the production activities such as capacity available, costs of raw material and resource costs;
- The *supplier database* manages all the information concerning the past negotiation with the customers.

2.4 The Agent-Based Architecture: Functional Context

In the present section, the multi-agent architecture is formalized through the use of IDEF0 formalism. IDEF0 models the decisions, actions and activities of the system, in order to communicate its functional perspective. The diagram describes each function or activity through boxes that specifies:

- *Inputs*: items that trigger the activity;
- *Controls*: guide or regulate the activity;
- *Mechanisms*: systems, people, equipment used to perform the activity;
- *Outputs*: results of performing the activity.

The IDEF0 diagrams can be organized in a hierarchical structure in order to describe different detailed level of the system. The context in which the system operates has been defined through the diagram A0 of Fig. 2.3 that distinguishes the considered system from the external environment: the global input is given by the market demand and the virtual marketplace could satisfy the requirements by the possible agreement among customers and suppliers.

The final outputs of the system are two: the suppliers' production and the customer–supplier agreement. The latter defines the which providers reach an agreement with the customer and the parameters of the agreement (volume, due date, price, etc.). If the bargaining process ends with a success, the order is

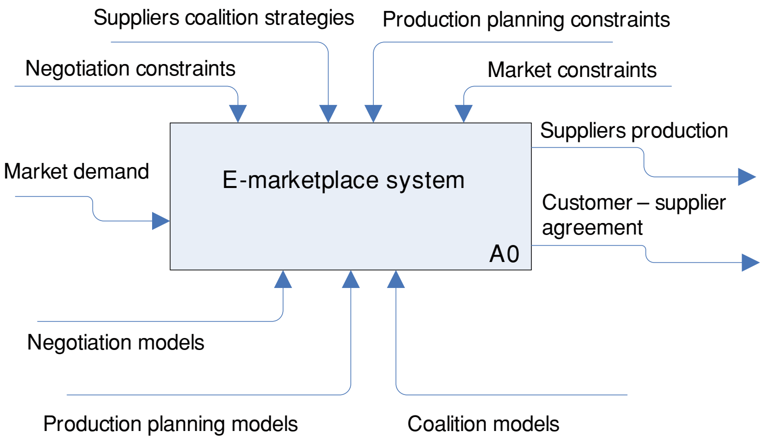

Fig. 2.3 E-marketplace system

launched in the physical system of the generic supplier with the related production activities. The described system is subject to the following constraints:

- "*negotiation constraints*": they concern the negotiation parameters of the customers and suppliers and the rules of the virtual marketplace for the exchange activities among suppliers and customers.
- "*market constraints*": they represent the technological operations required by the products and the volume required by the customers.
- "*production planning constraints*": they represent the suppliers' constraints of the manufacturing system in terms of capacity, costs and technological operations;
- "*supplier coalition strategies*": they are the rules and strategies that suppliers use to decide whether to form coalition or not.

The system operates through the following mechanisms:

- "*negotiation models*": they represent the models for the bargaining process among customers and suppliers;
- "*production planning models*": they represent the models for production planning activity to provide the alternatives for the bargaining process;
- "*coalition models*": they provides the models to perform the coalition activities among the suppliers.

2.4.1 The Customer–Supplier Structure

The virtual marketplace structure consists of two parts: Customer System and Supplier system (see Fig. 2.4).

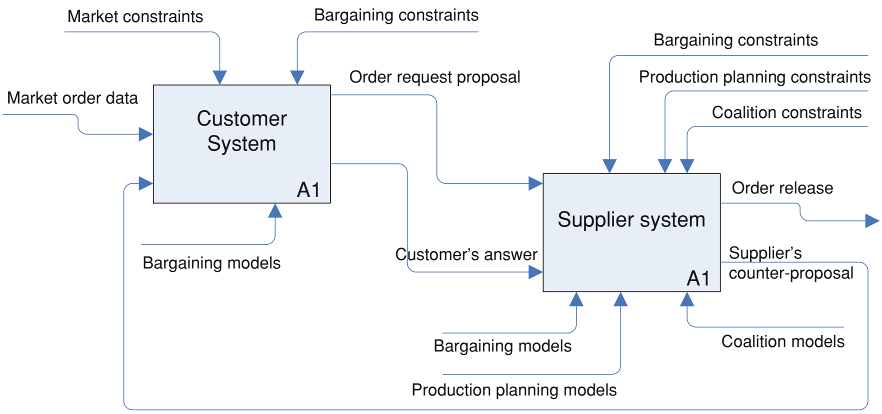

Fig. 2.4 Supplier–Customer structure

The inputs of the *Customer System* are the following: the global input of the system, named "*market order data*", and the "*supplier's counter-proposal*" submitted by the supplier system.

The activities of the system are the following: the customer formulates the request to the suppliers in terms of price, volume, due date and product typology ("*order request proposal*"); the customer answers to the supplier's counter-proposal in order to continue or quit the bargaining process ("*customer's answer*").

The above two activities generates two outputs that constitutes the inputs of the supplier system that processes these information in order to compute the counter-proposal (named "*supplier's counter-proposal*") and, if the bargaining process ends with an agreement, to release the orders ("order release") to the manufacturing system.

2.4.2 The Customer System

The *Customer System* consists of two function performed by the relative agents: *the Customer Scheduler Agent* and the *Customer Negotiation agent* (see Fig. 2.5). The *Customer Scheduler Agent* coordinates the activities of the customers. In particular, it formulates the order request proposal to submit to the e-marketplace using the customer proposal formulation models and subject to the market constraints. The supplier network constraints limit the orders request to transmit to the e-marketplace (technological capability of the e-marketplace). The customer orders can be transmitted to the e-marketplace if the network of suppliers is able to provide the typology of product requested.

The *Customer Negotiation Agent* receives the supplier's counter-proposal and applies the negotiation procedure to decide whether it is suitable to accept immediately or request for a new counter-proposal.

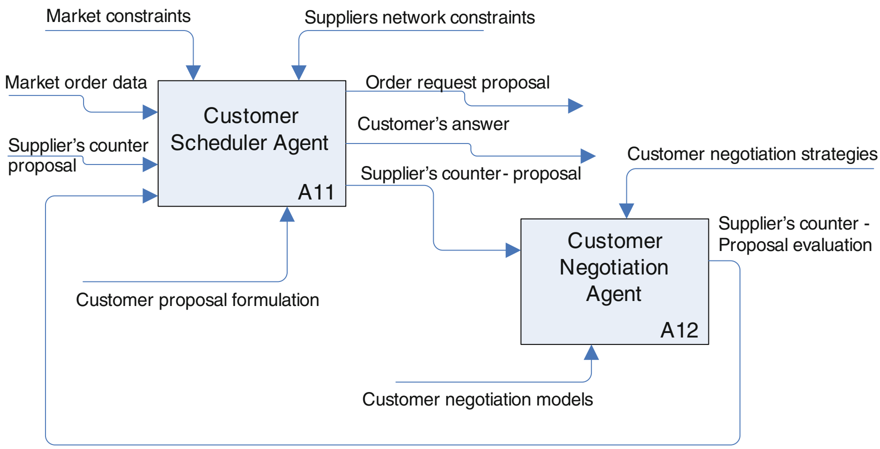

Fig. 2.5 Customer system

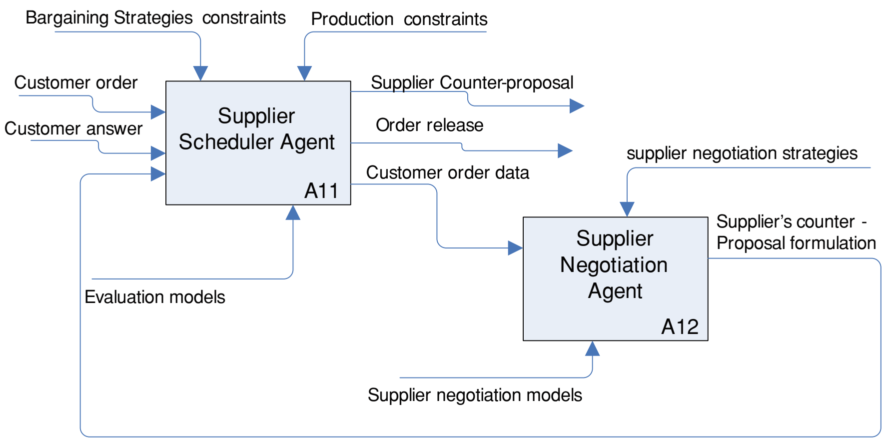

Fig. 2.6 Supplier system

2.4.3 The Supplier System

At first level of detail (see Fig. 2.6), the supplier system consists of two agents: the Supplier Scheduler Agent (SSA) and the Supplier Negotiation Agent (SNA).

The Supplier Scheduler Agent has three inputs: the *customer order data* that concerns the characteristics of the order requested by the customer, the *customer answer*, i.e., the output of the evaluation of the customer (when the supplier submits a counter-proposal), and the *Supplier's counter-proposal formulation* that is, the formulation of the new counter-proposal performed by the SNA. The SNA formulates the new counter-proposal for the supplier to submit to the customer in

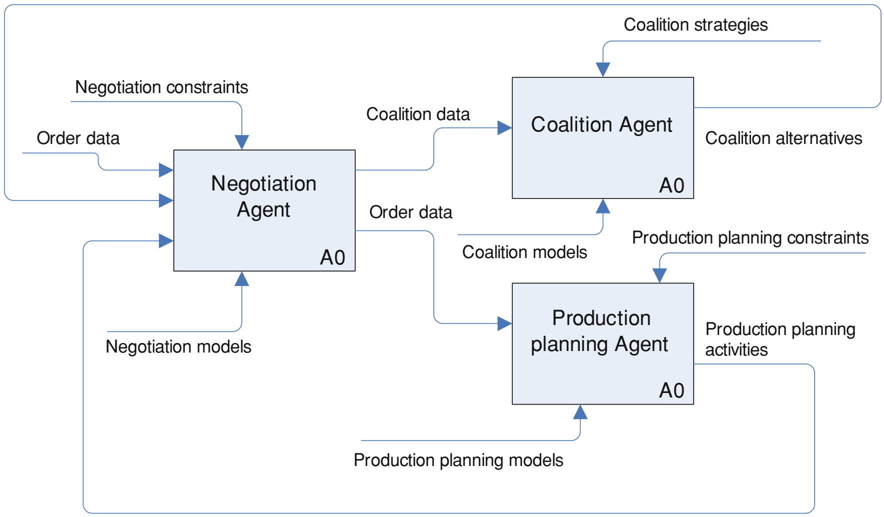

Fig. 2.7 Supplier system (detail of A12 of Fig. 2.6)

their bargaining process. The SNA uses the negotiation models, based on production planning alternatives, and at the same time evaluate the possibility to make a coalition with other suppliers. The formulation of the counter-proposal is subject to the negotiation strategies of the specific agent.

2.4.3.1 The Supplier Negotiation System

The detail "level 2" of the Supplier Negotiation Agent is showed in Fig. 2.7. The SNA formulates the counter-proposal by three processes: *Negotiation Agent*, *Production Planning Agent* and *Coalition Agent*.

The negotiation agent transmits the order data to the production planning agent in order to compute the production planning alternatives, computed using the production planning model considering the production planning constraints of the agent (capacity, profit, etc.). The input of the Coalition Agent is the decision concerning the possibility to make a coalition or not and the information concerning the production constraints. With this information, the *Coalition Agent* provides to the *Negotiation Agent* the coalitional alternatives using the related models.

2.5 System Dynamics

In this section the dynamic behavior of the e-marketplace system is described by using the UML activity diagram formalism. The notation of each drawing of the UML Activity Diagram describes a specific process: it is divided into many swim

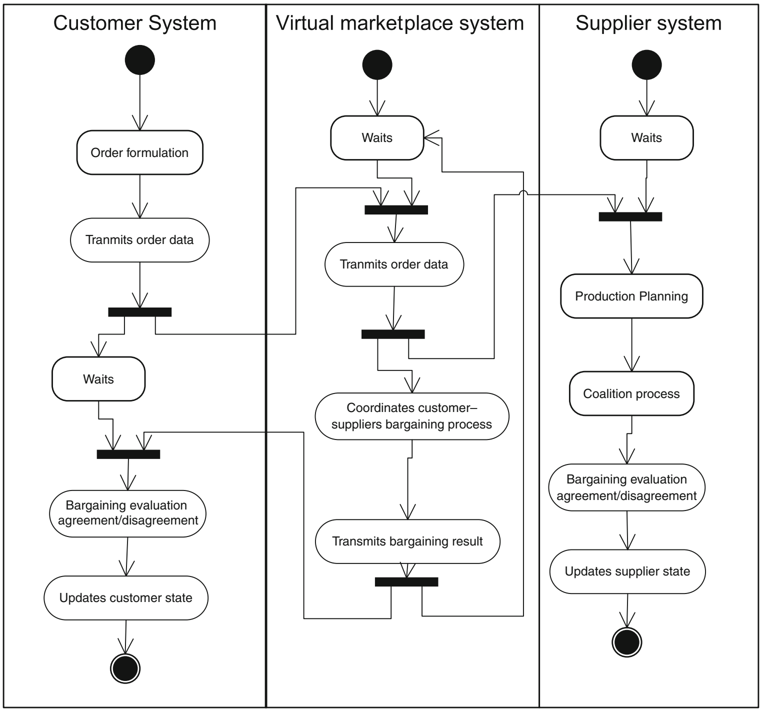

Fig. 2.8 Entire system: dynamic behavior

lanes, whatever may be the involved parts of the system are. In this way each activity is placed in the swim lane correspondent to class/part of the system that plays the action. The UML activity diagram of Fig. 2.8 shows the global activities, considering the three main actors: the *Customer System*, the *Virtual Marketplace System* and the *supplier System*. The diagram represents all the processes performed by the *Customer System* and the *Virtual Marketplace System* at the highest level of abstraction.

2.5.1 Customer System Activities

The *Customer System* interacts with the *Virtual Marketplace System* through the following activities:

- *Order data formulation*: the first activity of this system is the formulation of the order (technological and commercial requirements). This activity depends on the market conditions in terms of product typology, volume, etc.;
- *Transmits order data*: the specification of the order (technological and commercial requirements) is transmitted to the *Virtual Marketplace System*;

- *Waits*: after the data transmission, the customer activates the bargaining process through the *Virtual Marketplace System*. In this high level of representation, the customer waits for the result of the bargaining process;
- *Bargaining evaluation agreement/disagreement*: the customer evaluates the bargaining process. Two cases can happen: the customer accepts the terms of the contract proposed by the *Virtual Marketplace System* or it can refuse all the proposals and quit;
- *Updates customer state*: the customer updates all the information of the bargaining process. This updating is performed whatever the result of bargaining is.

The activities performed during the specific bargaining process are deeply described in Chap. 3.

2.5.2 Virtual Marketplace System Activities

The *Virtual Marketplace System* interacts with the *customer* and *supplier systems* through the following activities:

- *Waits*: the *Virtual Marketplace System* is in its initial state of waiting (for an order transmission by the customer);
- *Transmits order data*: the *Virtual Marketplace System* analyzes the customer order, then it transmits the order data to all the suppliers of the network able to satisfy the order requested by the customer;
- *Coordinates customer–suppliers bargaining process*: the *Virtual Marketplace System* coordinates all the activities of the bargaining process among the supplier and the customers. This process will be deeply described in Chap. 4.
- *Transmits bargaining results*: the virtual marketplace transmits to customer and suppliers the result of the bargaining process. The informations are the following: whether the process reaches an agreement or not and which supplier or coalition reaches the agreement with the customer.

2.5.3 Supplier System Activities

The supplier system performs the following activities:

- *Waits*: the supplier system is in the initial state of waiting for an order data transmission by the virtual marketplace;
- *Production planning*: the supplier computes the production planning alternatives for the order data transmitted by the virtual marketplace. The supplier uses the production planning model and an opportune algorithm to compute the alternatives (for details, see Chap. 4);

- *Coalition process*: the supplier uses the production planning information to evaluate if a coalition can be a valid opportunity, respect to compete alone, in the bargaining process or not. In case the supplier decides to make a coalition, the following activities will be performed: the selection of the partners, the definition of how to compute the coalition proposal and, lastly, how the profit can be divided in case of agreement. These activities will be deeply described in the Chap. 4 that discusses the coalition protocols proposed.
- *Bargaining evaluation agreement/disagreement*: the supplier evaluates the bargaining process. Two different cases can be observed: the customer accepts the terms of the contract proposed by the virtual market place system or the customer refuses all the proposals and quits.
- *Updates supplier state*: in case of agreement, the supplier releases the production order with the terms of the business accord. In case of disagreement, the supplier registers in its database the information that has led to the disagreement (the counter-proposal issues).

2.6 Production Planning Activities

The information flow and the main activities of the *Production Planner Agent* and the *Negotiation Agent* of the supplier are shown in the activity diagram of Fig. 2.9. All these activities are deeply described in the next sections.

2.6.1 Negotiation Agent Activities

The *Supplier Negotiation Agent* interacts with the *Production Planning Agent* through the following activities:

- *Waits for input*: the *Supplier Negotiation Agent* waits for the order data; after that it can require the production planning alternatives to the *Production Planning Agent*.
- *Transmits production planning constraints*: the *Supplier Negotiation Agent* transmits to the *Production Planning Agent* the constraints to follow in order to obtain the production alternatives (maximum and minimum values of due date, price and volume).
- *Waits for production data*: the *Supplier Negotiation Agent* waits for the production planning alternatives computed by the *Production Planning Agent*. *Computes counter-proposals*: the *Supplier Negotiation Agent* uses the production planning alternatives to compute the counter-proposal during the bargaining process.

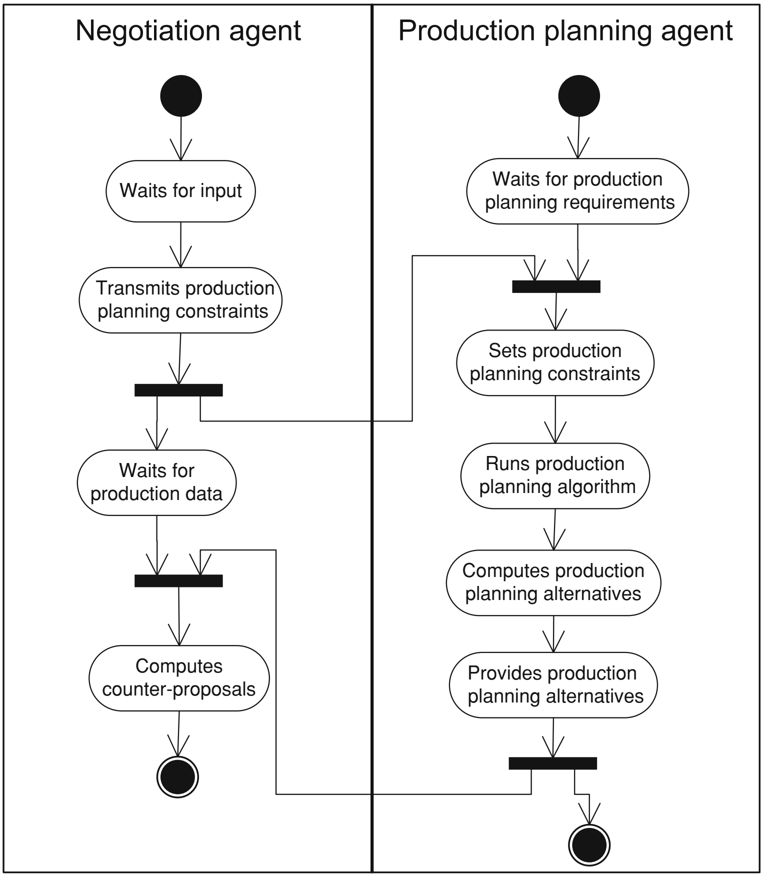

Fig. 2.9 Production planning activities

2.6.2 Production Planning Agent Activities

The *Production Planning Agent* interacts with the *Supplier Negotiation Agent* through the following activities:

- *Waits for input*: the *Production Planning Agent* waits for the request of the *Supplier Negotiation Agent* to compute the production planning alternatives;
- *Sets production planning alternatives*: the *Production Planning Agent* sets the constraints for the production planning algorithm: this task is done considering the information transmitted by the *Supplier Negotiation Agent*;
- *Runs production planning algorithm*: the *Production Planning Agent* runs the production algorithm elaborating all the production alternatives deriving for the *Customer Agent* request.

- *Computes production planning alternatives*: production alternatives are associated to the supplier profit: to elaborate them the *Production Planning Agent* builds a function that maps the production alternatives of the supplier's profit.
- *Provides production planning alternatives*: the function that maps the production alternatives of the supplier's profit is transmitted to the *Supplier Negotiation Agent* to negotiate with the customer.

2.7 Coalition Activities

The information flow and the main activities of the *Supplier Coalition Agent* and of the supplier's Negotiation Agent are shown in the activity diagram of Fig. 2.9. These activities are deeply described in the next sections.

2.7.1 Supplier Negotiation Agent Activities

The *Supplier Negotiation Agent* interacts with the Supplier Coalition Agent through the following activities (see Fig. 2.10):

- *Waits for input*: the *Supplier Negotiation Agent* waits for the production planning alternatives in order to evaluate whether forming a coalition is an opportunity, in confront to bargain alone with the customer, or not;
- *Evaluates coalition opportunity*: the *Supplier Negotiation Agent* uses the information coming from the production planning alternatives and opportune decision-making tool (see Chap. 4) to decide whether to try forming a coalition;
- *Transmits information*: if the *Supplier Negotiation Agent* decides to form a coalition, it transmits this information to the *Supplier Coalition Agent* in order to search the potentially available partners;
- *Waits*: the *Supplier Negotiation Agent* waits for the information concerning the possibility to make a coalition provided by the *Supplier Coalition Agent*;
- *Updates supplier state*: the information provided by the *Supplier Coalition Agent* updates the state of the *Supplier Negotiation Agent* during the bargaining process and also when the process ends (with agreement or disagreement is not important).

2.7.2 Coalition Agent Activities

The *Coalition Agent* interacts with the *Supplier Negotiation Agent* through the following activities:

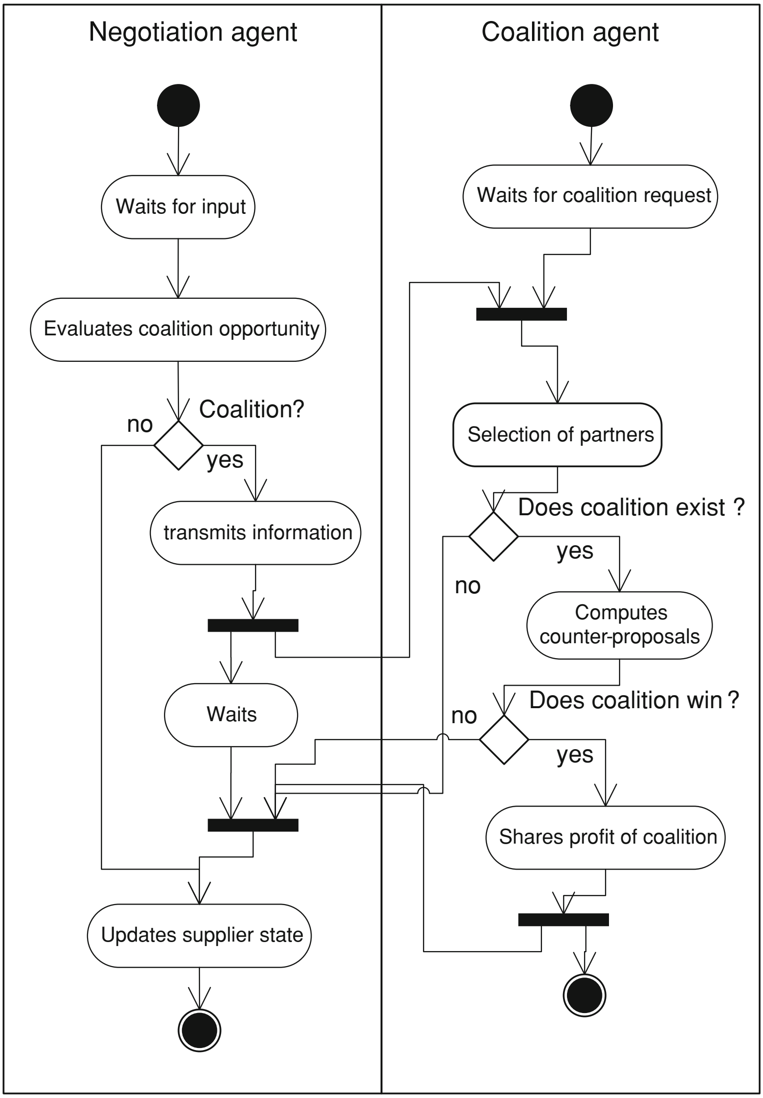

Fig. 2.10 Coalition activities

- *Waits for input*: the *Supplier Coalition Agent* waits for the request by the *Supplier Negotiation Agent*;
- *Selection of partners*: the *Coalition Agent* searches for the available partners among the suppliers of the network. Whether the coalition could exits (partners are available), the *Coalition Agent* goes to the next activity, otherwise it transmits to the *Negotiation Agent* the information that the coalition cannot be formed;

- *Computes counter-proposals*: the *Coalition Agent* provides to the *Negotiation Agent* the necessary information to propose a unique counter-proposal (the proposal of the coalition) combining the different proposals of the partners (the approach is described in Chap. 4);
- *Shares profit of coalition*: whether the coalition reaches an agreement with the customer, the *Coalition Agent* provides this information to the *Negotiation Agent* to share the profit gained by the coalition among the involved partners.

2.8 Discussion

The chapter describes the agent-based architecture designed to support the neutral third party e-marketplace, where a set of registered customers and suppliers can make business transactions. The architecture is described from both static and dynamic point of views. The methodologies proposed are based on IDEF0 and UML activity diagram formalisms.

The first result of this chapter concerns the business process modeling of the e-marketplace. The IDEF0 formalism allows to define the processes for the system and to support the workflow management system.

The integration of the IDEF0 with UML activity diagram allows to describe the dynamic point of view and to support the development of the proposed architecture.

In the last decades, most software systems dedicated to the development of this kind of MAS architecture are mainly based on C++, Java and other tools designed using object-oriented modeling languages. Therefore, the use of UML formalism leads to several benefits for the development of agent architecture. The main of this are: reducing the time necessary to develop a MAS architecture; the simple formalism capable to describe all the agents and the clarity of the information flows.

The proposed architecture is able to support and automate the workflow of the e-marketplace. The objectives of the agent-based architecture are mainly two: to support the development of the simulation environment based on object-oriented methodology; to support the development of real applications.

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Chapter 3
Game Theory: An Overview

3.1 Introduction

"*Game theory is a branch of mathematics that is concerned with the actions of individuals who are conscious that their actions affect each other*". As such, game theory (hereafter GT) deals with interactive optimization problems. While many economists in the past few centuries have worked on what can be considered game-theoretical (hereafter G-T) models, John von Neumann and Oskar Morgenstern are formally credited as the fathers of modern game theory. Their classic book *Theory of Games and Economic Behavior* (von Neumann and Morgenstern 1944) summarizes the basic concepts existing at that time. GT has since enjoyed an explosion of developments, including the concept of equilibrium (Nash 1950), games with imperfect information (Kuhn 1953), cooperative games (Aumann 1959; Shubik 1962) and auctions (Vickrey 1961), to name just a few. The models of game theory are highly abstract representations of classes of real-life situations. Their abstractness allows them to be used to study a wide range of phenomena. For example, the theory of Nash equilibrium has been used to study oligopolistic and political competition. The theory of mixed strategy equilibrium has been used to explain the distributions of tongue length in bees. The theory of repeated games has been used to illuminate social phenomena like threats and promises. The theory of the core reveals a sense in which the outcome of trading under a price system is stable in an economy that contains many agents. The boundary between pure and applied game theory is vague; some developments in the pure theory were motivated by issues that arose in applications.

Citing Shubik (2002), "*In the 50s game theory was looked upon as a curiosum not to be taken seriously by any behavioural scientist. By the late 1980s, game theory in the new industrial organization has taken over*: *game theory has proved its success in many disciplines*."

GT is divided into two branches, called the *non-cooperative* and *cooperative* branches. The two branches of GT differ in how they formalize interdependence

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among the players. In the non-cooperative theory, a game is a detailed model of all the moves available to the players. By contrast, the cooperative theory abstracts away from this level of detail, and describes only the outcomes that result when the players come together in different combinations. Though standard, the terms non-cooperative and cooperative game theory are perhaps unfortunate. They might suggest that there is no place for cooperation in the former and no place for conflict, competition etc. in the latter. In fact, neither is the case. One part of the non-cooperative theory (the theory of repeated games) studies the possibility of cooperation in ongoing relationships. And the cooperative theory embodies not just cooperation among players, but also competition in a particularly strong, unfettered form. The non-cooperative theory might be better termed *procedural* game theory and the cooperative theory *combinatorial* game theory. This would indicate the real distinction between the two branches of the subject, namely that the first specifies various actions that are available to the players while the second describes the outcomes that result when the players come together in different combinations.

The goal of this chapter is to give a brief overview about GT and, specifically, about GT concepts and tools. Obviously, due to the need of short explanations, all proofs will be omitted, and we will only focus on the intuition behind the reported results.

The chapter is structured as follows. Section 3.2 explains the game set-up, while in Sect. 3.3 and 3.4 discusses the rational behavior of the players. Section 3.5 describes the non-cooperative static games; while the Sect. 3.6 explains the conditions of equilibrium existence and multiple equilibrium in Sect. 3.7. In Sects. 3.8 and 3.9 the dynamic games are explained. The cooperative games characteristics are explained in the Sects. 3.10 and 3.11. Section 3.12 discusses the characteristic function and in Sect. 3.13 the Shapley value approach is introduced. Finally, Sect. 3.14 presents the bargaining game model.

3.2 Game Set-Up

A game is a description of strategic interaction that includes the constraints on the actions that the players can take and the players' interests, but does not specify the actions that the players do take. A solution is a systematic description of the outcomes that may emerge in a family of games. Game theory suggests reasonable solutions for classes of games and examines their properties. To break the ground for next section on non-cooperative games, basic GT notation will be introduced: the reader can refer to Friedman (1986) and Fudenberg and Tirole (1991) if a more deep knowledge is required. A game in the normal form consists of: *players* (indexed by $i = 1, 2, \ldots, n$), a set of *strategies* (denoted by $x_i, i = 1, 2, \ldots, n$) available to each player and *payoffs* $(\pi_i(x_1, x_2, \ldots, x_n), i = 1, 2, \ldots, n)$ received by each player. Each strategy is defined on a set X_i, $x_i \in X_i$, so we call the Cartesian product $X_1 \times X_2 \times \ldots \times X_n$ the strategy space (typically the strategy space is R^n). Each player may have a one-dimensional strategy or a multi-dimensional strategy. However, in simultaneous-move games each player's set of feasible strategies are independent from the strategies chosen by the other players, i.e., the strategy choice of one player does not limit the feasible strategies of another player. A player's strategy can be thought of as the complete instruction for which actions have to be taken in a game. For example, a player can give his or her strategy to a person who has absolutely no knowledge of the player's payoff or preferences and that person should be able to use the instructions contained in the strategy to choose the actions the player desires. Because each player's strategy is a complete guide to the actions that are to be taken, in the normal form the players choose their strategies simultaneously. Actions, which are adopted after strategies, are thus chosen and those actions correspond to the given strategies. The normal form can also be described as a static game, in contrast to the extensive form which is a dynamic game. If the strategy has no randomly determined choices, it is called a pure strategy; otherwise it is called a mixed strategy. There are situations in economics and marketing in which mixed strategies have been applied: e.g., search models (Varian 1980) and promotion models (Lal 1990). In a non-cooperative game the players are unable to make binding commitments regarding which strategy they will choose before they actually choose their strategies. In a cooperative game players are able to make these binding commitments. Hence, in a cooperative game players can make side-payments and form coalitions. After the explanation of what in GT is considered to be the rationality, the overview reported here starts with non-cooperative static games.

3.3 Rational Behavior

The models studied in this book assume that each decision-maker is rational in the sense that he is aware of his alternatives, forms expectations about any unknowns, has clear preferences and chooses his action deliberately after some process of optimization. In the absence of uncertainty the following elements constitute a model of rational choice:

- A set A of actions from which the decision-maker makes a choice;
- A set C of possible consequences of these actions;
- A *consequence function* that associates a consequence with each action;
- A *preference relation* on the set C.

Generally the decision-maker's preferences are specified by giving a utility function, which defines a preference relation. An assumption upon which the usefulness of this model of decision-making depends is that the individual uses the same preference relation when choosing from different set B. It could also be that individuals have to make decisions under conditions of uncertainty. The players may be

- Uncertain about the objective parameters of the environment;
- Imperfectly informed about events that happen in the game;

- Uncertain about actions of the other players that are not deterministic;
- Uncertain about the reasoning of the other players.

To model decision-making under uncertainty, almost all game theory uses the theories of von Neumann and Morgenstern, that is, if the consequence function is stochastic and known to the decision maker then the decision-maker is assumed to behave as if he maximizes the expected value of a function that attaches a number to each consequence. If the stochastic connection between actions and consequences is not given, the decision-maker is assumed to behave as if he has in mind a (subjective) probability distribution that determines the consequence of any action.

3.4 Bounded Rationality

In real-life context there is an asymmetry between individuals in their abilities. For example, some players may have a clearer perception of a situation or have a greater ability to analyze it. These differences, which are so critical in life, are missing from game theory in its current form. To illustrate the consequences of this fact, the game of chess could be a valid example. In an actual play of chess the players may differ in their knowledge of the legal moves and in their analytical abilities. In contrast, when chess is modeled using current game theory it is assumed that the players' knowledge of the rules of the game is perfect and their ability to analyze it is ideal. It has been demonstrated that chess is a trivial game for rational players: an algorithm exists that can be used to solve the game. This algorithm defines a pair of strategies, one for each player, that leads to an equilibrium outcome with the property that a player who follows his strategy can be sure that the outcome will be at least as good as the equilibrium outcome no matter what strategy the other player uses. The existence of such strategies suggests that chess is uninteresting because it has only one possible outcome. Nevertheless, chess remains a very popular and interesting game. Its equilibrium outcome is yet to be calculated; currently it is impossible to do so using the algorithm. Modeling asymmetries in abilities and in perceptions of a situation by different players is a fascinating challenge for future research, which models of bounded rationality have begun to tackle.

3.5 Non-Cooperative Static Games

In non-cooperative static games the players choose strategies simultaneously and are thereafter committed to their chosen strategies. The solution concept for these games was formally introduced by John Nash (1950) although some instances of using similar concepts date back to a couple of centuries. The concept is best described through best response functions.

Definition 1 Given the n-player game, player i's best response (function) to the strategies x_{-i} of the other players is the strategy x_i^* that maximizes player i's payoff $\pi_i(x_i, x_{-i}) : x_i^*(x_{-i}) = \arg\max_{x_i} \pi_i(x_i, x_{-i})$.

If π_i is quasi-concave in x_i the best response is uniquely defined by the first-order conditions. Clearly, given the decisions of other players, the best response is the one that the best player i can hope for. Naturally, an outcome in which all players choose their best responses is a candidate for the non-cooperative solution. Such an outcome is called a Nash equilibrium (hereafter NE) of the game.

Definition 2 An outcome $x_1^*, x_2^*, \ldots, x_n^*$ is a Nash equilibrium of the game if x_i^* is a best response to x_{-i}^* for all $i = 1, 2, \ldots, n$.

One way to think about an NE is as a fixed point of the best response mapping $R^n \to R^n$. Indeed, according to the definition, the NE must satisfy the system of equations $\partial\pi_i/\partial x_i = 0$, for all i. Recall that a fixed point x of mapping $f(x), R^n \to R^n$ is any x such that $f(x) = x$. Define $f_i(x_1, x_2, \ldots, x_n) = \partial\pi_i/\partial x_i + x_i$. By the definition of a fixed point,

$$f_i(x_1^*, x_2^*, \ldots, x_n^*) = \partial\pi_i(x_1^*, \ldots, x_n^*)/\partial x_i + x_i^* \to \partial\pi_i(x_1^*, \ldots, x_n^*)/\partial x_i = 0, \quad \text{all } i$$

Hence, x^* solves the first-order conditions if and only if it is a fixed point of mapping $f(x)$ defined above. The concept of the NE is intuitively appealing. Indeed, it is a self-fulfilling prophecy. To explain, suppose a player is able to guess the strategies of the other players. A guess would be consistent with payoff maximization (and therefore reasonable) only if it presumes that strategies are chosen to maximize every player's payoff given the chosen strategies. In other words, with any set of strategies that is not an NE there exists at least one player who is choosing a non-payoff maximizing strategy. Moreover, the NE has a self-enforcing property: no player wants to unilaterally deviate from it since such behavior would lead to lower payoffs. Hence the NE seems to be the necessary condition for the prediction of any rational behavior by players.

Although attractive, numerous criticisms of the NE concept exist. Two particularly vexing problems are the non-existence of equilibrium and the multiplicity of equilibria. Without the existence of an equilibrium, little can be said regarding the likely outcome of the game. If there are multiple equilibria, then it is not clear which one will be the outcome. Indeed, it is possible that the outcome is not even an equilibrium because the players may choose strategies from different equilibria. In some situations it is possible to rationalize away some equilibria via a refinement of the NE concept: e.g., trembling hand perfect equilibrium (Selten 1975), sequential equilibrium (Kreps and Wilson 1982) and proper equilibria (Myerson 1997). In fact, it may even be possible to use these refinements to the point that only a unique equilibrium remains.

An interesting feature of the NE concept is that the system optimal solution (a solution that maximizes the total payoff to all players) need not be an NE. In fact, an NE may not even be on the Pareto frontier: the set of strategies such that each player can be made better off only if some other player is made worse off. A set of strategies are Pareto optimal if they are on the Pareto frontier; otherwise a set of strategies are Pareto inferior. Hence, an NE can be Pareto inferior. The Prisoner's Dilemma game is the classic example of this: only one pair of strategies is Pareto optimal (both "cooperate"), and the unique Nash equilibrium (both "defect") is Pareto inferior.

3.6 Existence of Equilibrium

An NE is a solution to a system of n equations (first-order conditions), so an equilibrium may not exist. Non-existence of an equilibrium is potentially a conceptual problem since in this case it is not clear what the outcome of the game will be. However, in many games an NE does exist and there are some reasonably simple ways to show that at least one NE exists. As already mentioned, an NE is a fixed-point of the best response mapping. Hence fixed-point theorems can be used to establish the existence of an equilibrium. There are three key fixed-point theorems, named after their creators: Brouwer, Kakutani and Tarski. (see Border 1999 for details and references). However, direct application of fixed-point theorems is somewhat inconvenient and hence generally not done (see Border 1999 for existence proofs that are based on Brouwer's fixed-point theorem). Alternative methods, derived from these fixed-point theorems, have been developed. The simplest (and the most widely used) technique for demonstrating the existence of an NE is through verifying concavity of the players' payoffs, which implies continuous best response functions.

Theorem 1 Debreu (1952) *Suppose that for each player the strategy space is compact and convex and the payoff function is continuous and quasi-concave with respect to each player's own strategy. Then there exists at least one pure strategy NE in the game.*

If the game is symmetric (i.e., if the players' strategies and payoffs are identical), one would imagine that a symmetric solution should exist. This is indeed the case, as the next theorem ascertains.

Theorem 2 *Suppose that a game is symmetric and for each player the strategy space is compact and convex and the payoff function is continuous and quasi-concave with respect to each player's own strategy. Then there exists at least one symmetric pure strategy NE in the game.*

3.7 Multiple Equilibria

Many games are just not blessed with a unique equilibrium. The next best situation is to have a few equilibria. (The worst situation is either to have an infinite number of equilibria or no equilibrium at all.) The obvious problem with multiple equilibria is that the players may not know which equilibrium will prevail. Hence, it is entirely possible that a non-equilibrium outcome results because one player plays one equilibrium strategy while a second player chooses a strategy associated with another equilibrium. However, if a game is repeated, then it is possible that the players eventually find themselves in one particular equilibrium. Furthermore, that equilibrium may not be the most desirable one. If one does not want to acknowledge the possibility of multiple outcomes due to multiple equilibria, one could argue that one equilibrium is more reasonable than the others. For example, there may exist only one symmetric equilibrium and one may be willing to argue that a symmetric equilibrium is more focal than an asymmetric equilibrium. In addition, it is generally not too difficult to demonstrate the uniqueness of a symmetric equilibrium. If the players have one-dimensional strategies, then the system of n first-order conditions reduces to a single equation and one need only show that there is a unique solution to that equation to prove the symmetric equilibrium is unique. If the players have m-dimensional strategies, $m > 1$, then finding a symmetric equilibrium reduces to determining whether a system of m equations has a unique solution (easier than the original system, but still challenging).

3.8 Dynamic Games

The simplest possible dynamic game was introduced by Stackelberg (1934). In a Stackelberg duopoly model, player 1 chooses a strategy first (the Stackelberg leader) and then player 2 observes this decision and makes his own strategy choice (the Stackelberg follower). To find an equilibrium of a Stackelberg game (often called the Stackelberg equilibrium) we need to solve a dynamic two-period problem via backwards induction: first find the solution $x_2^*(x_1)$ for the second player as a response to any decision made by the first player: $x_2^*(x_1) : \frac{\partial \pi_2(x_2, x_1)}{\partial x_2} = 0$.

Next, find the solution for the first player anticipating the response by the second player:

$$\frac{d\pi_1(x_1, x_2^*(x_1))}{dx_1} = \frac{\partial \pi_1(x_1, x_2^*)}{\partial x_1} + \frac{\partial \pi_1(x_1, x_2)}{\partial x_2}\frac{\partial x_2^*}{\partial x_1} = 0.$$

Intuitively, the first player chooses the best possible point on the second player's best response function. Clearly, the first player can choose an NE, so the leader is always at least as well off as he would be in NE. Hence, if a player was allowed to choose between making moves simultaneously or being a leader in a game with complete information he would always prefer to be the leader.

3.9 Simultaneous Moves: Repeated and Stochastic Games

A different type of dynamic game arises when both players take actions in multiple periods. Two major types of this game exist: without and with time dependence. In the multi-period game without time dependence the exact same game is played over and over again (hence the term repeated games). The strategy for each player is now a sequence of actions taken in all periods. Consider one repeated game version of the competing newsvendor game in which the newsvendor chooses a stocking quantity at the start of each period, demand is realized and then leftover inventory is salvaged. In this case, there are no links between successive periods other than the players' memory about actions taken in all the previous periods. A fascinating feature of repeated games is that the set of equilibria is much larger than the set of equilibria in a static game and may include equilibria that are not possible in the static game. At first, one may assume that the equilibrium of the repeated game would be to play the same static NE strategy in each period. This is, indeed, an equilibrium but only one of many. Since in repeated games the players are able to condition their behaviour on the observed actions in the previous periods, they may employ so-called trigger strategies: the player will choose one strategy until the opponent changes his play, at which point the first player will change the strategy. This threat of reverting to a different strategy may even induce players to achieve the best possible outcome (i.e., the centralized solution) which is called an implicit collusion. Many such threats are, however, non-credible in the sense that once a part of the game has been played, such a strategy is not an equilibrium anymore for the reminder of the game. To separate out credible threats from non-credible, Selten (1965) introduced the subgame, a portion of the game (that is a game in itself) starting from some time period and a related notion of subgame-perfect equilibrium (this notion also applies in other types of games, not necessarily repeated), and equilibrium for every possible subgame see Hall and Porteus (2000) and van Mieghem and Dada (1999) for solutions involving subgame-perfect equilibria in dynamic games).

3.10 Cooperative Games

The idea behind cooperative game theory has been expressed in this way: "*Cooperative theory starts with a formalization of games that abstracts away altogether from procedures and concentrates, instead, on the possibilities for agreement. There are several reasons that explain why cooperative games came to be treated separately. One is that when one does build negotiation and enforcement procedures explicitly into the model, then the results of a non-cooperative analysis depend very strongly on the precise form of the procedures, on the order of making offers and counter-offers and so on. This may be appropriate in voting situations in which precise rules of parliamentary order prevail, where a good strategist can indeed carry the day. But problems of negotiation are usually more amorphous; it is difficult to pin down just what the procedures are. More fundamentally, there is a feeling that procedures are not really all that relevant; that it is the possibilities for coalition forming, promising and threatening that are decisive, rather than whose turn it is to speak. Detail distracts attention from essentials. Some things are seen better from a distance; the Roman camps around*

Metzada are indiscernible when one is in them, but easily visible from the top of the mountain" (Aumann 1989).

The subject of cooperative games first appeared in the seminal work of von Neumann and Morgenstern (1944). However, for a long time cooperative game theory did not enjoy as much attention in economics literature as non-cooperative GT. Cooperative GT involves a major shift in paradigms as compared to non-cooperative GT: the former focuses on the outcome of the game in terms of the value created through cooperation of (a subset of) players but does not specify the actions that each player will take, while the latter is more concerned with the specific actions of the players. Hence, cooperative GT allows us to model outcomes of complex business processes that otherwise might be too difficult to describe (e.g., negotiations) and answers more general questions (e.g., how well is the firm positioned against competition). In what follows, we will cover transferable utility cooperative games (including two solution concepts: the core of the game and the Shapley value).

3.11 N-Person Cooperative Games

Recall that the non-cooperative game consists of a set of players with their strategies and payoff functions. In contrast, in this case, although players are autonomous decision-makers, they may have an interest in making binding agreements in order to have a bigger payoff at the end of the game. This agreement or partnership is the basic ingredient of the mathematical model of a cooperative game, and it is called a *coalition*. Mathematically, a coalition is a subset of the set of players N and we can denote it by S. To form a coalition S, it is required that agreements take place involving all players in the future coalition S. Whenever all players approve joining in a new entity called coalition, we can say that the new coalition is formed. Joining a coalition S also implies that there is no possible agreement between any member of S and any member not in S (set $N\backslash S$). In short, the essential feature of a coalition is its foundational agreement that binds and reconstitutes the individuals as a coordinated entity. The *grand coalition* of all n players will be referred as coalition N (there are a total of $2^n - 1$ possible coalitions); The *empty coalition* is a coalition made up of no members (the null set $\varnothing$). A *coalition structure* is a means of describing how the players divide themselves into mutually exclusive coalitions. Any exhaustive partition of the players can be described by a set $S \equiv \{S_1, S_2, \ldots, S_m\}$ of the m coalitions that are formed. The set S is a partition of N that satisfies three conditions:

$$S_j \neq \varnothing,\ j = 1, \ldots, m$$

$$S_i \cap S_j = \varnothing, \quad \text{for all } i \neq j,\ \text{and } \cup S_j = N.$$

These conditions state that each player belongs to one and only one of the m non-empty coalitions within the coalition structure, and also specifies that none of the players in any coalition m are connected to other players not in the coalition; finally, the mutually exclusive union of all coalitions m forms the grand coalition.

3.12 Characteristic Function and Imputation

von Neumann and Morgenstern (1947) introduced the term *characteristic function* for the first time. More formally, we can define that:

Definition 3 For each subset S of N, the characteristic function v of a game gives the biggest amount $v(S)$ that the members of S can be sure of receiving if they act together and form a coalition, without any help from other players not in S.

A restriction on this definition is that the value of the game to the empty coalition is zero, that is, $v(\emptyset)$. A further requirement that is generally made is called *superadditivity*. Superadditivity can be expressed as follows:

$$v(S \cup T) \geq v(S) + v(T) \quad \text{for all} \quad S, T \subseteq N \text{ such that } S \cap T = \emptyset.$$

This means that the total payoff for the grand coalition is collectively rational because the total payoff to the players is always as much as what they would get individually. This suggests the following definition.

Definition 4 A game in characteristic function form which consists of a set of players, together with a function v defined for all subsets of N, such that $v(S \cup T) \geq v(S) + v(T)$whenever S and T are disjoint coalitions of players.

Games in which at least one possible coalition can increase the total payoff of its members are called essential, and those in which there are no coalition that improves the total payoff are called inessential. Mathematically, an essential game is one in which at least one of the superadditive inequalities $v(S \cup T) \geq v(S) + v(T)$ is strict. The specific actions that players have to take to create this value are not specified: the characteristic function only defines the total value that can be created by utilizing all players' resources. Hence, players are free to form any coalitions that are beneficial to them and no player is endowed with power of any sort. We will further restrict our attention to the transferable utility games in which the outcome of the game is described by real numbers $\pi_i, i = 1, \ldots, N$ showing how the total created value (or utility or pie) $\pi(N) = \sum_{i=1}^{N} \pi_i$ was divided among players. Of course, one could offer a very simple rule prescribing division of the value; for example, a fixed fraction of the total pie can be allocated to each player. However, such rules are often too simplistic to be a good solution concept. A much more frequently used solution concept of the cooperative game theory is the core of the game. This concept can be compared to the NE for non-cooperative games:

Definition 5 The utility vector $\pi_1, \ldots, \pi_N$ is in the core (and will be called imputation) of the cooperative game if it satisfies $\pi(N) = v(N)$, group rationality and $x_i \geq v(\{i\})$, individual rationality.

The core of the game, introduced by Gillies in 1953, can be interpreted through the added-value principle. Define ($N \backslash S$) as a set of players excluding those in coalition S (coalition can include just one player). Then the contribution of a coalition

S can be calculated as $v(N) - v(N \backslash S)$. Clearly, no coalition should be able to capture more than its contribution to the coalition (otherwise the remaining $N \backslash S$ players would be better off without the coalition S). Definition 5 clearly satisfies the added-value principle. Typically, when analysing a game, one has to calculate an added value from each player: if the value is zero, the player is not in the core of the game. If the core is non-empty, the added values of all players in the core comprise the total value that the players create. As it is true for NE, the core of the game may not exist (i.e., it may be empty) and the core is often not unique. When the core is non-empty, the cooperative demands of every coalition can be granted, but when the core is empty, at least one coalition will be dissatisfied.

Shubik (2002) noted that a game with a non-empty core is sociologically neutral, i.e., every cooperative demand by every coalition can be granted, and there is no need to resolve conflicts. On the other hand, in a coreless game, the coalitions are too strong for any mechanism to satisfy every coalitional demand. However, a core set with too many elements is not desirable, and it has little predictive power (Kahan and Rapoport 1984). Imputations in the core, where they exist, have a certain stability because no player or subset of players has any incentive to leave the grand coalition. But since many games have empty core, the core fails to provide a general solution for n-person games in characteristic form. von Neumann and Morgenstern (1947) proposed a different solution concept more generally applicable than the core that proposal is called the von Neumann Morgenstern solution or the stable set. The stable set is based on the concept of dominance, which is explained as follows. One imputation is said to dominate another if there is a subset of players who prefer the first to the second and can enforce it by forming a coalition.

3.13 Shapley Value

The concept of the core, though intuitively appealing, also possesses some unsatisfying properties. As we mentioned, the core might be empty or quite large or indeterministic. As it is desirable to have a unique NE in non-cooperative games, it is desirable to have a solution concept for cooperative games that results in a unique outcome and hence has a reasonable predictive power. Shapley (1953) offered an axiomatic approach to the solution concept that is based on three rather intuitive axioms. First, the value of the player should not change due to permutations of players, i.e., only the role of the player matters and not names or indices assigned to players. Second, if a player's added value to the coalition is zero then this player should not get any profit from the coalition, or in other words only players generating added value should share the benefits. Finally, the third axiom requires additivity of payoffs: for any two characteristic functions v_1 and v_2 it must be that

$$\pi(v_1 + v_2, N) = \pi(v_1, N) + \pi(v_2, N).$$

The surprising result obtained by Shapley is that there is a unique equilibrium payoff (called the Shapley value) that satisfies all three axioms.

Theorem 3 *There is only one payoff function* π *that satisfies the three axioms. It is defined by the following expressions for* $\forall i \in N$ *and all* $v{:}\pi_i(v) = \sum_{S \subseteq N \setminus i} \frac{|S|!(|N|-|S|-1)!}{|N|!}(v(S \cup \{i\}) - v(S))$.

The Shapley value assigns to each player his marginal contribution $v(S \cup \{i\}) - v(S)$ when S is a random coalition of agents preceding i and the ordering is drawn randomly. To explain further (see Myerson 1997), suppose players are picked randomly to enter into a coalition. There are $|N|!$ different orderings for all players, and for each set S that does not contain player i there are $|S|!(|N| - |S| - 1)!$ ways to order players so that all of the players in S are picked ahead of player i. If the orderings are equally likely, there is a probability of $|S|!(|N| - |S| - 1)!/|N|!$ that when player i is picked he will find S players in the coalition already. The marginal contribution of adding player i to coalition S is $v(S \cup \{i\}) - v(S)$. Hence, the Shapley value is nothing more than a marginal (expected) contribution of adding player i to the coalition. Due to its uniqueness, the concept of the Shapley value has found numerous applications in economics and political sciences.

3.14 The Bargaining Game Model

Following Nash we use the term *bargaining* to refer to a situation in which:

- individuals (players) have the possibility of concluding a mutually beneficial agreement,
- there is a conflict of interests about which agreement to conclude, and
- no agreement may be imposed on any individual without his approval.

A bargaining theory is an exploration of the relation between the outcome of bargaining and the characteristics of the situation. All the theories assume that the individuals are rational, and the theories abstract from any differences in bargaining skill between individuals. We consider the possibility that the individuals are not perfectly informed, but we maintain throughout the assumption that each individual has well-defined preferences over all relevant outcomes, and, when he has to choose between several alternatives, chooses the alternative that yields a most preferred outcome. In this context, bargaining situations could be considered as (extensive) games. Predictions about the resolution of conflict are derived from game-theoretic solutions (variants of subgame perfect equilibrium). Bargaining is a basic activity associated with trade. Even when a market is large and the traders in it take as given the environment in which they operate, there is room for bargaining when a pair of specific agents is matched.

3.14.1 The Axiomatic Approach: Nash's Solution

Consider a group of two or more agents facing with a set of feasible outcomes, any one of which will be the result if it is accepted by unanimous agreement of all participants. In the event that no unanimous agreement is reached, a given disagreement outcome is the result. If the feasible outcomes are such that each participant can do better than the disagreement outcome, then there is an incentive to reach an agreement; however, so long as at least two of the participants differ over which outcome is most preferable, there is a need for bargaining and negotiation over which outcome should be agreed upon. Note that since unanimity is required, each participant has the ability to veto any outcome different from the disagreement outcome. To model this atomic negotiation process, we use the cooperative bargaining process initiated by Nash (1951). It is pertinent to mention that experimental bargaining theory indicates stronger empirical evidence of this bargaining theory than any others. Nash engaged in an axiomatic derivation of the bargaining solution. The solution refers to the resulting payoff allocation that each of the participants unanimously agrees upon. The axiomatic approach requires that the resulting solution should possess a list of properties. The axioms do not reflect the rationale of the agents or the process in which an agreement is reached but only attempts to put restrictions on the resulting solution. Further, the axioms do not influence the properties of the feasible set. Before listing the axioms, we will now describe the construction of the feasible set of outcomes. Formally, Nash defined a two-person bargaining problem (which can be extended easily to more than two players) as consisting of a pair $\langle F, d \rangle$ where F is a closed convex subset of R^2, and $d = (d_1, d_2)$ is a vector in R^2. F is convex, closed, non-empty and bounded. Here, F, the feasible set, represents the set of all feasible utility allocations and d represents the disagreement payoff allocation or the disagreement point. The disagreement point may capture the utility of the opportunity profit. Nash looked for a bargaining solution, i.e., an outcome in the feasible set that satisfied a set of axioms. The axioms ensure that the solution is symmetric (identical players receive identical utility allocations), feasible (the sum of the allocations does not exceed the total pie), Pareto optimal (it is impossible for both players to improve their utilities over the bargaining solutions), the solution be preserved under linear transformations and be independent of "irrelevant" alternatives. Due to constraints on space, the reader can refer to Roth (1979) for a very good description of the solution approach and a more detailed explanation of the axioms. The remarkable result due to Nash is that there is a bargaining solution that satisfies the above axioms and it is unique.

Theorem 4 (Nash 1951) *There is a unique solution that satisfies all the "axioms". This solution, for every two-person bargaining game $\langle F, d \rangle$ is obtained by solving:* $\arg \max_{x=(x_1,x_2) \in F, x \geq d} (x_1 - d_1)(x_2 - d_2)$.

The axiomatic approach, though simple, can be used as a building block for much more complex bargaining problems. Even though the axiomatic approach is prescriptive, descriptive non-cooperative models of negotiation such as the Nash demand game (Roth 1995) and the alternating offer game (Rubinstein 1982), reach similar conclusions as Nash bargaining. This somehow justifies the Nash bargaining approach to model negotiations. In our discussion, we have only provided a description of the bargaining problem and its solution between two players. However, this result can easily be generalized to any number of players simultaneously negotiating for allocations in a feasible set.

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Chapter 4
Bargaining Models in E-Marketplaces

4.1 Introduction

Intelligent software agents allow to enhance the degree of automation and sophistication of e-marketplaces (Jennings and Leung 2003; Ye et al. 2001). Accordingly, the process to reach an agreement among agents with conflicting interests needs to be simpler, effective and efficient. The negotiation process is a crucial step of Business-to-Business transaction by an e-marketplace; the profitability of these tools is highly dependent by the design of the related protocol.

Among the several negotiation definitions proposed in the scientific literature, the one proposed by Druckman in 1977 is concise and clear at the same time: *"negotiation is an interaction process in which two or more actors, having conflicting interests, look for an agreement satisfying for all the contenting players*".

The main interest of managers is to ensure that the overall cost is reduced and operations among various systems are integrated through coordination (Fazel Zarandi et al. 2008).

In order to define the negotiation process, the main issues to be well defined (Perrone et al. 2005) are:

1. The negotiation static dimension
2. The negotiation dynamic dimension and
3. The negotiation protocol.

The static dimension is identified by the number of involved actors; the actors are the roles that can be assigned to a set of players. It is easy to identify two roles for the e-marketplace investigated in this book: the seller's and buyer's role. Specifically, the considered negotiation is bilateral among one buyer and many sellers. A further process discriminator regards the information during the negotiation process; the information can be common to all actors involved (public) or not (private). In this last context, the only public information is concerning the knowledge regarding the agreement of one supplier with the customer, while the

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other information (for example, the utility evaluation) is private (these are considered the counter-proposal characteristics of each supplier).

The dynamic dimension refers to the decision process, adopted by each involved actor, which allows to formulate and evaluate offers and counter-offers. The tactic and strategy, which each actor choices to adopt, represent the main dynamic dimensions (Faratin et al. 1998) and depends on the role assumed in the negotiation process. In particular, the seller role adopts a generative function to build the counter-proposal while the buyer evaluates the counter-proposal by using a utility function with a threshold level approach.

The adopted strategies, without distinction regarding the role, consist in defining the parameters of the generative and utility functions. These parameters are deeply explained in Sect. 4.3

Finally, the negotiation protocol should define:

- the start activity: the first move is the transmission of the order characteristics (volume, due date and price) from the buyer to all the sellers;
- the sequence of the alternatives: the considered negotiation is an interactive process based on Rubinstein's protocol of alternating offer (Rubinstein 1982);
- seller's tactic: the seller computes a new counter-proposal in order to improve the buyer satisfaction reducing its own satisfaction;
- buyer tactic: the buyer updates the utility thresholds reducing its satisfaction in order to have more opportunities to reach an agreement with the sellers;
- buyer action: at each round of negotiation the buyer can only accept the offer or request for a new counter-proposal.
- ending criteria: a maximum number of rounds for the process are defined. The agreement is reached only if the customer accepts the supplier counter-proposal at round $r < r_{\max}$; in this case customer and supplier sign an electronic agreement;
- seller and buyer's behavior is assumed to be rationale according to their utility functions;
- the buyer does not know suppliers' utility functions and vice versa; however sellers and buyers can only argue, by applying proper learning algorithms, the probable behavior of their counterparts.

The chapter is structured as follows. Section 4.2 discussed the literature review concerning the bargaining activities in electronic services. Section 4.3 describes the negotiation approach proposed. Section 4.4 describes the production planning activities to support the bargaining activities. Finally, in Section 4.5 the discussion on the negotiation and production planning activities is provided.

4.2 Literature Review

Recently, more interest of the researchers has been dedicated in developing electronic services, like e-procurement, combined with intelligent decision support systems by the creation of intelligent distributed systems like Multi-Agent Systems (MAS).

The most appropriate aim of this work is reported in the following. Dumas et al. (2005), in their research, propose an approach to develop bidding agents that participate in multiple alternative auctions, with the goal of obtaining an item with a given probability. The approach consists of a prediction method and a planning algorithm: the first one exploits the history of past auctions in order to build probability functions capturing the belief that a bid of a given price may win a given auction. The planning algorithm, instead, computes a price such that, by sequentially bidding in a subset of the relevant auctions, the agent can obtain the item at that price with the desired probability. The approach addresses the case where the auctions are for substitutive items with different values. Experimental results show that this approach increases the payoff of their users and the welfare of the market. Neubert et al. (2004) proposed a software agent capable of conducting an automated negotiation in order to assist the human decision-maker in an environment consisting of small independent units. The considered agent can perform an integrative negotiation about multiple interdependent properties of the supply contract, such as price, volume and delivery date. The paper developed a single agent and tested the generation of the offers. The main limit of this research is the lack of integration in a Multi-Agent System consisting of opponent actors. Wang and Benaroch (2004) investigated agents' decisions concerning whether or not to join in a B2B electronic market. The authors found that their decisions depend on the revenue structure of the e-market owner. In particular, the buyer pays the supplier to join the e-markets if the transaction percentage charged to the supplier is lower than the maximum Pareto-improving transaction percentage. The authors did not study the auctioning processes and mechanisms among suppliers in the e-marketplace. Guillén et al. (2005) presented a novel approach that provides decision support in making optimal offer proposals during the negotiation process between customers and suppliers that takes place in chemical industry supply chains. The main difference with the research proposed in this book is related to the industry context. Moreover, our approach is distributed (suitable for independent manufacturing units) with any centralized model able to optimize the whole performance of the system. Also Puigjaner et al. (2008) concerns the context of a supply chain in chemical process industry. Specifically, the authors presented a complete Multi-Agent Architecture for the considered Supply Chain. The approach was tested by a simulation environment, but the resolution of conflicts has been not deeply discussed. Hausen et al. (2006) discussed the electronic trading in agrifood sector with a majority of Small and Medium Enterprises. The paper presented results from experimental work showing that electronically supported transaction processes, in this complex SME situation, are more efficient than respective traditional transaction processes.

Wang et al. (2008) proposed an agent mediated approach to on-demand e-business supply chain integration. Each agent works as a service broker, exploring individual service decisions as well as interacting with each other for achieving compatibility and coherence among the decisions of all services. Mahdavi et al. (2009) proposed a dynamic model for the agent-based SN as a solution for coordinating buyers and sellers. They utilized the concept of users' profile in the network and presented an optimization model in conjunction with what-if simulation module to obtain mutually compatible solutions. In this model, however, the negotiation among the buyers and suppliers to enhance their relationship has not been discussed. Mohebbi and Shafaeiwe (2010) developed a framework based on multi-agent systems to facilitate collaboration and negotiation in dynamic environments while Huang et al. (2010) presented a multi-attributes negotiation model for Business-to-Consumer e-commerce, which deploys intelligent agents to facilitate autonomous and automatic on-line buying and selling by intelligent agents. Then Wong and Fang (2010) presented *ECN-Pro* (the Extended Contract-Net-like multilateral Protocol), which is a new multi-agent protocol for handling buyer–seller negotiations in supply chain management.

Starting from this perspective it is possible to claim that the main restrictions of the above cited papers are the following: no real-time information search on-demand by an agent is incorporated in the models, adaptive tracking of user profile is only based on the made offers and the profile of the opponent in order to infer the most likely directions for compromise and mutual benefits.

A different approach is developed by Kurbel and Loutchkor (2005). They presented a model for multi-lateral negotiations of agents with fuzzy constraints on an electronic marketplace for personnel acquisition. The approaches developed involving negotiation protocol and negotiation strategies for bilateral negotiations. Using the bilateral model and the partial order of the set of all employees' agents created by the pre-selection procedure, the case of multi-lateral negotiations with many negotiation issues was considered. Although this paper deals with the specific situation of an electronic marketplace for personnel acquisition, the proposed negotiation model can be only used with appropriate modifications in the framework of other agent-based e-marketplaces where agents have contradictory aims and negotiation is required.

Also Cheng et al. (2006) presented a formal heuristic model for making trade-offs in automated negotiations in a third-party-driven e-marketplace. The tactics that the agents are to employ when making trade-offs are explicitly formulated as fuzzy inference systems, which are used to infer new offers at each round of negotiation. The experimental results demonstrate that the proposed automated negotiation algorithm is efficient in terms of the number of offers exchanged, the joint utility obtained, and the Pareto-efficiency of the negotiated contracts. The automated negotiations formulated in this study do not consider the quantities that a buyer demands or the quantities that a supplier can provide.

Saha (2006) presented an extended protocol for bilateral multi-issue negotiation. The paper showed that with this protocol self-interested agents are able to explore and reach win–win agreements without revealing its complete preference. The scenarios investigated regards two agents and two and four attributes in negotiation.

Rahwan et al. (2007) introduced a methodology for designing strategies for negotiating agents. The methodology provides a disciplined approach to analyzing the negotiation environment and designing strategies in light of agent capabilities, and acts as a bridge between theoretical studies of automated negotiation and the software engineering of negotiation applications. The methodology is defined STRATUM (for STRATegy via Unorthodox Methodology); the main function of this methodology is to guide the designer of negotiation strategies from domain and requirements analysis to producing modular high-level specifications of strategies.

Louta et al. (2008) proposed a dynamic multi-lateral negotiation model and a negotiation strategy based on a ranking mechanism. The contract generation algorithm of the seller is coupled with a buyer ranking mechanism that entails identification of the most suitable contract among the contracts proposed. The framework developed is limited to price and due date and is tested between one buyer and one seller.

Bandyopadhyay et al. (2008) proposed a reverse auction mechanism by Multi-Agent System to automate transactions in e-marketplaces. The research developed concerns the mixed-strategy equilibrium in capacity-constrained reverse auctions. The approach proposed involves only the price attribute and for a limited number of player.

Lastly, Renna (2010) proposed a three value added services: workflow design, Multi-Agent System and negotiation approach. In particular, two negotiations, an auction and a single round approaches with three customer behaviors are proposed and tested by a proper simulative environment. The simulations have been conducted in several scenarios in order to highlight what is the best approach to perform. From the previous analysis of the literature, the following issues can be highlighted:

- few researches take into account a link between the negotiation process and the production planning activity;
- in the most part of the reported literature, to test the proposed approaches, only numerical examples have been developed. Moreover, just in very few papers the dynamicity of the environment has been tested by a distributed agent architecture;
- most of the researches deeply investigate the agreement in a negotiation when only two opponents try to reach an agreement.

The research presented in this book, to overcome the highlighted gaps, uses an innovative agent-based approach able to link both planning and negotiation tools in an e-marketplace context. This approach leads to a more realistic environment: in fact, production planning tools allow to create a relation between commercialization and production activities, providing a better service both for customers and suppliers, while negotiation consents to take into account identities and goals of all the involved actors, providing a better global satisfaction. Consequently, the innovations of the proposed approach are mainly related to:

- the development of a proper production planning algorithm directly linked to the negotiation mechanism in order to provide a set of information, useful for all the involved agents, to formulate the “right” proposal at each round of negotiation;

- the high flexibility of the proposed protocol that can be adapted to several strategies;
- the evaluation of the negotiation protocol proposed by an environment with many interacting customers and suppliers.

4.3 Negotiation Approach

The negotiation process starts with the customer's order submission. The order is processed through the *Customer Order Inputting Menu* and it is delivered to the Customer Negotiation Agent (CNA). The order is represented by the array $(i, V_i, dd_{i,} p_i)$, where $i \in \{1, \ldots, n\}$ the selected product from the supplier's catalogue, V_i the required quantity, dd_i the suitable delivery date and p_i the asked price. The activity diagram of Fig. 4.1 carries out the following actions:

- *Transmits order*: the CNA transmits the order array $(i, V_i, dd_{i,} p_i)$ to the Supplier Negotiation Agent (SNA);
- *Computes utility threshold*: The CNA computes its utility function and the lower threshold level according to the following expression (4.1):

$$\mathrm{Thu}(r) = \mathrm{Thu}_{\max} \cdot \left(1 - \frac{r-1}{r_{\max}-1}\right)^2 + F \cdot \left(\frac{r-1}{r_{\max}-1}\right) \cdot \left(1 - \frac{r-1}{r_{\max}-1}\right) + \mathrm{Thu}_{\min} \cdot \left(\frac{r-1}{r_{\max}-1}\right)^2 \qquad (4.1)$$

where:

- $\mathrm{Thu}_{\max}$ is given by the sum of the maximum values reached by the considered utility functions (obtained when all the requested parameters are fully satisfied);
- $r_{\max}$ is the maximum number of rounds of the negotiation; this value determines the temporal horizon of the negotiation process.
- F is the utility function slope. This value defines the behavior of the customer. The values assumed by F can be in the interval (2.5–6.5). The interval is obtained evaluating the expression (4.1) in several cases. The Fig. 4.2a and b show the behavior in two extreme cases. If F tends to the lower limit of the considered interval (equivalent at 2.5), the behavior of the customer is "*conceder*"; if F tends to the upper limit of the interval (equivalent at 6.5) the behavior of the customer is in its state of "*waiting*". This approach allows to adapt easily the customer behavior during the negotiation process. In this research, it is used as a value of parameter F as 4 (neutral behavior).

– *Computes Order Proposal Constraints*: the SNA computes a feasible range of variation of both the parameters: the required price (Δp_i) and the expected due

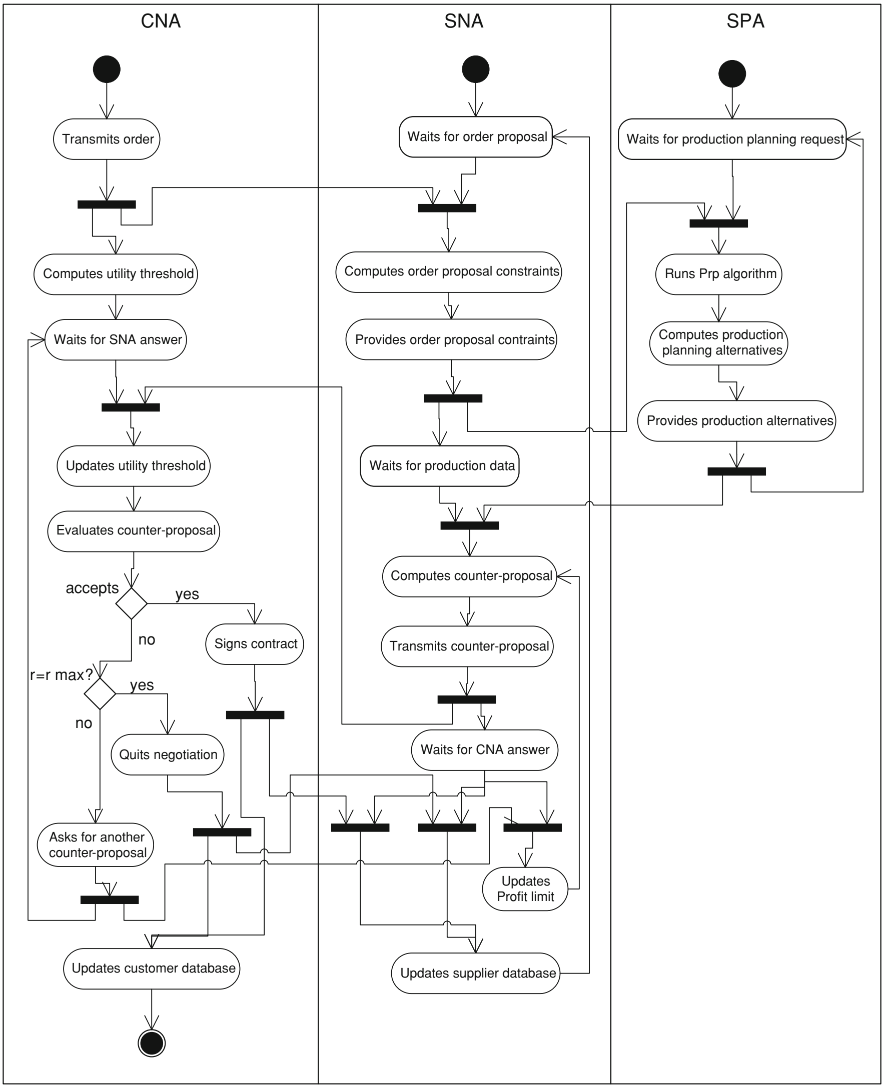


Fig. 4.1 UML Activity diagram

date (Δdd_i) by using the values reported in simulation environment section. These values depend on the strategy of the generic supplier;

- *Provides Order Proposal Constraints*: the values Δp_i and Δdd_i are transmitted to the Supplier Production Agent (SPA) and they will be considered as bounds by this agents;
- *Runs PrP*: the SPA runs the production planning (*PrP*) algorithm described in the following section;

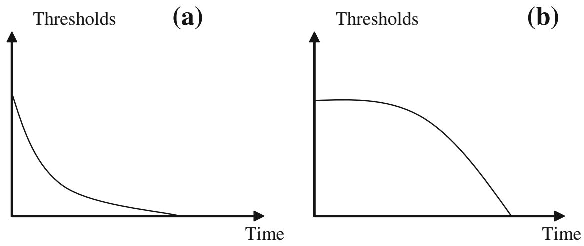


Fig. 4.2 (**a**) Conceder, (**b**) waiting

- *Computes Production Alternatives*: as output of the *PrP* algorithm, the SPA computes an array of production planning alternatives PA_j ($j = 1\ldots m$) that associate a supplier profit (Pr_j) and an offered volume (V_j) to each combination of offered due date (dd_j) and price (p_j) that is $PA_j = (Pr_j, V_j, dd_j, p_j)\forall j$, where $V_j \leq V_i$;
- *Provides production alternatives*: the set of values PA_j is transmitted to the SNA;
- *Computes counter-proposal*: if $r = 1$, the SNA builds the set of alternatives $K_0 = \{1, 2,\ldots k,\ldots,n^*\}$ such as:

$$Pr_k = Pr_{\max} = \max_{j=1,\ldots,n}\{Pr_j\}\forall k \in K_0 \tag{4.2}$$

and it searches within K_0 for the alternative j^* such as:

$$j^* | \min_{j\in K_0}\left(\frac{|dd_j - dd_i| + |p_j - p_i| + |V_j - V_i|}{3}\right) \tag{4.3}$$

The above expression (4.3) means that the three customer parameters have the same importance.

On the other hand, if $r > 1$, the SNA applies a profit reduction strategy according to the current negotiation round: it computes the new acceptable profit at the round r as reported in:

$$Pr_r = Pr_{\max} - \frac{PR_{\max} - PR_{\min}}{r_{\max}} \cdot r, \tag{4.4}$$

where the value $PR_{\min}$ is fixed and it is explained in the simulation environment section (Chap. 5). Afterward the SNA builds the set of production alternatives

$Kr = \{1, 2, k,\ldots,m^*\}$ such that:

$$Pr_k \geq Pr_r \forall k \in K_r \tag{4.5}$$

and it finds the alternative j^* that minimizes the relation (4.3) with $j \in Kr$. The array (V_j^*, dd_j^*, p_j^*), both in cases $r = 1$ and $r > 1$, represents the supplier counter-proposal;

- *Transmits counter-proposal*: the array (V_j^*, dd_j^*, p_j^*) is transmitted to the CNA. The SNA remains waiting for a CNA request;

– *Updates utility thresholds*: the CNA updates the utility function thresholds at the round r according to the expression (4.1);
– *Evaluates counter-proposal*: the CNA evaluates the utility related to the counter-proposal:

$$U_r^{c-p} = U_v + U_{dd} + U_p \tag{4.6}$$

where U_v, U_{dd}, U_p are respectively the utilities of the volume, due date and price, computed as reported in the following expressions:

$$U_v = \max\left(\left(\frac{V_{j*} - V_{\min}}{V_i - V_{\min},}\right); 0\right), \quad \text{where } V_{\min} = 0.3 * V_i; \tag{4.7}$$

The above expression means that the utility of the volume is linear, but the customer accepts a minimum value of the volume as 30% of the volume requested.

$$U_{dd} = \mathrm{Max}\left(\mathrm{Min}\left(\frac{dd_{j*} - dd_{\min}}{dd_i - dd_{\min}}; \frac{dd_{\max} - dd_{j*}}{dd_{\max} - dd_i}\right); 0\right), \tag{4.8}$$

where $dd_{\max} = dd_i + 5$ and $dd_{\min} = dd_i - 5$.

Also in this case, the customer has a range of parameter acceptable. In particular, the customer accepts a maximum delay of five periods and maximum of five periods of early due date.

$$U_p = \begin{cases} \mathrm{Min}\left(\left(\frac{p_i}{p_{j^*}}\right); 1\right), & \text{if } p_{j^*} < p_{\max} \\ 0 & \text{otherwise} \end{cases}, \tag{4.9}$$

where $p_{\max} = 1.6 * p_i$.

Finally, the customer accepts a maximum increment of the price as 60% of the price requested.

In case $U_r^{c-p} \geq \mathrm{Thu}(r)$, the CNA accepts (A) the counter-proposal and it signs the agreement with SNA; afterward they update their database with the agreement data. Conversely, if $U_r^{c-p} < \mathrm{Thu}(r)$ and $r < r_{\max}$, CNA asks for a new counter-proposal (N) otherwise, if $r = r_{\max}$, CNA rejects the proposal and quits the negotiation.

4.4 Production Planning as Tool to Support the Negotiation Process

The negotiation process has a significant effect on the efficiency and effectiveness of a Business-to-Business (B2B) electronic marketplace. The integration between negotiation and production planning tools allows to increase the effectiveness of the bargaining process among sellers and buyers for several reasons. The first one is the possibility to negotiate using numerous production planning alternatives with information related to the profit associated at each alternative. The second motivation is the possibility to increase the rapidity of the negotiation process. First of all, to correctly evaluate all the potentiality coming from the integration between negotiation and production planning, the manufacturing environment context has to be defined. The traditional classification regards: Make-To-Stock (MTS), Assemble-To-Order (ATO), Make-To-Order (MTO) and Engineering-To-Order (ETO) (McClain et al. 1992).

The MTO and ATO scenarios are the discrete production type most often found in Small and Medium Enterprises (SMEs) that require more manufacturing and IT flexibility (Babu 1999). Moreover, these scenarios require great complexity of buyer–seller relationships and therefore, a more intelligent form of a negotiation process. The importance of a MTO production model is confirmed by the study report of European Commission on ICT and e-business impact in the furniture industry: "*As in many manufacturing industries today, the furnishing sector in under increasing pressure to transform business form Make-To-Forecast* (*based on predictions*) *operations to short lead-time, small batch Made-To-Order* (*MTO*) *production*."

For the above reasons, the production planning model developed in here is referred to the MTO and ATO production contexts. The objective of the algorithm is to provide accurate information on production planning alternatives. In particular, the information concerns the combination of price, due date and volume (issues in negotiation) and the profitability of each combination. Moreover, the computation of production alternatives must be performed rapidly in order to respect the negotiation time constraint. What is proposed is a Mixed-Integer Linear Programming (MILP) with the effort to limit the computational time. Among the research proposed in the literature, the following latest papers show the importance of the production planning tools as a support to take the decisions in different manufacturing environment problems.

Calosso et al. (2004) proposed a model for the problem of supporting negotiations among manufacturing firms that operate on a MTO basis. The problem discussed concerns two issues: price and due date.

Oduoza and Xiong (2009) investigated the need of SMEs to use an effective decision support system. A flow chart is presented to highlight the influence of negotiation on customer due dates to serve as a basis for forward or backward planning. One of the major contributions of the research was how the production planning based on mathematical model links profit maximization with screening customer/order enquiries. Renna and Argoneto (2009) investigated the low level production planning with the problem of allocating the orders to the distributed plants. The coordination approaches are supported by a local production planning model of each plant. In this case, the production planning tool provides the information to improve the cooperation among plants. Renna and Argoneto (2010) proposed a research concerning the added value services in e-business applications for SMEs. In particular, the approach proposed creating a link between production planning and negotiation in a neutral e-marketplace. The research suggested how the simulation can be used to obtain a behavior map of the e-marketplace performance in several dynamic conditions, both for customers and for suppliers. The behavior map of an e-marketplace can be used as a support to the decision-making process: a generic SME can evaluate if it participates or not in an e-marketplace, considering the actual market conditions, and it can easily estimate the performance variation when the market conditions change (risks evaluation). Volling and Spengler (2011) provided a framework comprising separate interlinked quantitative models for order promising and master production scheduling. The focus of their contribution was on the modeling and evaluation of both models in a dynamic setting. The approach was evaluated by means of a simulative analysis using empirical data from the automotive industry.

The production planning algorithm presented in this chapter is characterized by the simplicity of the implementation and operation should support the negotiation process. Moreover, the algorithm proposed is characterized by none parameters to set in advance; therefore, the algorithm does not change when the negotiation process is modified. Finally, the algorithm can be used in different areas as: distributed production planning; dynamic capacity allocation, etc.

4.4.1 The Production Planning Model

The SPA provides the information to the SNA using a local production planning model. The production planning model used in this book is an extension of the model presented in Perrone et al. (2003). The production planning model is deeply explained in the following.

Indexes:

$i = 1,\ldots, m$ products order (job);
$j = 1,\ldots, n$ resources;
$t = 1,\ldots, T$ time buckets;

Decision variables:

$\text{sub}_i = 1$ if sub-furniture for product i is activated, 0 otherwise
x_i fraction of the job i assigned to the manufacturing system
y_{ijt} amount of resources j allocated to job i at time t
r_{jt} amount of ordinary manpower work to allocate to the resource j at time t
o_{jt} amount of overtime work to allocate to the resource j at time t
s_{it} fraction of the job i in sub-furniture at time t
i_{it} fraction of the job i in inventory at time t

Model parameters:

p_i order price
d_i order due date

FC_i	process plan fixed cost for job i
FCS_i	outsource fixed cost for job i
rs_{ij}	amount of type j resource needed for processing job i
CRG_j	time unit cost when used during ordinary time
COV_j	time unit cost when used during over time
CI_i	inventory cost for job i
$CAPR_{jt}$	resource j ordinary time capacity at time t
$CAPO_{jt}$	resource j overtime capacity at time t
$CAPS_i$	fraction of the job i capacity in sub-furniture
CSB_i	sub-furniture cost for job i

Objective function: *Seller Profit maximization*

$$\max\left\{\sum\nolimits_{t \le d_i} \sum\nolimits_i (x_i + s_{it}) \cdot p_i - C1 - C2 - C3 - C4 - C5\right\} \tag{4.10}$$

Constraints:

$$\sum\nolimits_{t \le d_i} y_{ijt} \ge x_i \cdot rs_{ij} \quad \forall i, j \tag{4.11}$$

$$i_{it} = i_{it-1} + \sum_{j=1}^{n} \frac{y_{ijt}}{rs_{ij}} \quad \forall t, i \tag{4.12}$$

$$i_{i1} = 0 \quad \forall i \tag{4.13}$$

$$\sum\nolimits_i y_{ijt} \le r_{jt} + o_{jt} \quad \forall i, t \tag{4.14}$$

$$r_{jt} \le \mathrm{CAPR}_{jt} \quad \forall j, t \tag{4.15}$$

$$o_{jt} \le \mathrm{CAPO}_{jt} \quad \forall j, t \tag{4.16}$$

$$\sum\nolimits_{t \le d_i} s_{it} \le \mathrm{CAPS}_i \quad \forall i \tag{4.17}$$

$$s_{it} \le \mathrm{sub}_i \quad \forall i, t \tag{4.18}$$

$$C1 = \sum\nolimits_i FC_i \tag{4.19}$$

$$C2 = \sum\nolimits_j \sum\nolimits_t (\mathrm{CRG}_j \cdot r_{jt}) \tag{4.20}$$

$$C3 = \sum\nolimits_j \sum\nolimits_t (\mathrm{COV}_j \cdot o_{jt}) \tag{4.21}$$

$$C4 = \sum_i \left(\mathrm{FCS}_i \cdot \mathrm{sub}_i + \mathrm{CSB}_i \cdot \sum_{t \le d_i} s_{it} \right) \tag{4.22}$$

$$C5 = \sum\nolimits_i \sum\nolimits_t i_{it} \cdot \mathrm{CI}_i \tag{4.23}$$

$$y_{ijt} \geq 0 \quad \forall\, i,j,t \tag{4.24}$$

$$r_{jt} \geq 0 \quad \forall\, j,t \tag{4.25}$$

$$o_{jt} \geq 0 \quad \forall\, j,t \tag{4.26}$$

$$x_i \geq 0 \quad \forall\, i \tag{4.27}$$

$$s_{jt} \geq 0 \quad \forall\, j,t \tag{4.28}$$

$$\mathrm{sub}_i \in \{0,1\} \quad \forall\, i \tag{4.29}$$

$$\sum\nolimits_{t \leq d_i} \sum\nolimits_i (x_i + s_{it}) \leq 1 \quad \forall\, i \tag{4.30}$$

Constraint (4.11) forces the total amount of working time units of each resource to be at the least equal to the amount of working time units needed to complete the job assigned to be manufactured internally. It is to be highlighted that the job must be completed within the specified due date. Constraint (4.12) computes the amount of product in inventory for each t, while constraint (4.13) initializes the inventory level for the $t = 1$. Constraint (4.14) computes the resource, while Constraints (4.15) and (4.16) put a bound on regular and overtime resources. Constraint (4.17) defines the bound of sub-furniture for the fraction of job i. Constraint (4.18) assures that sub-furniture not activated cannot be used for the job i. The costs of the production planning are computed in: Constraint (4.19) of using a specific process plan for job i; Constraint (4.20) computes costs for regular time resource use, while Constraint (4.21) calculates costs of using resources in overtime; Constraint (4.22) computes the fixed and variable costs of the sub-furniture process; Constraint (4.23) computes the inventory cost. Constraints (4.24–4.29) defines decision variables domain. Finally, Constraint (4.30) assures that the total fraction of volume is lower than 100% that is, the volume requested by the customer.

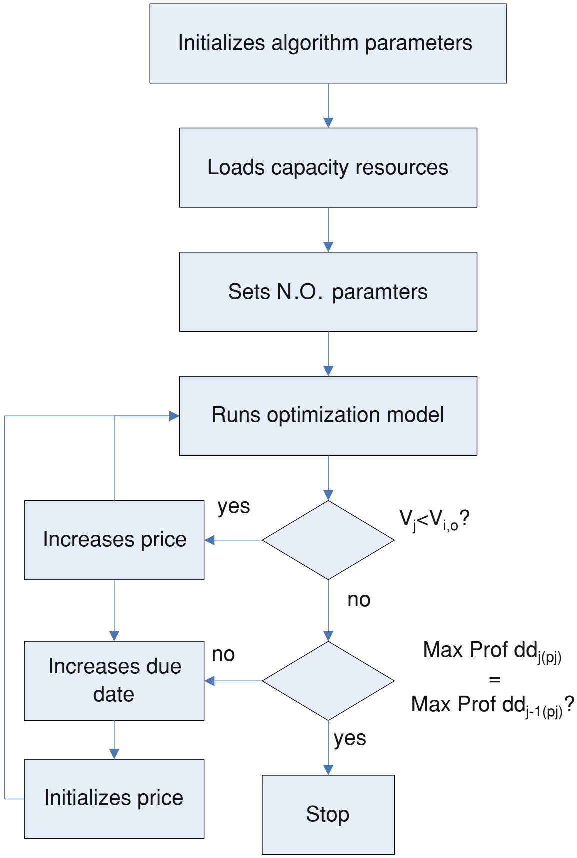
4.4.2 The Production Planning Algorithm

The production planning model described in the previous paragraph is used to compute the production planning alternatives.

The model is activated by the Production Planning Agent (PrPA) within the proposed multi-agent architecture described in Chap. 2. The main task of the PrPA is to support the negotiation process performed by the SNA providing the information on production alternatives; the SNA uses this information to build the counter-proposal for the seller during the negotiation. The production planning alternatives create a "*behavior map*" of the supplier that allows to support the negotiation process with detailed information.

The diagram of Fig. 4.3 describes in detail the activities of the algorithm to compute the production planning alternatives.

Fig. 4.3 Production planning alternatives algorithm



The production alternatives (PA_j) are computed replying to the customer's order in terms of volume $V_{i,o}$, price $Pr_{i,o}$ and due date $dd_{i,o}$ for product i and order o. The production alternatives PAj ($j = 1,\ldots n$) consisting of an offered volume (V_j), due date (dd_j), price (pj) and the associated profit (Pr_j): that is $PA_j = (V_j, dd_j\, pj, Pr_j)\ \forall\, j$.

It has been assumed that production planning activity proceeds by planning period of fixed length T, in particular, the length is between the time in which the customer inputs the order ($t^a_{i,o}$) and the dd_j of the PA_j computed.

The algorithm works through the following steps (see Fig. 4.3):

Initializes algorithm parameters: the PrPA sets the production alternatives count $j = 1$ and the start time of the period of planning to $t^a_{i,o}$. Moreover, the PrPA sets the indexes and model parameters of the optimization model.

Loads capacity resources: the PrPA loads all the information of the resources capacity.

Sets N.O. parameters: the PrPA sets the following Negotiation Order (N.O.) parameters:

- $p_{i*} = p_{i,o}$: p_{i*} is the price used to compute the PA_j
- $dd_{i*} = dd_{i,o}$: dd_{i*} is the price used to compute the PA_j

The PrPA computes the first alternative starting from the customer request.

Runs optimization model: the PrPA runs the optimization model presented in the previous section, where *pi** and dd_i* are respectively implied in the model parameters. After the model is solved, optimal volume and profit level associated to p_{i*} and dd_{i*} are found out, the new vector is added to the *PA* grid.

$V_j < V_{i,o}$?: the PrPA verifies if the volume obtained by the optimization model is lower than the volume requested by the customer. In positive case, the PrPA increases the price p_{i*} according to the following expression:

$$p_{i^*} = p_{i^*} + \alpha \cdot p_{i^*}, \quad \alpha \in [0, 1] \tag{4.31}$$

The value of α characterizes the *resolution* of the production planning algorithm. In this research the value of α is fixed to 0.1; this means that the price has a step of 10%.

The higher price can lead to increase the volume of the production planning alternatives using overtime or sub-furniture.

After the price is updated, the PrPA runs the optimization model to compute the new PA and increment $j = j + 1$.

To avoid algorithm deadlock, the PrPA verifies the potential resources capacity allocated by the optimization model. If the PA_j uses all the resources capacity, the algorithm goes on to the following step. In fact, in this case the higher price cannot improve the volume of the production planning alternative.

Max Prof ddj = Max Prof ddj-1?; The PrPA computes the maximum profit of the production alternatives with the same p_{i*}. If the last increment of dd_{i*} does not change profit, the PrPA ends to explore new production alternatives because the new alternative reduces the satisfaction of the customer (the due date increases) and does not improve the profitability. Otherwise, the PrPA increases the due date dd_{i*} according to the following expression:

$$dd_{i^*} = dd_{i^*} + 1 \tag{4.32}$$

At the end of the algorithm, the PrPA builds the production alternative grid and it defines the maximum value of price and due date.

The proposed algorithm explores all the production alternatives that can improve the profitability of the seller (seller's satisfaction) or improve the satisfaction of the buyer. The outputs of the production planning algorithm are two matrixes. The first matrix provides the volume alternatives for each combination of price and due date (for example, see Table 4.1).

The second matrix provides the profit alternatives for each combination of price and due date (for example, see Table 4.2).

The two matrixes computed is the knowledge on the production planning that the generic supplier can use to improve the negotiation process. The dimension of the matrixes (*M*, *N*) depends on the customer issues requested (volume, price and due date).

Table 4.1 Production planning alternatives—volume

	Due $date_1$	Due $date_2$	Due $date_3$	Due $date_N$
$Price_1$	$Volume_{11}$	$Volume_{12}$	$Volume_{13}$	$Volume_{1N}$
$Price_2$	$Volume_{21}$	$Volume_{22}$	$Volume_{23}$	$Volume_{2N}$
$Price_3$	$Volume_{31}$	$Volume_{32}$	$Volume_{33}$	$Volume_{3N}$
$Price_M$	$Volume_{M1}$	$Volume_{M2}$	$Volume_{M3}$	$Volume_{MN}$

Table 4.2 Production planning alternatives—profit

	Due $date_1$	Due $date_2$	Due $date_3$	Due $date_N$
$Price_1$	$Profit_{11}$	$Profit_{12}$	$Profit_{13}$	$Profit_{1N}$
$Price_2$	$Profit_{21}$	$Profit_{22}$	$Profit_{23}$	$Profit_{2N}$
$Price_3$	$Profit_{31}$	$Profit_{32}$	$Profit_{33}$	$Profit_{3N}$
$Price_M$	$Profit_{M1}$	$Profit_{M2}$	$Profit_{M3}$	$Profit_{MN}$

4.5 Discussion

The research proposed in this chapter deals with a real value added services in e-business for small and medium enterprises. In particular, an innovative approach has been proposed creating a link between production planning and negotiation in a neutral e-marketplace based on multi-agent architecture. In context of e-marketplaces, the negotiation process occurs frequently; therefore, the integration between production planning and negotiation can be a real improvement of the bargaining process between customers and suppliers. The main contributes of the proposed approach are the following:

- the integration between production planning and negotiation allows to automate and improve the negotiation process in e-marketplaces.
- the production planning algorithm is performed without set parameters at priori. The approach proposed provides to the negotiation process the alternatives built using only the information of the negotiation issues (price volume and due date).
- the approaches based on multi-agent architecture can be support several applications: e-marketplace in Business-to-Business environment; multi-plant production planning; Virtual Enterprise operation phase, etc. Therefore, the approach proposed in this chapter is more general.
- the approaches have been developed in order to operate in real case by cut down the computational time of the algorithm.

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Chapter 5
Models for Coalition Management

5.1 Introduction

In Business-to-Business applications, it is necessary to find synergy factors that are able to create extra profit to guarantee e-marketplace fee. As stated in Barrat and Rosdahl (2002), market-sites will generate revenue either through percentage of the transactional value or through other value adding service fees. One of the main drivers for SMEs to join a marketplace is to gain more than with traditional market channel, more than ever if a percentage of transactional value is due to market-site administrator. This profit increase can be enhanced by a co-operative strategy and it will also improve order fulfillment; this last issue is considered as one of the key areas where electronic market-sites can differentiate themselves (Woods, 2000). But, cooperation should not be specific: as Keenan observes market-site must offer frictionless environment because parties do not necessarily have previous relationships and therefore, they have not built up any trust between them. In this context it is helpful to distinguish between human and automated task: the former has human actors while the latter has autonomous agents actors (Ferber, 1999). In particular, we will focus our attention on automated task supporting the settlement transaction phase: suppliers and coalition among suppliers to fulfill customer order.

The coalition of suppliers can be defined as a temporary network of independent companies linked by information technology to share the customer order and to increase the probability to reach an agreement with the customer. The coalition is characterized by a life cycle articulated in the following steps:

1. *Coalition condition strategy*: it is the identification of the suppliers who are available to participate in a coalition. The suppliers apply a coalition condition strategy to decide during the interaction process if the coalition can be a valid opportunity to get major benefits.
2. *Coalition formation*: in this step, the suppliers who are available to make a coalition try to reach an agreement to form a coalition.

P. Argoneto and P. Renna, *Innovative Tools for Business Coalitions in B2B Applications*, DOI: 10.1007/978-0-85729-707-5_5,

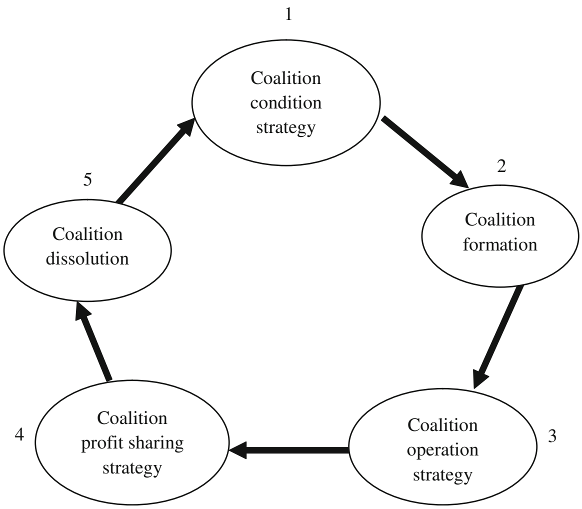

Fig. 5.1 Life cycle of coalition

3. *Coalition operation strategy*: in this phase a coalition is made, the problem is how the coalition formulates and submits its own counter-proposals to the customer during the negotiation process.
4. *Coalition profit sharing strategy*: in this step, if the coalition reaches an agreement with the customer, how profits are shared among the coalition's participants.
5. *Dissolution of the coalition*: after the negotiation process ends, the coalition is dissolved.

Figure 5.1 graphically explains the life cycle activated at each order submitted by the customer. Regarding the Multi-Agent architecture discussed in Chap. 2, the agents involved in the coalition management are: the *Supplier Negotiation Agent* (SNA), the *Supplier Coalition Agent* (SCA) and the *Coalition Negotiation Agent* (CoNA). The tasks of the life cycle described above are assigned to the agents as follows:

- the SNA decides, during the interaction process, whether the coalition can be a profitable opportunity or not. In the first case, the supplier participates in a coalition and the agent provides the necessary information in its proposal formulation; Therefore, the SNA acts during this first phase of the life cycle and on the operative phase;
- the SCA is activated in order to reach an agreement with the other suppliers available to collaborate. It acts only in the coalition formation phase and applies an opportune strategy to indentify their potential partners;
- the CoNA is activated only when the coalition is created. It acts, during the operation phase of the coalition, collecting the information by each partner in order to formulate the coalitional proposal. Moreover, it applies the defined strategy in sharing the profit in case the coalition reaches an agreement with the

customer. Finally, it communicates to the suppliers when the coalition is dissolved.

The chapter is structured as follows. Section 5.2 discusses the literature review concerning the coalition in e-marketplaces. Section 5.3 presents the coalition approaches based on NASH equilibrium and Shapley value. Finally, in Sect. 5.4 the discussion on the coalition approaches proposed is provided.

5.2 Literature Review on Coalitions

The cooperation among SMEs in e-marketplaces can be an important opportunity to improve the benefits gained. Among the possible cooperation models, the impact that sellers' coalition might have on e-marketplaces has been investigated. A coalition is a set of self-interested agents who agree to cooperate to achieve a goal that, in this case, can be considered the agreement with the buyer. This kind of coalition was thoroughly investigated within game theory studies (Peleg 1984; Sandholm et al. 1999). Lerman and Shehory (2000) have proposed a new model for coalition formation and applied it to coalition formation among buyer agents in an e-marketplace. Yamamoto and Sycara (2001) describe global behavior of a set of agents, from the macroscopic point of view, by differential equations and simulate how buyer coalitions evolve and reach the steady state. However, the model does not assist individual agents either to form a coalition or to negotiate surplus distribution.

Li et al. (2004) proposed a mechanism design problem of coalition formation and cost sharing in a group-buying electronic marketplace, where buyers can form coalitions to take advantage of volume-based discounts. Simulation results show positive correlation between stability and incentive compatibility (which is in turn related to efficiency).

Renna et al. (2005) proposed two approaches to support coalition in e-marketplace environment by Multi-Agent Architecture. The approaches proposed are based on game theory; in particular one on Nash Equilibrium and other on Shapley Value. The approaches are discussed for (a) coalition existence conditions; (b) coalition operation and (c) coalition profit sharing. The simulation results showed how the possibility to make coalition among suppliers is a real value added for both customers and suppliers.

Jin and Wu (2006) investigated the formation process of supplier coalitions in on-line reverse auctions. The mechanism concerns the possibility to form coalitions of suppliers for the purpose of enhancing their profitability and providing them incentives to participate in on-line reverse auctions. Basic requirements are identified for a valid coalition mechanism, and the requirements include individual rationality, market efficiency compatibility, maintaining competition, observability and controllability, and financial balancedness. The proposed coalition mechanism is well-defined and satisfies all validity requirements. The stable coalition structure under this mechanism is also studied, and it is proved that under symmetric information there exists one unique strongly stable coalition structure.

Nagarajan and Sosic (2006, 2007) investigated the alliance formation process among agents in competitive markets. The model proposed considers only the price competition among n agents in market characterized by deterministic and stochastic demand. The authors highlighted that cooperative bargaining between coalitions is still an important but relatively unexplored area of study.

Chandrashekar and Narahari (2007) addressed the problem of forming procurement networks for items with value adding stages that are linearly arranged. We model the problem of Procurement Network Formation (PNF) for multiple units of a single item as a cooperative game where agents cooperate to form a surplus maximizing procurement network and then share the surplus in a stable and fair manner.

Granot and Yin (2008) investigated competition and cooperation in a multiple-supplier, one-manufacturer supply chain with complementary products. For the pull and push systems, these authors considered two levels of problems: at the first level, they used the concepts of Nash equilibrium and farsighted stability to identify stable coalitional structures among suppliers; and at the second level they developed a Stackelberg game to examine the interactions between the manufacturers and suppliers.

Michalak et al. (2009) considered a model for exogenous coalition formation in e-marketplaces. Using its informational advantage, an e-retailer creates coalitions of customers based on geographical proximity. They analyzed a situation in which an existing e-retailer exogenously forms customers' coalitions. The proposed approach combined delivery service may offer significant efficiency gains as well as opportunities for Pareto improvement.

Argoneto and Renna (2010) presented an innovative approach, based on multi-agent system, and a concerning simulation test-bed conducted to demonstrate, in a quantitative way, the advantages arising by adopting the proposed approach.

Renna (2010) deals with real added value services in e-marketplaces for Business-To-Business applications. In particular, the value added services investigated regarding the negotiation protocol among suppliers and customers and the customer's tactics and the coalition among suppliers.

Li et al. (2010) introduced the concept of Combinatorial Coalition Formation (CCF), which allows buyers to announce and reserve prices for combinations of items. These reserve prices, along with the sellers' price-quantity curves for each item, are used to determine the formation of buying groups for each item. They proposed a heuristic algorithm to support the proposed approach because the optimal coalition configuration in CCF is *NP-hard*. Simulation results showed that their approximate algorithm generates fairly good solutions compared to the optimal results, and is greatly superior to a simpler distributed approach.

From the analysis of the literature, it is possible to extrapolate some useful highlights:

- most research papers concern only price or only one item in negotiation;
- few research studies concern a link between the negotiation process and the production planning activity;
- the research presented does not investigate the exchange of information among the coalition participants.
- the approach proposed based on game theory are characterized by high computation complexity; therefore, these approaches can be used in environment with reduced number of suppliers.

The research presented in this chapter overcomes the scientific literature on these innovative subjects.

- The research presented here provides a coalition formation protocol focusing on feasibility and fairness, and suggests heuristics that provide benefits and maintain stability.
- It is assumed that the coalition formation process, as an economic process, is bounded in time and that the involved agents have incomplete information about the played game.
- The approaches proposed are based on reduced information sharing (NASH approach) and complete information sharing (Centralized and Shapley value approach).
- The coalition approaches proposed are completely integrated with the negotiation and production planning activities.

5.3 Coalition Approaches

In this paragraph, and in its subsections, the proposed approaches to support the coalition management over the steps of the life cycle are described. The aim of this part of the research is to propose models to support the Multi-Agent Architecture when n suppliers decide to make a coalition: this opportunity is investigated from the sellers' point of view. This choice is driven from the fact that the coalition of suppliers is quite complex because of the involved strategies, and production planning models and objectives are different for each considered player. Two of the proposed approaches are based on game theory, while the last one is based on a simple information sharing strategy and it is utilized as benchmark. In particular, game theory is proposed in two crucial activities to manage a coalition: the first is concerning the Nash approach for partners' selection phase, while the second activity is the application of the Shapley value approach for the profit allocation among the partners of the winning coalition. Obviously, all three mechanisms are modeled in order to be integrated in the Multi-Agent architecture presented in Chap. 2.

5.3.1 The NASH Equilibrium Approach

The first approach proposed is based on the Nash equilibrium: it is basically used to select the partners among several suppliers available to participate in a coalition. The possibility to make a partnership among suppliers is evaluated at beginning of the second round of negotiation, as shown in the activity diagram already presented in Chap. 2. At that time all the suppliers verify their availability to make a coalition by computing a specific counter-proposal. More precisely it is the offer each of them would be able to submit in the last round of negotiation. Therefore, the NASH approach proposed concerns mainly the formation process of the coalition, while the profit sharing (if the coalition reaches an agreement with the customer) is a secondary process.

5.3.1.1 Availability of the Players and Coalition Creation

The first activity in the coalition process is the evaluation if a generic supplier is available to make a coalition. The availability is evaluated considering the best proposal that the supplier can submit during the negotiation process. The best proposal is the proposal computed at the last round of the negotiation.

The best proposal the generic supplier s_j can submit to the customer at the last round of negotiation is given by the vector: (V_s^{last}, dd_s^{last}, p_s^{last}). Knowing that, it computes the following values:

$$V_s^{\%} = \frac{\left| V_j^{\text{last}} - V^* \right|}{V^*} \cdot 100 \tag{5.1}$$

$$dd_s^{\%} = \frac{\left| dd_j^{\text{last}} - dd^* \right|}{(dd^* - t_0{}^a)} \cdot 100 \tag{5.2}$$

$$P_s^{\%} = \frac{\left| P_j^{\text{last}} - P^* \right|}{P^*} \cdot 100 \tag{5.3}$$

where (V^*, dd^*, p^*) is the customer request and t_o^a the arrival time of the generic *o*th order.

The Expressions (5.1), (5.2) and (5.3) describe the difference between the customer request and the best proposal that the supplier s_j could submit. The sum of the three values represent the *distance* between customer and supplier (to seek simplicity the considered parameters have the same importance):

$$\Delta = \left(V_s^{\%} + dd_s^{\%} + P_s^{\%} \right) \tag{5.4}$$

The supplier needs to apply a strategy to decide its availability to participate in a coalition. The methodology proposed in this research is to set a *threshold* value of the maximum distance (of the considered parameters) admissible for the supplier: the probability to reach an agreement is inversely proportional to the distance Δ. The supplier that has a distance greater than the fixed threshold (5.5) estimates a low probability to prevail by its own ability in the negotiation process. For that reason it becomes available to join in a coalition with other suppliers.

$$\Delta > \gamma \tag{5.5}$$

where γ is a numerical value (in this research, the value is fixed to 0.5) expressing the attitude of each supplier to make a coalition.

This means that the supplier is available to make a coalition if its best counter-proposal differing from the customer requests is over 50%.

It has to be noticed that the strategy proposed is more adaptable. For example, it can be fix the weights of each issue in negotiation to define the function Δ.

At this point, each supplier $s_\upsilon \in N^c(\upsilon = 1, 2, \ldots, |N^c|)$, N^c a subset of all the suppliers N, is available to make a coalition. The set N^c is constituted considering the subgroup of sellers satisfying the following condition:

$$N^c = \{s : \Delta \geq \gamma, \gamma > 0, s \in N\} \tag{5.6}$$

The first activity of the coalition life cycle is performed by the determination of the set of suppliers available to make a coalition.

The second activity regards the coalition formation performed by the following algorithm (see Fig. 5.2):

1. If $N^c = \{\varnothing\}$ or $N^c = \{1\}$ no coalitions are possible. Otherwise go to step 2;
2. Seek $s_{\upsilon=1} \in N^c$, then set $s_{\upsilon=1} = a$;
3. For $\upsilon > 1$, set $s_\upsilon = b$ and go to step 4;
4. The coalitional compatibility between the sellers a and b is verified using the Nash equilibrium concept explained in the next subsection. The possible cases are the following:
   i. a Nash equilibrium exists and the coalition is created. The seller a provides a volume quota equal to $\zeta \cdot V^*$, while the seller b puts $(1 - \zeta) \cdot V^*$, where $\zeta \in (0, 1)$;
   ii. a Nash equilibrium does not exist. In this case the parameter υ is increased to one unit and the algorithm starts again from point 3. Whether no equilibrium is found for each possible $b \in \{N^c \backslash a\}$, then a is removed from the set N^c and the algorithm starts again from point 1.

In this research, the values of the parameter ζ are fixed to three values (0.25, 0.5 and 0.75). This means that two potential suppliers (supplier 1 and supplier 2) evaluate the NASH equilibrium evaluating three possibilities to subdivide the volume requested by the customer:

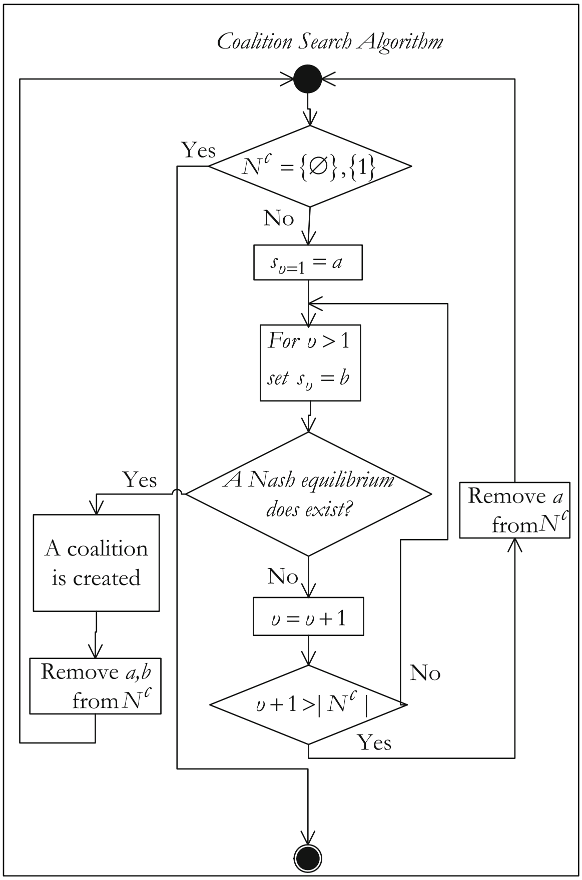

Fig. 5.2 Coalition search algorithm

- supplier 1 with 25% of volume and supplier 2 with 75% volume;
- supplier 1 with 50% of volume and supplier 2 with 50% volume;
- supplier 1 with 75% of volume and supplier 2 with 25% volume.

This strategy allows to reduce the time to take the decision on the coalition creation process. It has been considered that for each combination each supplier needs to perform the production planning algorithm to provided the production alternatives.

5.3.1.2 Nash Equilibrium Searching Method

To verify the existence of equilibrium between the selected suppliers, the following steps are considered:

1. The supplier s_υ, with $s_\upsilon = \{a, b\}$, elaborates its response to the requested volume (respectively $\zeta \cdot V^*$ and $(1 - \zeta) \cdot V^*$) in terms of two matrixes: the

		Seller b				
		dd_1	...	dd_w	...	dd_W
Seller a	p_1	$po^a_{dd_1,p_1}; po^b_{dd_1,p_1}$	...	$po^a_{dd_w,p_1}; po^b_{dd_w,p_1}$	...	$po^a_{dd_W,p_1}; po^b_{dd_W,p_1}$
	...	...	...		...	
	p_q	$po^a_{dd_1,p_q}; po^b_{dd_1,p_q}$	...	$po^a_{dd_w,p_q}; po^b_{dd_w,p_q}$	...	$po^a_{dd_W,p_q}; po^b_{dd_W,p_q}$
	...	...	...		...	
	p_Q	$po^a_{dd_1,p_Q}; po^b_{dd_1,p_Q}$	...	$po^a_{dd_w,p_Q}; po^b_{dd_w,p_Q}$	...	$po^a_{dd_W,p_Q}; po^b_{dd_W,p_Q}$

Fig. 5.3 Suppliers coalitional game

profit matrix, i.e., $\mathbf{P}(s_\upsilon) = \{\mathrm{Pr}_j(dd_w, p_q)\}$, and the offered ratio volume matrix, $\mathbf{V}(s_\upsilon) = \{V_j(dd_w, p_q)\}$;

2. The matrix $\mathbf{P}(s_\upsilon)$ is normalized regards the maximum profit within the matrix; let us indicate $\mathbf{P}(\bar{s}_\upsilon)$, the normalized matrix;
3. The supplier s_υ computes the payoff matrix $\mathbf{PO}(s_\upsilon) = \mathbf{P}(\bar{s}_\upsilon) + \mathbf{V}(s_\upsilon)$; this matrix represents (for an example, see Fig. 5.3), for each supplier, the payoff associated with each combination of due date and price (a possible move in the game); it is to be noticed that the supplier computes its own payoff by taking into account both its personal profit and the possibility to satisfy customer request (the order quota); the generic element of $\mathbf{PO}(s_\upsilon)$ is indicated as $\mathrm{PO}^{s_\upsilon}_{dd_w,p_q}$.It is possible to consider the static form of the game, as reported in the following.
4. Sellers *a* and *b* seek a Nash Equilibrium. To do this it is useful consider that:

- each player has two or more well-specified choices;
- every possible combination of choices leads to a well-specified end-state that terminates the game;
- a numerically meaningful payoff is defined for each possible end-state;
- each player knows the full rules of the game (perfect knowledge);
- all decision-makers are rational. This implies that a player will always choose the action that yields the greatest payoff.

With these considerations, the game can be solved by comparing the rewards of all possible strategy combinations: indeed, by the last assumption, each player will choose the move (dd_w, p_q) with its own highest expected return.

The output is a dominant strategy equilibrium that means a Nash equilibrium.

- If the equilibrium does not exist the algorithm quits.
- If the equilibrium exists, a and b make a coalition and they produce a coalitional counterproposal generated as explained in the following subsection.
- Given their theoretical equivalence, in case of multiple equilibriums the first one encountered by the algorithm is selected.

5.3.1.3 Coalition Operation Strategy

The third activity of the coalition is the *coalition operation strategy*, in other words, how the coalition computes the counter-proposal to submit to the customer. This activity is done according to the Nash equilibrium procedure, as it follows:

- the offered due date is the *Nash equilibrium due date* $\left(dd_w^E\right)$: it is the due date corresponding to the column w where the Nash equilibrium has been found (see Fig. 5.3);
- the offered price is the *Nash equilibrium price* $\left(p_q^E\right)$: it is the price corresponding to the column w where the Nash equilibrium has been found (see Fig. 5.3);
- the offered volume, V^E, is the *sum* of the equilibrium volume quota, respectively offered by seller a and seller b:

$$V^E = V^{E,a} + V^{E,b}. \tag{5.7}$$

It is found at the qth row and wth column, where the Nash equilibrium is:

$$V^E = \{ V^{E,a}(dd_w^E, p_q^E) + V^{E,b}(dd_w^E, p_q^E)\} \cdot V^* \tag{5.8}$$

After this first elaboration of the counterproposal, two matrixes are generated by the coalitional agent:

- $P^c = \mathbf{P}(a) + \mathbf{P}(b)$, the common profit matrix and (5.9)

- $V^c = \mathbf{V}(a) + \mathbf{V}(b)$, the common volume matrix. (5.10)

These matrixes are utilized during the prosecution of the bargaining, taking into account two different policies:

- *NEA*1: the first coalitional counterproposal is generated by using the procedure explained above. The subsequent ones, necessary in the remainder rounds of negotiation, are formulated considering the coalition as a single player with profit and volume matrixes given by P^c and V^c. With this policy the proposal is constituted by:

– the price: it is computed as the weighted average of the prices offered by seller a, $p_q(a)$ and by seller b, $p_q(b)$ using the formula (5.11):

$$p_q = \zeta \cdot p_q(a) + (1 - \zeta) \cdot p_q(b) \tag{5.11}$$

– the due date: it is the maximum one between the value offered by seller a, $dd_q(a)$, and seller b, $dd_q(b)$:

$$dd_w^{\max} = \max\{dd_w(a); dd_w(b)\} \tag{5.12}$$

– the offered V is the sum of the volume quota, respectively offered by seller a, V^a, and by seller b, V^b that is:

$$V = \{V^a(dd_w^{\max}, p_q(a)) + V^b(dd_w^{\max}, p_q(b))\} \cdot V^* \tag{5.13}$$

- *NEA2:* the suppliers belonging to the coalition elaborate their coalitional proposal by using the Nash equilibrium procedure *at each* round of negotiation. Realized in this way the counterproposals can be considered as a *Nash equilibrium path*. In a generic step of negotiation, the non-existence of equilibrium implies the incapacity of the coalition to elaborate a counterproposal. In this case, the coalition has to wait for the next round of bargaining to try again to engage the negotiation process.

The second policies (*NEA2*) based on *nash equilibrium paths* are tested, but leads to very low performance. The motivation is the reduced number of possible counter-proposal that the supplier can submit because the counter-proposal needs to be a NASH equilibrium. For this reason, the simulation results are not described in the Chap. 7.

5.3.2 Shapley Value Approach

The second approach proposed is based on SHAPLEY value approach. The coalition process uses centralized information to perform the activities of the coalition life cycle. The SHAPLEY value is used in the activity of profit sharing among the partners of the coalition in case of agreement with the customer.

5.3.2.1 Coalition Formation

The first activity, also in this case, is the coalition formation among the suppliers that are available to make a coalition: as deeply discussed in Tombuş and Bilgiç (2004) the coalition formation problem is a set of partitioning problems. The number of variables of possible coalitions grows exponentially with the number of partners: to avoid this complication, the authors will consider coalitions with a maximum of three suppliers. Moreover, in the considered case, the set of partners combination S does not represent a partition of N; indeed, indicating with $S_{N,2}$ and with $S_{N,3}$ the set of possible suppliers combination with two and three elements, respectively, it will be $S = S_{N,2} \cup S_{N,3}$. Let us indicate with (i, j) or with (i, j, k) the generic set s_l belonging to S; $s_l \in S$ can compete for the order acquisition if:

$$V_l = \sum_{z=i,j/z=i,j,k} V_z \leq V^* \tag{5.14}$$

Equation 5.14 expresses that for each combination of suppliers (two or three suppliers), the coalition l is created if the offered volume (V_l) is minor than the volume requested by the customer; each single supplier is also allowed to compete for the order as a particular case of coalition. In this case, the volume is the parameter that the generic supplier evaluates to decide whether or not it is available to join into a coalition.

5.3.2.2 Coalition Operation Strategy

The second activity is the operative strategy to elaborate the counter-proposal. The parameters to be taken into account are:

- the due date (dd_l): it is obtained by the maximum value of due date among those proposed by each single supplier participating in the coalition:

$$dd_l = \max_{z=i,j/z=i,j,k} \{dd_z\} \tag{5.15}$$

This implies that the customer will receive the ordered goods as they are manufactured by only one supplier, and not in several lots (one for each partner of the coalition). By this point of view, the customer does not perceive difference if the agreement is reached with one supplier or one coalition.

- the volume (V_l): it is obtained by using the Eq. 5.14;
- the price ($pr\_coa_l^*$). This parameter is computed as follows. First of all, a weighted price (pr_mp_l) is computed through the following expression:

$$\text{pr\_mp}_l = \frac{\sum_{z=i,j/z=i,j,k} p_z \cdot V_z}{\sum_{z=i,j/z=i,j,k} V_z}. \tag{5.16}$$

Then the Coalition Agent computes an index (d_l) measuring the distance between the proposed counter offer and the customer request:

$$d_z = \frac{V^* - V_z}{V^*} + \frac{p_z - p^*}{p^*} + \frac{dd_z - dd^*}{dd^* - t_o^a} \tag{5.17}$$

This value is used to evaluate an *indifference price* pr_ind_l : it represents the price that, given dd_l and V_l, will guarantee the customer with an offer as good as the best one among those generated by suppliers of the coalition, if separately considered. It is computed as the price satisfying the following equation:

$$d_l = \frac{V^* - V_l}{V^*} + \frac{\text{pr\_ind}_l - p*}{p^*} + \frac{dd_l - dd*}{dd * -t_o^a} = \min_{z=i,j/z=i,j,k}(d_z) \tag{5.18}$$

Finally, a coalition price pr_coa_l^* is computed as the price satisfying the following expression:

$$d_l \cdot f_s = \frac{V^* - V_l}{V^*} + \frac{pr\_coa_l^* - p^*}{p^*} + \frac{dd_l - dd^*}{dd * -t_o^a} = \min_{z=i,j/z=i,j,k}(d_z) \tag{5.19}$$

where $f_s < 1$.

In this research the value of f_s is fixed to 0.8.

pr_coa_l^* represents the price that, together given dd_l and V_l, will guarantee to the customer an offer at least equal to the ones individually generated by the suppliers of the coalition. In other words it represents the added value the coalition l provides to the customer.

At this point it is possible evaluate the price offered by the coalition, pr_coa_l. It is computed by the following Expression 5.20:

$$\text{pr\_coa}_l = \left\{\text{if pr\_mp}_l > \text{pr\_coa}_l^*;\ \max(\text{pr\_mp}_l; \text{pr\_ind}_l);\ \text{pr\_coa}_l^*\right\} \tag{5.20}$$

This value assures to all the participants at least the same profit they would have achieved by competing alone; moreover, if possible, it allows them to gain an extra profit (specifically when $\text{pr\_coa} = \text{pr\_ind}_l$). At the same time, when the best alternative is considered, the customer also gains a benefit from the coalition formation (specifically when $\text{pr\_coa} = \text{pr\_coa}_l^*$).

The Coalition Agent collects the coalition and the single supplier's proposals and evaluates the index d, as reported in Eq. 5.18, for each of them. Then it submits to the customer the proposal with minimum value of d : if the proposed price is $\text{pr\_coa} = \text{pr\_mp}$ and if an agreement is reached, each coalition supplier updates its database with the proposed price and no sharing mechanism is necessary.

5.3.2.3 Coalition Profit Sharing

The last activity, in case the coalition signs an agreement with the customer with a proposed price $\text{pr\_coa} > \text{pr\_mp}$, is the profit sharing among the participants. The surplus to share is evaluated by the expression (5.21):

$$\text{extra} - \text{profit}_l = (\text{pr\_coa}_l - \text{pr\_mp}_l) \cdot V_l \tag{5.21}$$

The mechanism is based on the Shapley's value of each player: the key to this value-based approach is the characteristic function. It will be used to calculate the Shapley's value, that is, a measure of the average contribution that a seller makes to the coalition. For each possible *i, j,* and *k* that contributes in making a generic coalition, the characteristic function is made as follows:

$v(i)$ = supplier i profit;
$v(i, j)$ = coalition extra profit;
$v(i, j, k)$ = coalition extra profit;

For each case, the extra profit is computed as in Eq. 5.22: the proposed mechanism shares this quantity proportional to the Shapely's value calculated as follows:

$$\Phi_i(v) = \frac{1}{n!} \sum_{k=1,2,3/k=1,2} (n-k)!(k-1)![v(K) - v(K \backslash i)] \tag{5.22}$$

where k is the magnitude order of coalition with seller i and n the sellers number.

In order to evaluate the profit sharing mechanism, a benchmark model is proposed. In this case the profit sharing mechanism is performed by the profit allocation based on the volume provided in the counter-proposal of the coalition. The benchmark is defined as a centralized coalition approach.

5.4 Discussion

The chapter formalizes the life cycle of a coalition in an e-marketplace context owned by a third, independent partners. Three approaches to support the coalition has been proposed. In particular two approaches are based on game theory, while the last one is performed with any intelligence support and it is utilized as benchmark.

The coalition strategies proposed have a flexible nature. They do not require either specific investment or partners' behavior modifications. In other words, the supplier can participate in a coalition with any disturbances on the entire *supplier system*.

This is important because it allows the creation of several virtual coalitions during all the possible interactions and, if someone of them has the necessary characteristics to become effective, it could survive for the considered transaction.

Moreover, the coalition strategies need to be integrated in a bargaining protocol. The proposed strategies can be integrated in different transaction protocols, with any adjustments that can be introduced. This allows to use the proposed approaches in a wide range of e-marketplace typology.

The two mechanisms based on game theory are different: while the Nash equilibrium approach focuses on the selection of the partners to form a coalition, the approach based on Shapley value focuses on the profit sharing (when the coalition signs an agreement with the supplier).

The last approach, with any profit sharing mechanism, is used as a benchmark to evaluate the added value of the game theory to support coalition of SMEs in e-marketplace.

The possibility to make coalitions brings added value both for customers and suppliers in an e-marketplace: roughly speaking, the first ones gain advantages from the possibility to improve their capacity to respond to customer orders; the customers get their advantages from the possibility to reduce unfeasible orders.

Moreover, such strategy could be adopted for other scopes (not just for order fulfillment) and in a vertical manner (among firms which produce different components of the same product required by the customer of the e-marketplace) (Argoneto et al. 2005).

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Chapter 6
Simulation Environment

6.1 Introduction

The development of simulations facilitates scientific study of complex systems. A simulation model is an abstraction of real-world environment that allows to investigate real-world systems and perform experiments that are not possible in the real systems (Law and Kelton 2000). The approaches proposed in this book are integrated in a multi-agent architecture, therefore the simulation environment developed is based on the interactions among the agents presented in the previous chapters.

In the last few years, several agent-based toolkits have been proposed with a wide variety of characteristics. Railsback et al. (2006) examined four main platforms: NetLogo, Mason, Repast and Swarm. Castle and Crooks (2006) examined eight simulation platforms: Swarm, Mason, Repast, StarLogo, NetLogo, Obeus, Agent-Sheets and AnyLogic. The above review has some limitations: the limited number of toolkits examined and their evaluation only in a specific scientific sector.

Nikolai and Madey (2009) presented a review of over 40 toolkits for agent-based simulation. In particular, they examined five characteristics in depth: programming language required, type of license governing the toolkit, type of operating system required, primary domain for which the toolkit has been designed and degree of support available to the user.

Najlis et al. (2001), Railsback et al. (2006) and Berryman (2008) identified these important general issues of an agent-based simulation environment:

- Open source: this issue allows the experimenter to read and update the instructions of the simulation environment. This is more relevant to extend the functionality of the simulation environment or adding new tools (for example, to perform a statistical analysis or write a report).

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- Flexibility: it is the possibility to define a custom agent in terms of behavior and knowledge.
- Speed of execution: the speed of the simulation is relevant when more replications are necessary for the statistical analysis.
- Documentation: the use of the simulation environment depends on the documentation provided. For example, the support and documentation developed by the user communities can be more important to extend the functionality of the simulation environment.
- Facilities: the facilities are provided by the simulation environment to draw graphs, perform statistical analysis (confidence interval, analysis of variance, etc.), analysis of the input data, etc.

The main programming languages used to develop agent-based simulation toolkits are C, C++ and Java. The authors have developed the simulation environment using the last cited language. The main benefits of this choice are the following:

- it is a language easy to learn (and it is easy for C and C++ developers to switch from one language to another);
- a java program can run on any computer with Java Virtual Machine (JVM) installed (from pocket computer to mainframe) and on any operating system;
- the language is open source with several package that can extend the functionality of the models developed;
- it is objected oriented: that allows to enormous potential for code re-use for very rapid application development; moreover, the object oriented is a functionality that allows to develop multi-agent systems;
- its easy integration with several other tools such as database, mathematical programs, eXtensible Markup Language (XML) integration and web integration communication over;
- the possibility to develop graphical user interface (GUI) interface for the development of real application.

The main limit of java program is the computation performance, but this limit can be moderate with the concurrent elaboration of the objects.

The java language is more suitable to develop simulation based on multi-agent architecture (Tobias and Hofmann 2004; Berryman 2008).

For the above reasons the multi-agent architecture has been developed using java language.

The chapter is structured as follows. The Sect. 6.2 discusses the agent-based simulation architecture proposed. In Sect. 6.3 the design of experiments is presented. Section 6.4 describes the performance measures developed to evaluate the proposed approaches. Finally, in Sect. 6.5 the use of the simulation tool developed as a decision-support system is discussed.

6.2 Agent-Based Simulation Architecture

The modeling formalism adopted here is a collection of independent objects interacting via messages. This formalism is quite suitable for Multi-Agent Systems development. In particular, each object represents an agent and the system evolves through a message sending engine managed by a discrete event scheduler. An object can be defined as (Fídeíro and Maíbaum 1991): "*[…] an entity that has an identity independent of its state that encapsulates a collection of attributes (its private memory) which it is able to manipulate according to a well defined set of actions, and that is able to interact with other objects*."

The object oriented approach is more suitable for developing agent-based simulation, but some differences are relevant between object and agent. These differences are important for the development of the simulation environment, the main distinctions are the following (Odell 2002):

- objects need a centralized organization, while the agents have a dynamic autonomy. For this reason, in the simulation model there are two objects to manage the interactions: *model* and *scheduler*. Moreover, the absence of an object in the architecture will cause exception error, while multi-agent systems can operate without an agent;
- objects' behaviors are static and never changed over the time; therefore to simulate the unpredictable behaviors of the agents, all the possible behavior will be estimated and implemented in the objects;
- objects need to be activated to start running, while agents have an autonomous behavior without external activation;
- the objects react to other objects message, while agents react to their environment events or requests from other agents;
- the interactions among objects are synchronous, while agents' interactions can be asynchronous;
- the action of objects can affect only the objects that communicate with them, while the agents' action can be affected by the whole system;
- objects are concern of their states, method, control and method invocations. Agents have their goals, knowledge, planning strategy and negotiation with other agents.

The architecture developed takes into account the above differences between object and agent. During the implementation several IT problem had to be solved. All of the implementation issues related to the software development phase are not of interest for the purpose of the book and therefore they will be neglected in the following.

The objects developed for the simulation have been: the Customer Negotiation Agent, the Supplier Negotiation Agent, the Supplier Planning Agent, the scheduler, the model, the input data and the statistical object.

The CNA object represents the Customer Negotiation Agent; it has all the information, algorithms and function for their implementation. The SNA object

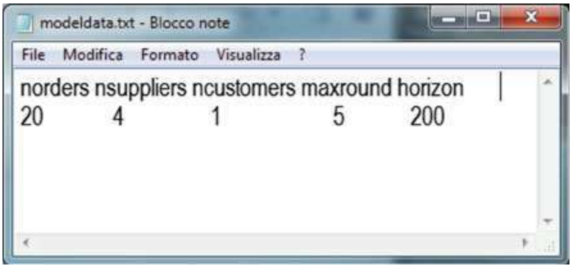


Fig. 6.1 Model data to set the simulation experiment

represents the Supplier Negotiation Agent, it has all the information, algorithms and function for their implementation.

The SPA object is in charge to manage the interface with the LINGO model in order to provide the production planning alternatives to the SNA object. A proper interface has been developed to link the SPA object to the production planning model implemented with the LINGO© package.

The Scheduler Agent is in charge of the system evolving by managing the discrete events of the simulation engine. Differently, Model Agent is in charge of the agents' interaction with the coordination of the messages exchanged among the involved objects. The input data agent generates the data of the simulation for the generic experiment to investigate, while the statistical agent collects the simulative data in order to write the report of the simulation.

The simulation needs the setting of some parameters, by the use of the following information:

- number of the orders input by the customers;
- number of suppliers of the e-marketplace;
- number of customers that input their orders in the e-marketplace;
- maximum number rounds for the negotiation protocol;
- horizon time of the simulation.

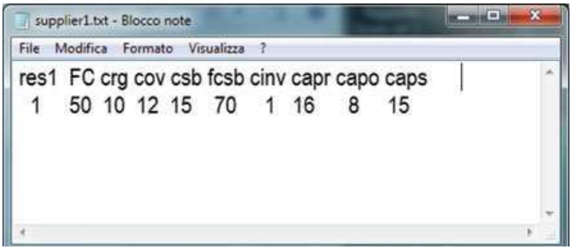
Each supplier is provided by a local database with the following information:

- production planning information for the products each supplier is able to manufacture;
- capacity of the plants for ordinary, overtime and sub-furniture;

The above information are defined outside the architecture, this allows to characterize the simulation experiment by changing the input without changing the entire architecture. In particular, it is defined as a set of files that the experimenter can customize to set the simulation experiments.

Figure 6.1 shows an example; the experimenter can define the number of orders (*norders*), the number of suppliers (*nsuppliers*), the number of customers (*ncustomers*), the maximum number of rounds for the bargaining process (*maxround*) and the horizon time of the simulation. As the reader can notice, the simulation can be easily adapted to different conditions.

Fig. 6.2 Model data to set the suppliers' knowledge



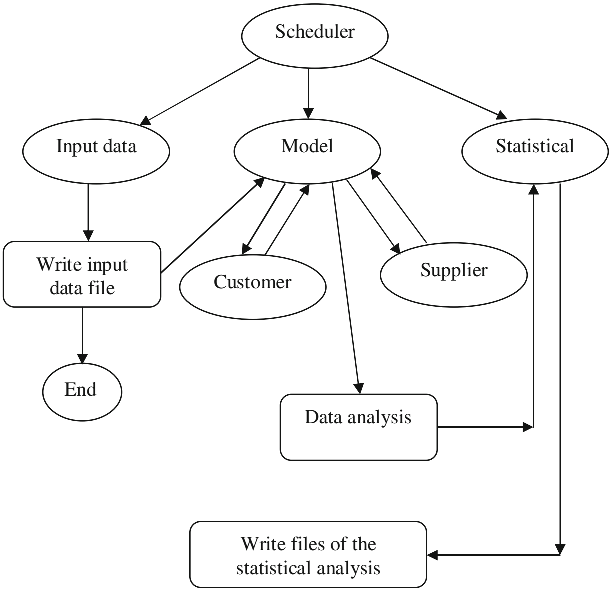


Fig. 6.3 Simulation architecture

Figure 6.2 shows an example of the knowledge of each supplier that can be set by the experimenter. The data that can be set are the following. The number of hours necessary to manufacture the product (*res1*). It can add more resources into the simulation. The information of the supplier that was explained in the Chap. 4 and concerning the production planning information.

The generic experiment simulation is performed by the following activities (see Fig. 6.3):

1. scheduler agent activates: the input data agent, the model agent and the statistical agent;
2. the input agent generates the orders' data of the customers (as described in the following paragraphs) and it is deactivated;

3. the scheduler agent sets the time of the start; then, the model agent activates the customers and the suppliers, setting the initial data.
4. the model agent manages the customers and suppliers interactions at the end of each bargaining. The data of each bargaining are stored for the data analysis.
5. the model agent transmits the information to the statistical agent;
6. the scheduler agent checks when the simulation has completed the bargaining of all orders; at this point it sends the message to the statistical agent for writing the final report of the experiments.

The supplier object has been linked with a LINGO solver by a proper interface developed in Java. The interface synchronizes the activities and the communication between supplier object and production planning model in LINGO.

The developed architecture, used to simulate the proposed approaches, with simple adjustment can be adapted to a real distributed architecture to implement a real application in B2B e-marketplaces. In fact, the java language can be easily integrated to develop a website to support a real e-marketplace and provide the value added services proposed in this book.

6.3 The Design of Experiments

The simulation environment developed is used to test the approaches proposed in the above chapters. The objective is to evaluate their benefits in different environment conditions. The first test case consists of one customer and four suppliers. The number of suppliers characterizes the competitive situation; in this case, the low number is a simplification useful to investigate the case in which the competition is limited.

Twenty orders are input in the supplier system during a time horizon of 200 periods (days).

The customer's order is defined by the following data:

- order is the ordinal number referred to the orders; it is the unique identification of the order in the e-marketplace.
- ta_i is the time in which the customer inputs the order in the e-marketplace;
- dd_i is due date requested by the customer;
- V_i is the volume requested by the customer;
- p_i is the price requested by the customer;
- C_num_i is a customer identification;
- Type_i is the product type identification.

The parameters, to set the generic experimental class for the orders generation, are the following:

- Tot_ord: it is the number of total orders input by the customers over the time horizon considered;
- Time_hor: it is the horizon time of the simulation;

- av_costs: it the average cost for unit of product. The average cost is computed by the costs of the suppliers that compose the e-marketplace.

The algorithm used to generate the orders is described in the following steps.

- The average time between the arrival of two consecutive orders. This is computed by the ratio between the total number of periods (horizon time of simulation) and the number of orders introduced by the customers. The obtained parameter is used to distribute the orders over the horizon time.

$$\text{av\_periods} = \frac{\text{Time\_hor}}{\text{Tot\_ord}} \tag{6.1}$$

This strategy allows to distribute the orders over all the horizon time of the simulation.

- The time of arrival for all orders scheduled for the simulation is generated. The ta_i is obtained by the following expression (it is used a uniform distribution):

$$ta_i = \text{UNIF}[1 + \text{av\_periods}(i-1);\ \text{av\_periods}(i)] \quad i = 1, \ldots., \text{Tot\_ord} \tag{6.2}$$

After that, the ta_i are re-arranged in a list in increasing order.

- The due date for each order is determined. The dd_i is obtained by the following expression:

$$dd_i = \text{UNIF}[ta_i;\ ta_{i+1} - 1 + \text{overlap}] \quad i = 1, \ldots, (\text{Tot\_ord} - 1) \tag{6.3}$$

The dd_i of the last order ($i = \text{Tot\_ord}$) cannot exceed the horizon time of the simulation, therefore the due date is obtained by the following expression:

$$dd_i = \text{UNIF}[ta_i;\ \text{Time\_hor}] \quad i = \text{Tot\_ord} \tag{6.4}$$

The parameter *overlap* is used to define the overlapping among the orders in terms of periods.

- The volume for each order is determined. The volume is obtained by the following expression:

$$V_i = (dd_i - ta_i + 1) \cdot \text{UNIF}[V\_\text{low};\ V\_\text{high}] \quad i = 1, \ldots, \text{Tot\_ord} \tag{6.5}$$

where V_low and V_high are the minimum and maximum volume for each period, respectively.

The volume of the generic order depends on the horizon time of the order $(dd_i - ta_i + 1)$ and the fluctuation of the market:

$$\text{UNIF}[V\_\text{low}; V\_\text{high}]$$

- The price for each order is defined. The price is obtained by the following expression:

$$p_i = V_i \cdot \text{av\_costs} \cdot \text{UNIF}[mk\_\text{low}; mk\_\text{high}] \quad i = 1, \ldots, \text{Tot\_ord} \tag{6.6}$$

where, *mk*_low and *mk*_high are the minimum and maximum of mark-up, respectively, and av_costs is the average cost for unit of product. The range of the uniform distribution [*mk*_low; *mk*_high] characterizes the market fluctuation in terms of price.

At the end of this process, the list of orders in terms of arrival time, due date, volume and price is generated . The characterization of the particular experimental class is obtained by setting the following parameters:

- Overlap: this parameter sets the maximum number of periods of overlapping between two consecutive orders. Therefore, it allows to investigate the effect of overlap among orders of different customers.
- *V*_low and *V*_high: these parameters have two effects. The first is on the congestion level of the suppliers' available capacity. Therefore, the average of *V*_low and *V*_high leads to the volume congestion of the customers on the suppliers. The value (*V*_high–*V*_low) concerns the demand volatility of the customers. The increase of this difference means that the volatility of the demand is higher.
- *mk*_low and mk_high: these parameters have two meanings. The first effect is on the mark-up level that the suppliers can gain. Therefore the average of *mk*_low and mk_high leads to the price pressure of the customers on the suppliers. The value (mk_high–mk_low) concerns the price fluctuation of the customers. The increase of this difference means that the fluctuation of the price is higher.
- number of suppliers: this number characterizes the competition pressure on the suppliers. The increase of the suppliers who participate to the e-marketplace increases the number of competitors with the reduction of probability to reach an agreement with the customer by the generic supplier.

The above parameters are used to design all the experiments in the following reported.

The evaluation of the effect of price fluctuation, demand volatility, overlap among orders and the number of suppliers allows to investigate the robustness of the proposed approaches and the risks related to uncertainty for customers and suppliers. In particular, the overlap parameter is selected in order to obtain three conditions. Overlap "0" means that the orders are generated with no periods of overlapping among them. Overlap "5" means that the orders are generated with a maximum of 5 periods of overlapping, while "10" leads to generate the orders with a maximum of 10 periods of overlapping. The overlap effect is important because it characterizes the workload on the suppliers changing the information provided by the production planning algorithm.

The effect of volume fluctuation is investigated considering the following conditions:

- A low level of fluctuation of the volume is considered. In this case, the parameters of volume are the following (market case 1):
  - V_low = 40;
  - V_high = 70.
- A high level of fluctuation of the volume is considered. In this case, the parameters of volume are the following (market case 2):
  - V_low = 40;
  - V_high = 110.
- The third case considered concerns a low fluctuation of volume with a certain probability of some peak of request (orders with a high level of volume). This means that the parameters of volume are the same as the *low level* fluctuation (market case 1), but with a probability of 20% to be generated with high value of volume. In this case, the volume of peak is extracted by the following parameters:
  - V_low = 140;
  - V_high = 140.
- The fourth case considered concerns a high fluctuation of volume with a certain probability of some peak of request (orders with a high level of volume). This means that the parameters of volume are the same as the *high level* fluctuation (market case 2), but with a probability of 20% to be generated with high value of volume. In this case, the volume of peak is extracted by the following parameters:
  - V_low = 140;
  - V_high = 140.

The effect of price fluctuation is investigated considering the following conditions:

- A low level of fluctuation of the price is considered. In this case, the parameters of price are the following (market case 1):
  - mk_low = 0.8;
  - mk_high = 1.2.
- A high level of fluctuation of the price is also simulated. In this case, the parameters of price are the following (market case 2):
  - mk_low = 1.2;
  - mk_high = 1.6.

Thus, combining the level of the above parameters, 12 simulation classes of experiments have been obtained for each number of suppliers (four and eight) and approaches considered: negotiation, NASH, Centralized and Centralized with Shapley (see Table 6.1).

Table 6.1 Experimental classes

Exp. No.	Overlap	Volume	Price
1	0	Low	Low
2	5	Low	Low
3	10	Low	Low
4	0	High	High
5	5	High	High
6	10	High	High
7	0	Low with peak	Low
8	5	Low with peak	Low
9	10	Low with peak	Low
10	0	High with peak	High
11	5	High with peak	High
12	10	High with peak	High

Table 6.2 Suppliers data

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
CAPR (h)	16	16	8	8
CAPO (h)	8	8	16	16
CAPS (products)	15	15	15	15
Total capacity (h)	24	24	24	24
FC (cost)	50	30	50	30
FCS (cost)	70	30	70	70
CRG (unit cost/h)	10	10	10	10
COV (unit cost/h)	12	12	12	12
CSB (unit cost/h)	15	30	15	30
CINV (unit cost/product)	1	1	1	1

The total number of experimental classes is 12 (Table 6.1) × 4 (approaches proposed) × 2 (two dimensions of the network) = **96 simulation experiments**.

The suppliers are characterized by the following data:

- CAPR: it is the capacity in ordinary time;
- CAPO: it is the capacity in overtime;
- CAPS: it is the capacity in outsourcing;
- FC: it is the fixed cost of the process plan;
- FCS: it is the fixed cost of sub-furniture;
- CRG: it is time unit cost in regular time;
- COV: it is time unit cost in overtime;
- CSB: it is time unit cost in outsourcing;
- CINV: it is the cost to keep in inventory for unit time and product;

Table 6.2 reports the suppliers' data for the four suppliers who participate in the network (small network dimension), while Table 6.3 reports the suppliers' data for the others who participate in case of big network dimension. These two network

Table 6.3 Suppliers data

	Supplier 5	Supplier 6	Supplier 7	Supplier 8
CAPR (h)	8	8	8	8
CAPO (h)	8	8	16	16
CAPS (products)	15	15	15	15
Total capacity (h)	24	24	24	24
FC (cost)	45	35	45	35
FCS (cost)	70	70	70	70
CRG (unit cost/h)	8	8	10	10
COV (unit cost/h)	10	10	12	12
CSB (unit cost/h)	15	15	15	30
CINV (unit cost/product)	1	1	1	1

dimension allows to investigate the performance of the proposed approach in different competitive environment among suppliers.

The suppliers are characterized by the same costs of inventory and the same capacity of sub-furniture. This choice is made to reduce effects of these parameters on the simulation results.

The costs and the capacity are constant for each period t and resource j. Moreover, one process plan for each product type is hypothesized, then the parameter L is set as $L = 1$ (see Production planning algorithm paragraph in Chap. 4). These values simplify the production planning algorithm by reducing the computational time and allow to conduct a complete statistical analysis.

In order to investigate only the characteristic of the suppliers, it has been assumed 1 h to make one product for all suppliers production planning.

Considering that the market conditions are statistically distributed, the authors have decided to conduct a statistical analysis because of its high degree of fitting with reality.

6.4 The Simulation Output Analysis

The output analysis data of a simulation experiment is a crucial activity to obtain a real advantage from a simulation process.

In terms of analyzing the output data, there are two types of simulations:

- *terminating simulation*: in this case, the simulation has a specific event that ends the simulation process. For example, the number of products processed by a manufacturing system or the period length of the process simulated.
- *non-terminating simulation*: the simulation does not have an end condition. The performance measures are evaluated with a simulation length large enough to get good estimation.

The case of the simulations used in this book is the terminating simulation because the simulation experiments are conducted for a length of 200 periods and a fixed number of orders submitted by the customer. Therefore, for each performance measure there are n output data collected for the statistical analysis (Baker 1998). The performance measure is obtained by the estimation of the mean over n independent replications (the n output data). The experiments are conducted by running n independent replications of the system simulated. Each run starts in the same state, but they are different the values extracted from the statistical distribution used in the system.

The statistical package developed in java to define the number of replications is activated when the number of replication is greater than 10.

The activities of the package developed are the following:

- For each performance measure observed the values of the replications run are collected. Let X_j be the value of the generic performance for the replication j and J is the actual number of replication. The average value of the performance is computed:

$$\bar{X} = \frac{1}{J}\sum_{j=1}^{J} X_j \tag{6.7}$$

  Then, the half-width (hw) is computed:

$$\mathrm{hw} = t_{J-1,1-\alpha/2}\sqrt{\frac{S^2(J)}{J}} \tag{6.8}$$

  where $S^2(J)$ is the sample variance of the J output data X_j.
- The second activity is the computation of the half confidence degree (hcd) in percentage:

$$\mathrm{hdc} = \frac{t_{J-1,1-\alpha/2}\sqrt{\frac{S^2(J)}{J}}}{\frac{1}{J}\sum_{j=1}^{J} X_j} \tag{6.9}$$

- Finally, if the hdc is lower than 5% then the experiment ends and the performance is statistically significant; otherwise, the experiment goes on with another replication. This mechanism is applied for each performance measure.

Each experiment class has been replicated in order to achieve a confidence degree equal to the 95% (α) and 10% confidence intervals for each performance index considered.

The statistical package evaluates the expression 6.9 for each performance measure and it ends automatically the simulation experiment and writes the report files.

An important consideration regards the time necessary to obtain the statistical results according to the above parameters. The average time to obtain statistical results for each experimental class in the network of four suppliers is about 10 h of simulation. In the case of network with eight suppliers, the average time of simulation is about 22 h. The PC used is a multi-core (four processors) Intel® Core i7 2.93 GHz with 6 GB of RAM. The total hours of simulation are: 48 (experiments with four suppliers) $\times$ 10 (hours) + 48 (experiments with eight suppliers) $\times$ 22 (hours) = 1,536 h of simulation.

6.5 The Performance Measures

The evaluation of the proposed approaches in different conditions is conducted by the definition of the performance measures described in this paragraph. The performance measures can be divided in two main categories: customers and suppliers' performances.

From the point of view of the customers the following performance measures have been defined:

- average price (Av. Price): it is the average of the ratio between the price requested over all orders that the customer input in the e-marketplace and the price obtained by the customer for the orders that reach an agreement. The value of this performance is between zero and one. One is better performance value. It is a measure of the customer satisfaction for the price issue.
- average volume utility (Av. Volume): it is the degree of satisfaction of the volume requested by the customer. In particular, it is the ratio between the volume obtained and the volume requested by the customer over all the orders input by the customer in the e-marketplace. The value of this performance is between zero and one. One is better performance value. It is a measure of the customer satisfaction for the volume issue.
- average due date utility (Av. due date): it is the average of the days in delay over all the orders that the customer input in the e-marketplace reached an agreement. It is a measure of the customer satisfaction for the due date issue.
- average customer utility (Av. customer utility): it is the average of the equation 4.6 (in Chap. 4) over all the orders that the customer inputted in the e-marketplace reached an agreement. The value of this performance is between zero and three. The value three means that the customer satisfies all the issues requested. It is the performance measure from the point of view of the customer that implements its evaluation strategy.

From the point of view of the suppliers the following performance measures have been defined:

- average total suppliers utility (total profit): It is the sum of the profit for all the suppliers over all orders that reach an agreement.
- suppliers unbalanced index (unbalance profit index): it is the index of unbalanced profit among the suppliers computed by the following expression:

$$\text{unbalanced} = \sum_{i=1}^{N} \left| \frac{1}{N} - \frac{\text{utility supplier}_i}{\text{total profit}} \right| \tag{6.10}$$

N is the number of suppliers

utility supplier$_i$ is the profit gained by the *i*th supplier

If the profit is fairly distributed among the suppliers, the Expression (6.10) is equal to 0, otherwise the same expression assumes a value greater than 0. This performance is an important index that describes how the profit is shared among the suppliers. In fact, if the profit is unbalanced it means that some suppliers gain lower profit than the other suppliers from the e-marketplace. Therefore, this performance measure highlights the ability of the e-marketplace to distribute the profit among the participants.

From the point of view of general management of the e-marketplace the following performance measures have been defined:

- Rounds of negotiation (No. rounds.): the performance measure is the average time to reach the agreement. It is computed, both for customer and supplier, in terms of average number of rounds to reach the agreements over all the orders. It is a performance measure that highlights the rapidity to reach an agreement.
- Orders agreement (orders agr.): it is computed as the ratio between the number of orders that reach an agreement and the number of orders submitted by the customer. The value of this performance is between zero and one. The value one means that all the orders reach an agreement.
- Number of coalition (No. coalitions): it is the number of coalitions that reach an agreement with the customer. It is a performance measure of the efficacy of the coalition approach used.

Finally, the utilization performance of the suppliers is evaluated:

- Utilization in ordinary time (ord. utiliz.): it is the number of hours used in ordinary time by the suppliers of the e-marketplace.
- Overtime in overtime utilization (over. utiliz.): it is the number of hours used in over time by the suppliers of the e-marketplace.
- Sub-furniture utilization (Sub. Uiliz.): it is the number of products in sub-furniture requested by the suppliers of the e-marketplace.

Moreover, the performance measures can be combined in order to obtain a single value of performance for the proposed approaches. Therefore, the performance values can be normalized. The normalization can be computed by the following expressions:

$$\frac{\text{value}_i - \min_i(\text{value})}{\max_i(\text{value}) - \min_i(\text{value})} \tag{6.11}$$

and

$$\frac{\max_i(\text{value}) - \text{value}_i}{\max_i(\text{value}) - \min_i(\text{value})} \tag{6.12}$$

The first one (Eq. 6.11) is utilized when the high value of the performance leads to better performance, while in the opposite case the formula (6.12) is utilized. Therefore, for each performance class, the value 1 identifies the best performance measure, while the value 0 identifies the worst performance value. Given that, each performance measure has the same importance, so the average of the performances ([0, 1] interval) assigns the goodness of each analyzed approach, for a simple readability of the simulation results.

6.6 The Simulations as a Decision-Support System

A decision-support system (DSS) can be defined as a computer system that assists decision-makers in choosing between alternative beliefs or actions by applying knowledge about the decision domain to arrive at recommendations for the various options (Fox and Das 2000; Shim et al. 2002).

There are various kinds of decision-support systems; the kind of interest for the objective of this book is the Simulation—based DSS (Berna et al. 2006; Tekin and Sabuncuoglu 2004).

Moreover, the research presented is based on agent-based simulation. Parunak et al. (1998) discussed and pointed out the relative strengths and weaknesses of Agent-based simulation and centralized simulation tools based on mathematical equations. They concluded that *"…agent-based modeling is most appropriate for domains characterized by a high degree of localization and distribution and dominated by discrete decision. Equation based modeling is most naturally applied to systems that can be modeled centrally, and in which the dynamics are dominated by physical laws rather than information processing.*"

The benefits of simulation tools such as DSS can be summarized as follows:

- *costs*: often, it is much cheaper to build a model than to experiment in a real system. However, it is important to evaluate the costs of simulation tools in terms of acquisition (fixed cost) and model development (variable cost). The research presented in this book is based on open—source tool, therefore the fixed cost is eliminated;
- *time*: the model is faster than the real time of an experiment conducted in a real system. The time of the model depends on the complexity of the model and the hardware resources used. However, it is important to take into account the time involved to develop the model;
- *number of experiments*: the number of experiments that can be conducted in a real system are limited. Moreover, the experiments can influence the real system;
- if the real system does not exist the simulation model is the only option possible.

The use of the simulation to support the decision-making process is a promising methodology in recent years. The simulation tools can help the managers understand the performance of the system analyzed and the impact of different scenarios that can occur. In this way, risk involved in investment and modifications can be identified before implementing decisions (Laguna and Marklund 2005).

The simulation environment developed here allows to build a knowledge base related to the real conditions of interest. These information can be used for twofold objectives. The first can be the design phase of an e-marketplace owned by a third independent part. In this phase, the system manger of the e-marketplace can evaluate the value added tools that provide to the actors (customers and suppliers) involved. Moreover, it can be evaluated new value added services before the implementation in the e-marketplace.

The second objective regards the actors involved: customers and suppliers. The generic actor can use this simulation tool to investigate the real benefits obtained by the e-marketplace and, therefore take the decision to participate. The simulation tool can be, also, used to generate a knowledge base in order to forecast the actions of the opponent. A proper learning algorithm will be developed in order to select the most appropriate strategy for the proposal of formulation. The methodologies that can support this approach are: Q-learning method and fuzzy logic.

An example of the approach proposed is presented in other fields of research. Sueyoshi and Tadiparthi (2007) proposed the use of the simulation based on multi-agent to estimate the fluctuations of electricity prices. The simulation environment proposed integrates in the multi-agent architecture other methods such as neural networks, genetic algorithms and learning capabilities. Sueyoshi and Tadiparthi (2008) described an application of simulation software for analyzing and understanding a dynamic price change in the US wholesale power market.

Briefly, the research suggests how, through simulation, to evaluate the real value of planning, bargaining and coalition tools in e-business environment and who, among customers and suppliers, get the main advantages from them, and, therefore, should pay for them.

The simulation tool proposed allows to investigate the robustness of the e-marketplace and which parameters have the major effect on the performance of the actors involved.

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Chapter 7
Simulation Results

7.1 Introduction

The simulations have been conducted using the data of the experimental classes described in Chap. 6. The simulations highlight the value added by the services proposed in the e-marketplace such as:

- Negotiation models, specifically how the negotiation approaches allow to reach the better agreement among customers and suppliers. The interaction between the negotiation mechanism and the coalition approaches.
- Production planning algorithm: how the link between production planning activity and commercial function improves the conflict resolution;
- Coalition approaches: in which ways the possibility to make a coalition among sellers provides real benefits to the e-marketplace participants.

Moreover, the simulation results evaluate all the coalitional approaches proposed:

- Nash equilibrium; it is characterized by a limited information sharing among the plants. At the same time, each plant has to compute several production planning alternatives. Moreover, this approach allows to create a coalition of only two partners.
- Centralized approach; it is characterized by a complete information sharing among the partners, including the computed production planning alternatives. The coalition can be created with two or three partners.
- Centralized approach with Shapley value; this case is similar to the previous one, but the profit among the plants is subdivided by using the Shapley value.

The simulation results are obtained in different market conditions, and it has been considered the effect of fluctuations of price and volume in order to evaluate the proposed approaches in different market conditions. The complete numerical results are reported in appendix.

P. Argoneto and P. Renna, *Innovative Tools for Business Coalitions in B2B Applications*, DOI: 10.1007/978-0-85729-707-5_7,

The chapter is structured as follows. Section 7.2 discusses the effect of the overlap among the orders input by the customers. In Sect. 7.3, the value added by the coalition approaches proposed is evaluated.

7.2 Overlap Effect

The first effect analyzed concerns the overlap among the orders input by the customer. The overlap among the orders leads to increase the production planning complexity for the plants, due to the number of contemporary orders, increases proportionally.

Table 7.1 shows the simulation results for the negotiation approach. The table reports the average and the standard deviation (over all the experimental classes) of the percentage difference between five vs. zero and ten vs. five periods of the overlap factor. It has been observed that the difference between four and eight suppliers is very low.

In fact, the possibility to input overlapped orders allows the customer to have a higher horizon time for his requests and, therefore, accumulate orders with a global higher value of volume. It is easy to observe that the price and volume satisfaction indexes have low fluctuations due to the overlap factor: in fact, the suppliers react to the production planning complexity increasing the delay of the orders reaching an agreement. At the same time, the global profit of suppliers increases proportionally to the overlap because of the high value of the requested volume. Moreover, the distribution of the profit, among the actors involved in the e-marketplace, is fairer when the overlap degree is higher. This is because, the consumption of the available resources strongly increases because of their overtime utilization.

The standard deviation highlights in which way the different market conditions influence the estimated results.

The performance indexes with the higher percentage difference (highlighted in the table) have higher standard deviation values, except for the unbalance profit index. In general, the effect between five and zero periods of overlap is the more relevant, while the effect between ten and five periods reduces. The only exception is the total profit that has a higher increment between ten and five periods. The percentage differences are very similar for the two considered network dimensions: four and eight suppliers.

From the analysis of the values, it can be summarized that the suppliers are more affected by the overlap than the customer (see average customer utility and total profit).

The Tables 7.2 and 7.3 show the simulation results for the NASH approach.

Table 7.2 reports the results for the case of a small network (only four suppliers). In this case, there is relevant fluctuation of the customer issues for all the three considered indexes. In particular, the due date has the greater reduction (increment of delay). Also, the number of coalitions that reach an agreement has

Table 7.1 Simulation results—negotiation

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	0.65	0.00	−20.38	0.00
Average volume	−0.24	−1.94	0.32	−1.53
Average due date	41.83	23.37	33.29	23.73
Average customer utility	1.59	0.30	3.75	1.23
Total profit	44.07	24.38	66.38	42.42
Unbalance profit index	−11.80	−5.18	59.17	−1.66
No. rounds	−3.18	−2.29	−5.68	−2.37
Order. agr.	0.71	−0.53	2.79	−1.07
Ord. utiliz.	33.10	20.15	21.58	23.46
Over utiliz.	71.26	37.74	85.82	39.33
Sub utiliz.	47.71	26.92	45.74	36.45

Table 7.2 Simulation results—NASH approach with a network of 4 suppliers

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	3.88	2.87	−21.26	−18.10
Average volume	−7.32	7.52	1.45	−27.95
Average due date	103.95	48.23	−31.12	−22.75
Average customer utility	0.77	−0.98	−38.52	20.42
Total profit	26.67	42.23	−29.59	144.25
Unbalance profit index	−20.00	10.90	−41.11	−49.40
No. rounds	−0.32	1.17	−59.81	−31.49
Orders agr.	5.14	−0.26	−83.40	−45.57
Ord. utiliz.	16.74	10.00	−68.51	75.08
Over utiliz.	37.03	14.35	−20.76	37.47
Sub utiliz.	35.53	31.78	−34.18	−46.42
No. coalitions	4.32	−18.50	−2.71	−22.42

high fluctuations among the variation of the overlap values. In sum we can say that the overlap parameter has a relevant influence, in case we consider the network with four plants and NASH approach, than the negotiation approach with four suppliers. This is confirmed by the higher values of standard deviation. Moreover, the number of coalitions highlight that the approach operates better when the periods of overlap is five; in case of ten periods, the number of coalitions that reach an agreement drastically reduces.

Table 7.3 reports the results for the case of the network with eight suppliers. The increased number of suppliers allows to make more coalitions among suppliers: that is why the network better reacts to the overlap effect. It can be noticed that the reduction of the due date satisfaction is very low and the global profit is greater than the same parameters in case of the network with only four plants. This

Table 7.3 Simulation results—NASH approach with a network of 8 suppliers

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	−1.30	−2.97	3.21	8.55
Average volume	−1.35	−3.41	6.47	11.64
Average due date	13.33	−2.75	19.51	32.62
Average customer utility	0.97	−0.38	−26.74	−12.26
Total profit	43.14	25.22	43.65	26.00
Unbalance profit index	0.63	−7.76	−12.67	−27.07
No. rounds	−4.72	−1.33	−11.67	11.06
Orders agr.	0.25	−0.25	−13.40	15.47
Ord. utiliz.	33.43	25.55	−10.16	288.22
Over utiliz.	50.08	26.86	−34.92	34.59
Sub utiliz.	71.35	50.72	28.17	−21.62
No. coalitions	−1.72	−1.21	−0.04	4.30

Table 7.4 Simulation results—centralized model with a network of 4 suppliers

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	3.17	12.72	1.91	49.66
Average volume	−3.98	−0.96	−16.05	−6.48
Average due date	100.29	31.24	−14.41	1.41
Average customer utility	−4.22	0.94	−14.93	−28.54
Total profit	45.16	27.69	40.42	37.91
Unbalance profit index	−11.38	0.55	−67.73	−29.80
No. rounds	−2.09	−1.34	−16.61	−15.53
Orders agr.	−2.01	0.58	−9.82	−18.82
Ord. utiliz.	61.50	36.54	−7.09	49.33
Over utiliz.	36.28	27.49	26.67	84.37
Sub utiliz.	54.18	34.92	35.78	52.81
No. coalitions	−4.53	1.45	−6.92	−3.33

is confirmed by the low fluctuation of the number of coalition compared to the case with four suppliers. In summary, the higher number of suppliers allows to react better to the overlap effect.

The Tables 7.4 and 7.5 show the simulation results for the centralized approach.

The following highlights can be drawn comparing the Centralized model and the approach based on the NASH equilibrium:

- The centralized approach, applied in the network of four plants, better reacts to the overlap effect if compared to the NASH approach;
- The standard deviations underline that the centralized approach is more robust to the market fluctuations;

Table 7.5 Simulation results—centralized model with a network of 8 suppliers

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–57%	5–10%
Average price	3.08	−1.71	0.70	0.48
Average volume	−0.60	2.10	−19.29	−29.68
Average due date	99.67	36.89	−16.58	−9.20
Average customer utility	−0.98	1.21	−22.26	18.99
Total profit	52.00	35.52	56.07	36.15
Unbalance profit index	−10.24	−5.48	90.78	−40.08
No. rounds	1.19	0.94	7.05	−7.45
Orders agr.	1.42	1.40	−17.55	−18.60
Ord. utiliz.	62.47	44.40	101.45	40.37
Over utiliz.	47.87	32.37	19.29	40.76
Sub utiliz.	56.58	40.15	72.32	50.15
No. coalitions	−0.27	2.28	−0.17	−3.29

Table 7.6 Simulation results—centralized (with Shapley approach) with a network of 4 suppliers

Performance indexes	Average (%)		Standard deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	1.33	−3.93	3.57	3.25
Average volume	−3.09	−6.05	−17.04	−2.81
Average due date	96.76	40.18	−18.18	11.26
Average customer utility	−2.84	−3.24	39.98	−4.44
Total profit	42.43	27.57	38.61	25.37
Unbalance profit index	−10.65	−1.90	−73.24	24.03
No. rounds	−2.73	−4.20	−6.63	−47.50
Orders agr.	−1.44	−4.39	1.92	9.86
Ord. utiliz.	59.09	36.47	−9.41	24.02
Over utiliz.	34.97	26.02	13.06	33.91
Sub utiliz.	52.43	35.20	29.25	38.56
No. coalitions	−4.72	−2.15	−6.70	−8.81

- The higher number of suppliers involved in the network does not imply any variations between the two approaches: the considerations concerning this second case are the same as the small network already described.

In summary, the centralized approach is suitable in the case of lower number of suppliers, while if the number of suppliers is higher the benefits are limited.

The Tables 7.6 and 7.7 show the simulation results for the centralized approach with the use of Shapley value to share the generated profit among the actors.

As the reader can notice, the Shapley value approach leads to values very similar to results of the centralized approach: this means that the overlap factor does not influence the profit sharing mechanism.

Table 7.7 Simulation results—centralized (with Shapley approach) with a network of 8 suppliers

Performance indexes	Average (%)		Standard Deviation (%)	
	0–5%	5–10%	0–5%	5–10%
Average price	0.87	−2.58	−3.17	1.32
Average volume	1.82	0.89	1.24	−17.34
Average due date	99.67	34.72	−21.65	7.66
Average customer utility	−0.44	1.32	0.00	−33.33
Total profit	51.11	35.23	54.31	36.13
Unbalance profit index	−22.32	−6.70	−64.78	−36.74
No. rounds	1.20	1.73	13.44	−4.22
Orders agr.	1.42	1.12	−4.48	−21.93
Ord. utiliz.	62.71	43.33	87.24	49.45
Over utiliz.	46.91	31.90	11.70	40.36
Sub utiliz.	56.80	39.32	60.35	52.82
No. coalitions	1.83	5.85	−1.95	0.92%

7.3 Coalition Value Added Services

In this paragraph, the simulation results are analyzed in order to highlight the value added services of the coalition models proposed in this book. To do this, the overlap degrees among the orders are equally probable: this means that the reported results are the average values over all the investigated overlap degrees.

Table 7.8 reports the simulation results for the case characterized by low fluctuations of price and volume (market case 1, see Sect. 6.3).

From the analysis of the results the following issues can be drawn:

- *Average price*: the approach with the Nash equilibrium and the centralized one allow to improve the performance related to the price. This is a consequence of the fact that the price reached at the agreement is really close to the price originally required by the customer. Differently, the Shapley approach leads to worst values of this performance;
- *Average volume*: the approach with the Nash equilibrium provides the same volume of the negotiation approach. Otherwise, the centralized approaches strongly improve this performance;
- *Average due date*: the approach with the Nash equilibrium leads to increase the average periods of delay, if compared to the negotiation model. Also in this case, the centralized approaches improve this performance;
- *Average customer utility*: the approach with the Nash equilibrium slightly reduces the customer utility of the agreements, while the centralized approaches improve this value;
- *Total profit*: the total profit reached by all the suppliers has a low variation over the model investigated. It can be easily noticed that the coalition approaches, in these conditions, does not improve significantly the suppliers' profit.

Table 7.8 Simulation results Market Case 1—network with 4 suppliers

Market case 1

Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	0.94	0.97	0.97	0.89
Av. volume	0.87	0.87	0.89	0.89
Av. due date	2.05	2.69	1.99	2.07
Av. customer utility	2.35	2.30	2.39	2.39
Total profit	27456.09	26438.01	27136.04	26518.27
Unbalance profit index	1.14	1.09	1.05	1.06
No. rounds	58.98	62.76	56.79	56.90
Orders agr.	0.97	0.97	0.95	0.95
Ord. utiliz.	2451.47	2841.79	1940.85	1907.40
Over utiliz.	1854.54	1558.53	2482.71	2460.66
Sub utiliz.	2582.55	2180.71	2638.63	2598.85
No. coalitions	–	0.55	0.77	0.72

- *Unbalance profit index*: the coalition approaches reduce the dis-homogeneity of profit gained by the suppliers: the profit distribution is fair. The better result for this performance is obtained by the centralized approach.
- *Number of rounds*: the time necessary to reach agreements increases using the NASH approach, while it decreases in case the centralized model is utilized.
- *Orders agreement*: the NASH approach leads to the same number of orders ending with an agreement obtained by using the negotiation model. In this case, the centralized approaches are characterized by a marginal reduction of this performance.
- *Utilization*: the utilization of ordinary, overtime and sub-furniture as an impact rather dissimilar among the tested approaches: the NASH model maximizes the utilization of the ordinary time, minimizing overtime and sub-furniture utilization. The centralized approaches have the opposite behavior.
- *Number of coalitions*: the number of coalitions that reach an agreement with the customer is very low. It can be noticed, this number is always minor than one. Therefore, the contribution of the coalition is limited.

Briefly, the benefits of the coalition approaches are limited, more effective in a stable environment and with limited number of suppliers. The main benefit of the coalition approaches is the reduction of the unbalanced distribution of the profit among the suppliers. As the reader can notice, the low fluctuation of volume and price values, together with a low number of plants, leads to reduce the global market compared to the case in which the negotiation approach is utilized.

Table 7.9 reports the simulation results when the fluctuation of price and volume is high (market case 2, see Sect. 6.3): in these conditions, the coalition approaches provide a real value added to the network.

The NASH approach improve the volume with a reduction of the due date performance, but with a global improvement of the customer satisfaction.

Table 7.9 Simulation results—Market case 2—network with 4 suppliers

Market case 2				
Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	1.00	1.00	0.47	0.43
Av. volume	0.37	0.53	0.87	0.83
Av. due date	1.76	2.53	1.39	1.38
Av. customer utility	2.27	2.34	2.53	2.46
Total profit	38902.79	45838.89	78406.61	77964.98
Unbalance profit index	1.23	0.64	0.92	0.91
No. rounds	38.29	59.56	64.94	63.11
Orders agr.	0.58	0.98	0.89	0.86
Ord. utiliz.	1496.90	2774.64	2430.19	2440.15
Over utiliz.	1162.67	2229.78	2981.01	3037.64
Sub utiliz.	1501.84	1562.62	3442.70	3469.97
No. coalitions	–	11.47	9.02	8.94

The centralized approaches lead to the better volume satisfaction and a reduction of the price and due date satisfaction. In particular, the price satisfaction is drastically reduced.

The main differences compared to the case with low fluctuations are the following.

- *Average price*: Nash approach leads to the best performance because the price required by the customer is completely satisfied. Concerning this performance, the centralized approaches drastically reduce the customer satisfaction.
- *Average volume*: the information sharing and the possibility to make coalitions of three partners allow the centralized approaches to keep a high level of volume satisfaction.
- *Average due date*: this performance has no significant difference if compared to the case with low fluctuations.
- *Average customer utility*: the high fluctuation leads to reduce the customer utility for the negotiation case, while for the coalition approaches the customer utility increases.
- *Total profit*: in case of high fluctuations of the input parameters, the coalition approaches improve significantly the reached suppliers' global profit. In particular, the centralized approach reaches the best values of each performance.
- *Unbalance profit index*: the NASH approach leads to a better distribution of the profit among the suppliers than the centralized approaches. This is a significant result, in fact, the centralized approaches have also the possibility to create coalitions of three partners, differently from Nash that is not centralized and can have alliance of maximum two suppliers.
- *Number of rounds*: the time to reach an agreement is strongly reduced for the negotiation approach because of the major difficulties to reach an accord among the involved actors. Conversely, the centralized approaches need a major number of rounds to reach the agreements.

- *Orders agreement*: the NASH approach has a high number of orders ended with an agreement, but with low transaction volume. On the other hand, the centralized approaches reach less agreements but the global exchanged volume is higher than the decentralized approach utilized in here.
- *Utilization*: concerning this performance there are no great differences with the case in which we have a low fluctuation of the input parameters: the utilization of ordinary, overtime and sub-furniture is the same.
- *Number of coalitions*: the number of coalitions that reach an agreement with the customer is significantly increased. The NASH approach leads to a number of orders assigned to coalitions about 50% of their total amount.

Summarizing, the benefits of the coalition approaches are significant when the market fluctuations are very high. The NASH approach distributes the profit among the suppliers in a more uniform way. At the same time, it particularly satisfies the price attribute (requested by the customer) by reducing the other two attributes: due date and volume. Otherwise, the centralized approach satisfies the volume and due date, improving the total profit reached by the suppliers too. What is coming out by this analysis is that the NASH approach allows to obtain a good compromise between customers' and suppliers' satisfaction; while the centralized approach seems to improve the suppliers' fulfillment but with a drastic reduction of the customer's approval.

The Figs. 7.1, 7.2 and 7.3 show the simulation results in case of low market fluctuations (market case 1) but with some peak of demand for the network composed by four suppliers. In particular, the percentage differences with the case without peak demand are reported.

Figure 7.1 shows the performance from the customers' point of view. The NASH approach improves the customer satisfaction in terms of price and it has the lower value of volume reduction; while the due date satisfaction is drastically reduced (the average delay increases). The customer utility computed by the customer during the bargaining process has a small reduction. The centralized approaches react very well to the peak demand in terms of due date and customer utility, while the price and volume indexes have a significant decrease. However, the centralized approaches lead to the better average customer utility.

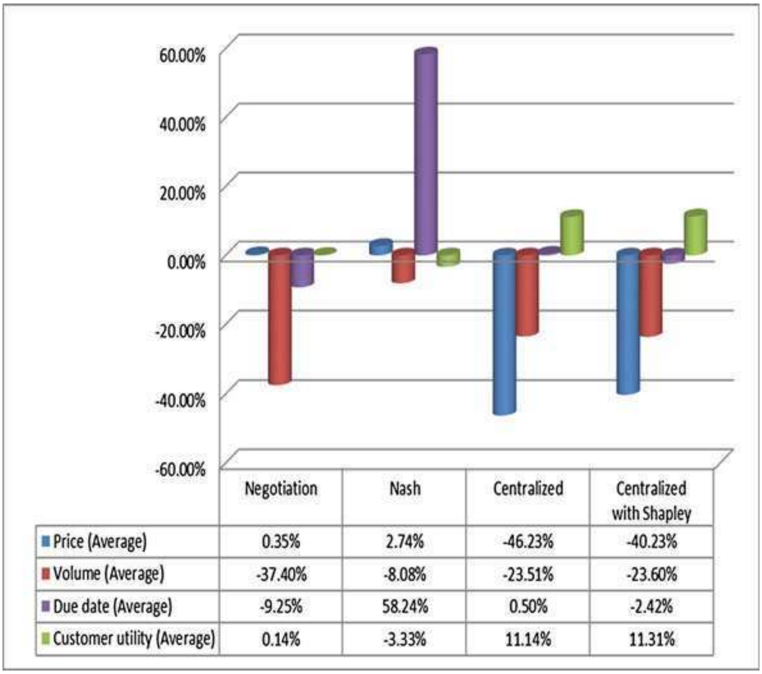
Figure 7.2 reports the performance measures from the suppliers' point of view.

The negotiation approach is the methodology that has an important reduction of the total profit reached by the suppliers. Therefore, the negotiation approach is not able to react to unforeseen peak of customer demand.

Among the coalition approaches, the NASH approach is the better because the reduction of total profit is very low. Moreover, it can be noticed that the NASH approach has a greater reduction of the sub-furniture of products than the other coalition approaches.

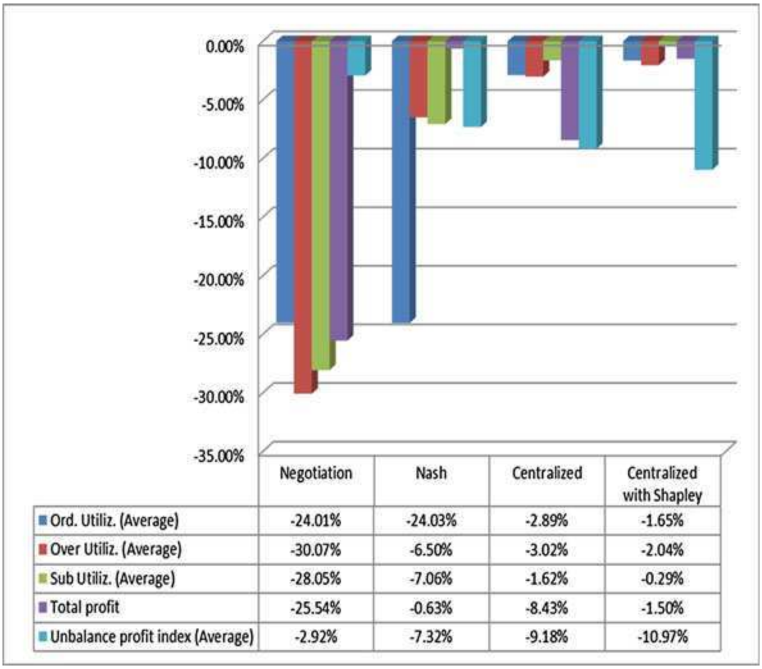
Figure 7.3 reports the performance measures from the e-marketplace' point of view.

The NASH approach is characterized by a very low reduction of the orders with agreement, while the other approaches have significant reduction for this



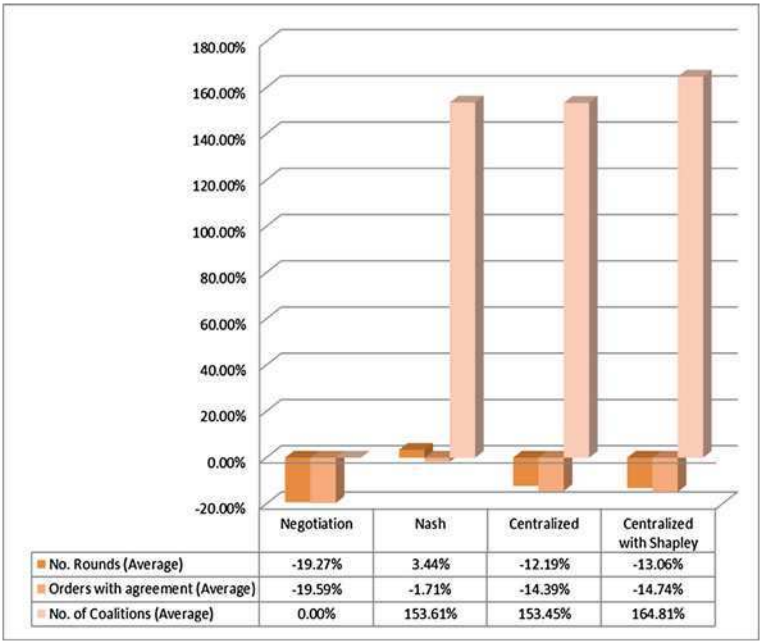
	Negotiation	Nash	Centralized	Centralized with Shapley
Price (Average)	0.35%	2.74%	-46.23%	-40.23%
Volume (Average)	-37.40%	-8.08%	-23.51%	-23.60%
Due date (Average)	-9.25%	58.24%	0.50%	-2.42%
Customer utility (Average)	0.14%	-3.33%	11.14%	11.31%

Fig. 7.1 Customer utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
Ord. Utiliz. (Average)	-24.01%	-24.03%	-2.89%	-1.65%
Over Utiliz. (Average)	-30.07%	-6.50%	-3.02%	-2.04%
Sub Utiliz. (Average)	-28.05%	-7.06%	-1.62%	-0.29%
Total profit	-25.54%	-0.63%	-8.43%	-1.50%
Unbalance profit index (Average)	-2.92%	-7.32%	-9.18%	-10.97%

Fig. 7.2 Suppliers' utility results



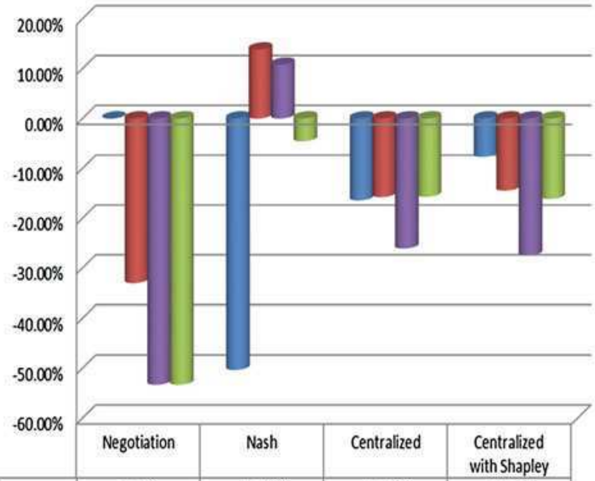
	Negotiation	Nash	Centralized	Centralized with Shapley
No. Rounds (Average)	-19.27%	3.44%	-12.19%	-13.06%
Orders with agreement (Average)	-19.59%	-1.71%	-14.39%	-14.74%
No. of Coalitions (Average)	0.00%	153.61%	153.45%	164.81%

Fig. 7.3 E-marketplace results

performance measure. The number of round (the time to reach an agreement) is characterized by low fluctuation for the NASH approach. Figure 7.2 shows the better total profit of the suppliers reached with the NASH approach; this result is obtained by an increment of the coalitions that reaches an agreement. However, it can be notice that the increment of the number of coalitions for the centralized approaches is characterized by a high increment. This underlines that the NASH approach makes coalition more efficacy than the centralized approaches from the suppliers' point of view.

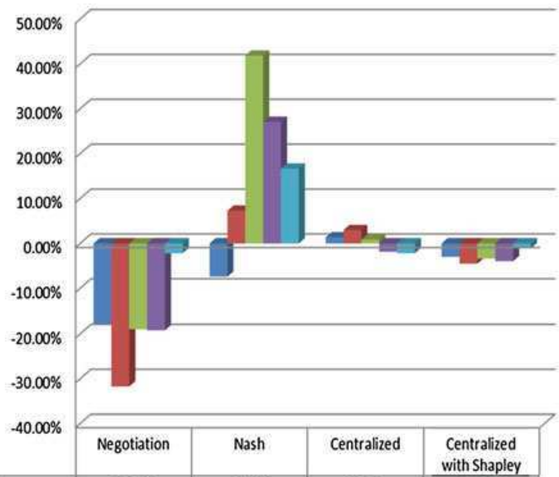
The Figs. 7.4, 7.5 and 7.6 show the simulation results in case of high market fluctuations (market case 2) but with some peak of demand for the network composed by four suppliers. In particular, the percentage differences with the case without peak demand are reported.

Figure 7.4 shows the performance from the customers' point of view. In this scenario, the NASH approach leads to the better customer performance result. On the contrary, the centralized approaches lead to reduce the average customer utility more relevant than the NASH approach. In particular, The NASH approach reduces the price and delay satisfaction, but increases the volume provided to the customer. The centralized approaches improve the due date satisfaction (the average delay reduces), but this is obtained providing lower volume to the customer. The negotiation approach has a drastic reduction of the customer performance; the peak of demand affects negatively the negotiation approach.



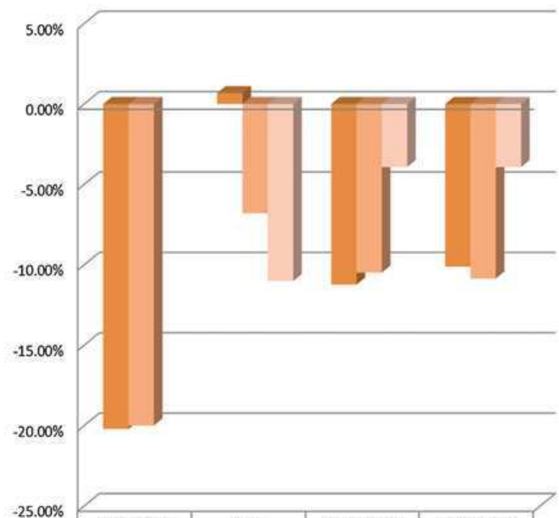
	Negotiation	Nash	Centralized	Centralized with Shapley
Price (Average)	0.00%	-50.33%	-16.43%	-7.69%
Volume (Average)	-33.04%	13.84%	-15.77%	-14.46%
Due date (Average)	-53.31%	10.79%	-26.08%	-27.47%
Customer utility (Average)	-53.30%	-4.56%	-15.70%	-16.15%

Fig. 7.4 Customer utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
Ord. Utiliz. (Average)	-17.68%	-7.41%	1.35%	-3.00%
Over Utiliz. (Average)	-31.72%	7.27%	2.96%	-4.51%
Sub Utiliz. (Average)	-18.98%	41.82%	0.85%	-3.38%
Total profit	-19.21%	27.06%	-1.84%	-3.95%
Unbalance profit index (Average)	-2.17%	16.67%	-2.18%	-1.10%

Fig. 7.5 Suppliers' utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
No. Rounds (Average)	-20.21%	0.68%	-11.23%	-10.12%
Orders with agreement (Average)	-20.00%	-6.80%	-10.49%	-10.85%
No. of Coalitions (Average)		-11.01%	-3.92%	-3.91%

Fig. 7.6 E-marketplace results

Figure 7.5 reports the performance measures from the suppliers' point of view. Also in this scenario, the negotiation approach is the methodology that has an important reduction of the total profit reached by the suppliers. Therefore, the negotiation approach is not able to react to unforeseen peak of customer demand.

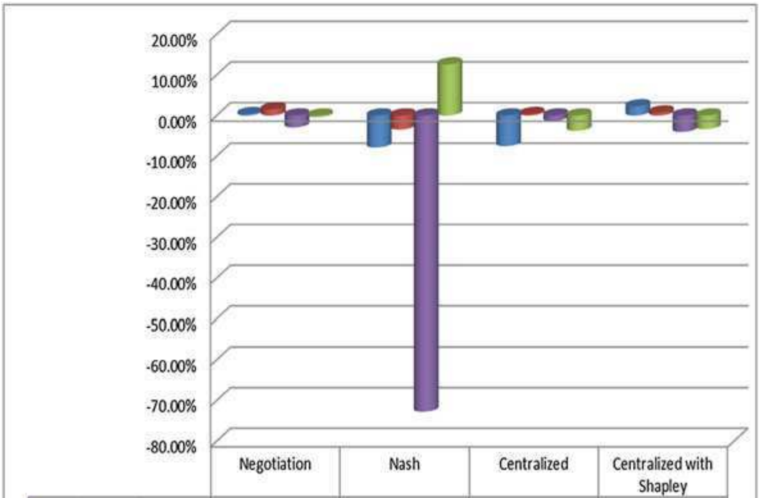
Among the coalition approaches, the NASH approach is the better because it is the only approach with an increment of total profit. This result is obtained with a relevant increment of sub-furniture utilization.

Figure 7.6 reports the performance measures from the e-marketplace' point of view.

The NASH approach is characterized by the lower reduction of orders with agreement than the other approaches; moreover, this performance measure is very close among all the coalition approaches. The number of round (the time to reach an agreement) is characterized by low fluctuation for the NASH approach.

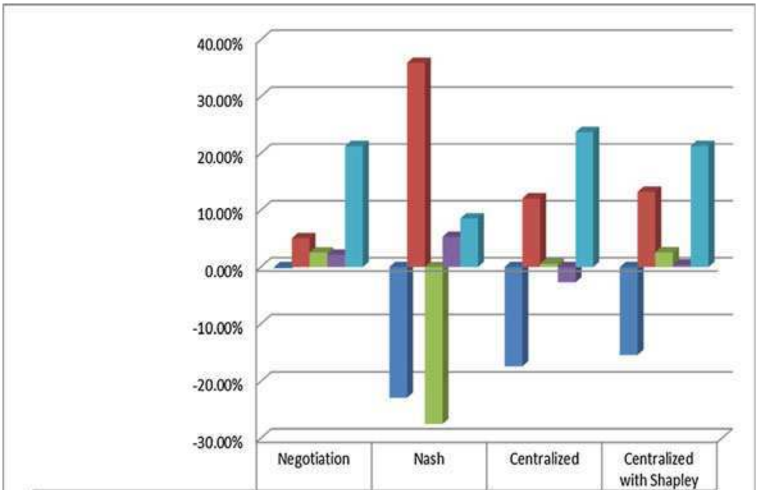
Compared to the precedent scenario, the number of coalitions that reaches an agreement reduces for all coalition approaches. The reduction is more significant for the NASH approach. This performance with the increment of total profit (see Fig. 7.5) means that the NASH approach uses the coalition in a better way compared to the centralized approaches.

The Figs. 7.7, 7.8 and 7.9 show the simulation results in case of low market fluctuations (market case 1). In particular, the percentage differences between eight and four suppliers (four suppliers as used as base).



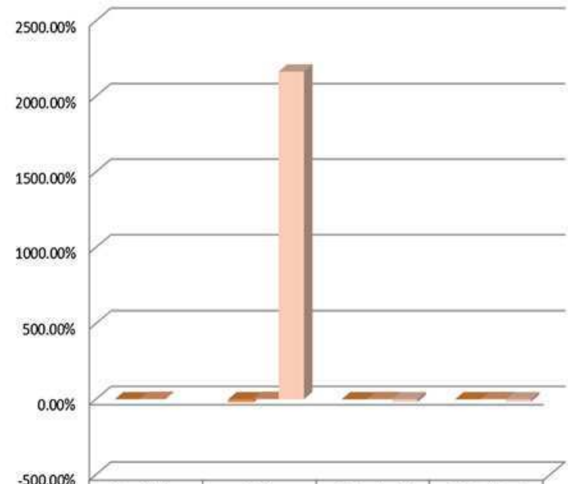
	Negotiation	Nash	Centralized	Centralized with Shapley
Price (Average)	0.35%	-7.88%	-7.53%	2.26%
Volume (Average)	1.53%	-3.46%	0.37%	0.75%
Due date (Average)	-2.92%	-72.74%	-1.34%	-4.03%
Customer utility (Average)	-0.43%	12.59%	-3.76%	-3.35%

Fig. 7.7 Customer utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
Ord. Utiliz. (Average)	-0.23%	-22.87%	-17.36%	-15.34%
Over Utiliz. (Average)	5.07%	35.91%	12.07%	13.23%
Sub Utiliz. (Average)	2.55%	-27.50%	0.56%	2.57%
Total profit	2.18%	5.32%	-2.69%	0.42%
Unbalance profit index (Average)	21.28%	8.54%	23.73%	21.32%

Fig. 7.8 Suppliers' utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
No. Rounds (Average)	-0.06%	-20.04%	-1.09%	-1.47%
Orders with agreement (Average)	1.72%	2.05%	0.35%	0.70%
No. of Coalitions (Average)		2165.06%	-18.53%	-17.13%

Fig. 7.9 E-marketplace results

Figure 7.7 shows the performance from the customers' point of view. In this scenario, the relevant result is the improvement of the customer satisfaction obtained by the NASH approach. On the contrary, the centralized approaches lead to reduce the average customer utility. Then, negotiation approach has low variance of the performance measures because in this case the new suppliers (from four to eight) do not affect the customer utility.

Figure 7.8 reports the performance measures from the suppliers' point of view.

The network composed by eight suppliers leads to increase the total profit for all approaches (also the negation approach). The only exception is the centralized approach that has a low reduction. The result of the negotiation is obtained because the competitive scenario with more suppliers is an advantage for the customer. The NASH approach has the better result in terms of profit with a relevant reduction of utilization in sub-furniture. Moreover, the NASH approach distributes the profit among the suppliers more uniformly than the other approaches.

Figure 7.9 reports the performance measures from the e-marketplace' point of view.

As the reader can notice, the results show that the NASH approach leads to better performances when the number of plants increases. Specifically, it leads to better customers' and suppliers' satisfaction. Moreover, the number of coalitions reaching an agreement is very high. The result is very important: the NASH approach makes coalition competitive in the bargaining process without information sharing.

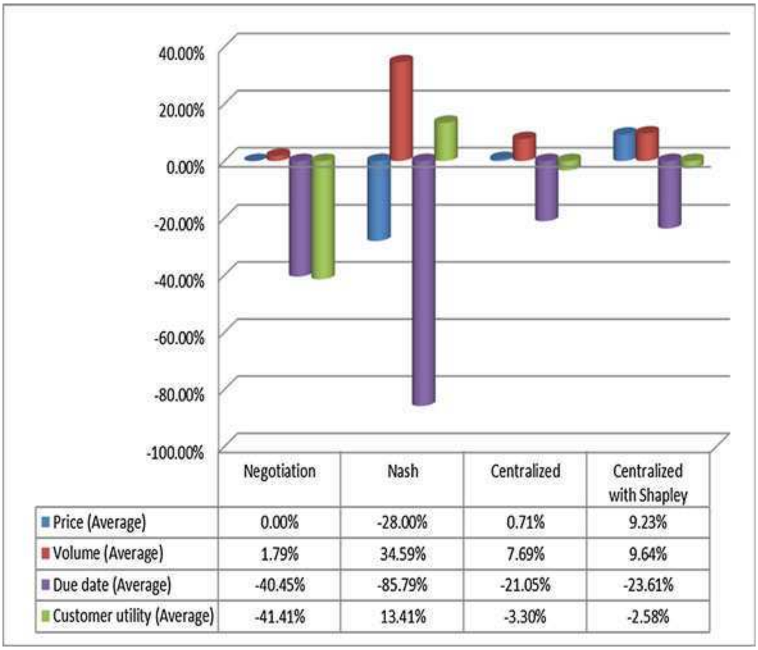


Fig. 7.10 Customer utility results

The network composed by eight plants allows the NASH approach to find more possibilities to make efficacy and efficient coalitions than in the previous case. Differently, the centralized approaches have a small difference compared to the results obtained in case the network is composed by only four plants; this means, the proposed methodologies for the centralized approaches do not take any substantial advantage from the increasing number of plants participating to the market. Demonstration of this is that in case with eight plants the number of coalitions reaching an agreement with the customers is decreased.

The Figs. 7.10, 7.11 and 7.12 show the simulation results in case of high market fluctuations (market case 2). In particular, the percentage differences between eight and four suppliers (four suppliers as used as base).

Figure 7.10 shows the performance from the customers' point of view. In this scenario, the relevant result is the improvement of the customer satisfaction obtained by the NASH approach. On the contrary, the centralized approaches lead to reduce the average customer utility. In this scenario, the negotiation approach has a relevant reduction of the customer utility. This is due to the reduction of orders that reach an agreement as shown in the Fig. 7.12.

Figure 7.11 reports the performance measures from the suppliers' point of view.

Also in this case, the NASH approach is the methodology that allows to gain more benefits from the increasing number of plants. The benefits are both for customers and suppliers. Specifically, the NASH approach has two main issues:

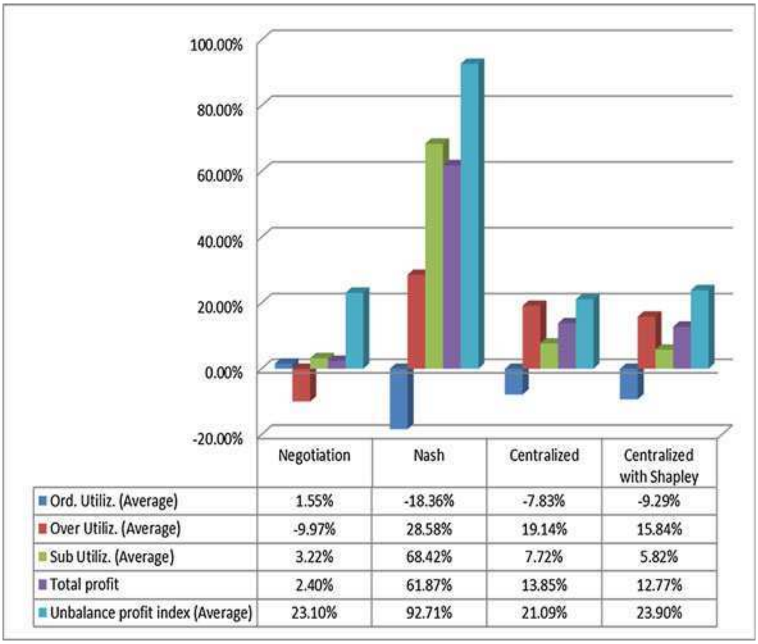


Fig. 7.11 Suppliers' utility results

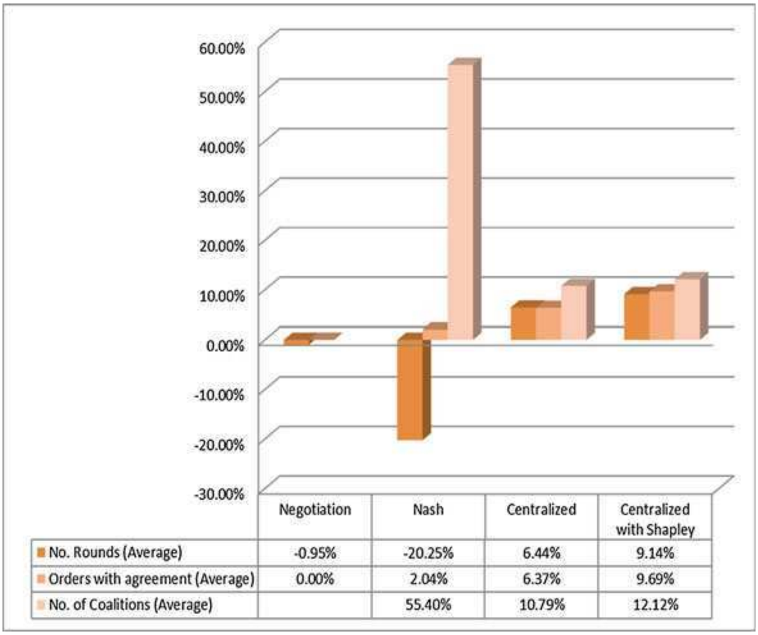
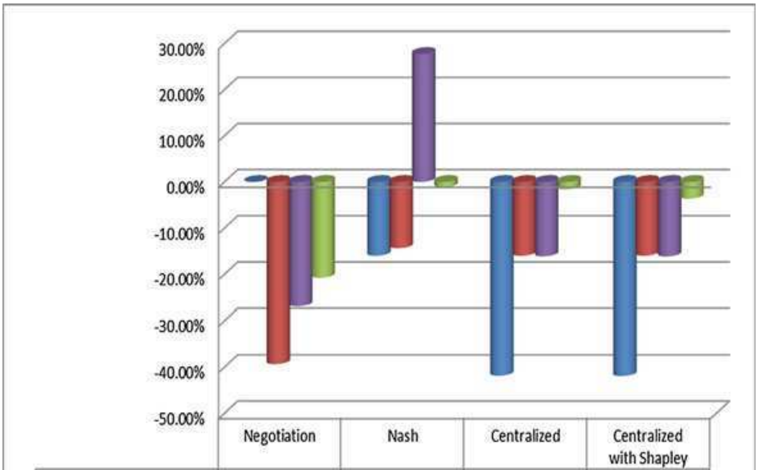


Fig. 7.12 E-marketplace results



	Negotiation	Nash	Centralized	Centralized with Shapley
Price (Average)	0.00%	-15.99%	-41.85%	-41.91%
Volume (Average)	-39.33%	-14.34%	-15.99%	-15.99%
Due date (Average)	-26.90%	27.73%	-16.10%	-16.13%
Customer utility (Average)	-20.76%	-1.16%	-1.59%	-3.61%

Fig. 7.13 Customer utility results

- It is the approach that leads to the better compromise between customers' and suppliers' satisfaction;
- The coalitions realized using the NASH approach are more incisive in the bargaining process: generally, they sign a high number of agreement than the centralized approaches.

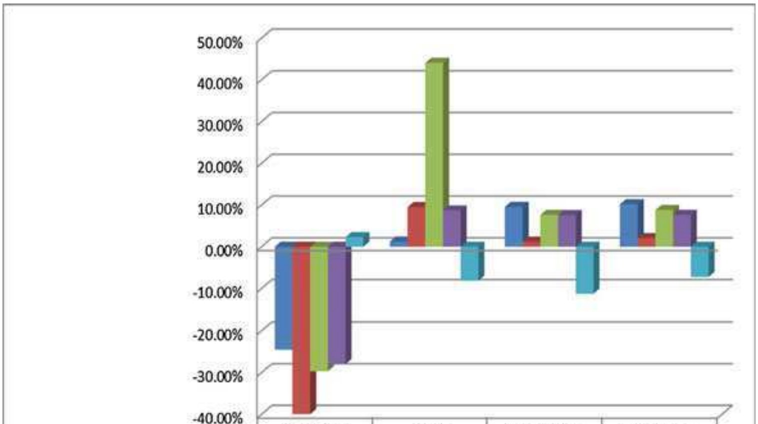
The centralized approaches lead to obtain benefits for the suppliers reducing the satisfaction of the customers. The difference between the centralized approaches highlight that the profit sharing mechanism has lower influence on the evaluated performances.

Figure 7.12 reports the performance measures from the e-marketplace' point of view that supports the above comments.

The Figs. 7.13, 7.14 and 7.15 show the simulation results in case of low market fluctuations (market case 1) but with some peak of demand for the network composed by eight suppliers. In particular, the percentage differences with the case without peak demand are reported.

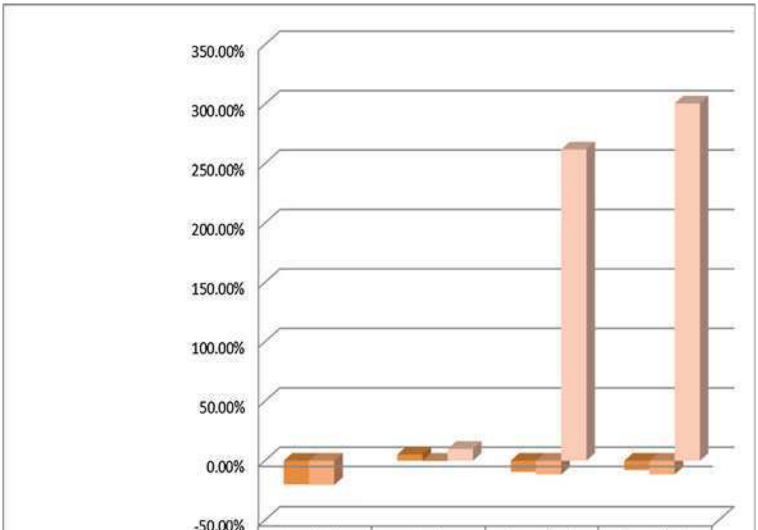
Figure 7.13 shows the performance from the customers' point of view. In this scenario, all the coalition approaches lead to average customer utility in a similar way. The difference is the satisfaction of the single issue; in particular, the NASH approach has a lower reduction of the price, but the a higher average delay. The centralized approaches have the opposite behavior.

Figure 7.14 reports the performance measures from the suppliers' point of view.



	Negotiation	Nash	Centralized	Centralized with Shapley
Ord. Utiliz. (Average)	-24.51%	1.22%	9.58%	10.21%
Over Utiliz. (Average)	-39.96%	9.50%	1.21%	2.06%
Sub Utiliz. (Average)	-29.64%	44.08%	7.65%	8.81%
Total profit	-27.94%	8.70%	7.58%	7.64%
Unbalance profit index (Average)	2.30%	-8.15%	-11.25%	-7.24%

Fig. 7.14 Suppliers' utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
No. Rounds (Average)	-20.04%	5.27%	-9.29%	-7.97%
Orders with agreement (Average)	-20.41%	-0.34%	-11.54%	-11.50%
No. of Coalitions (Average)		10.03%	261.90%	300.56%

Fig. 7.15 E-marketplace results

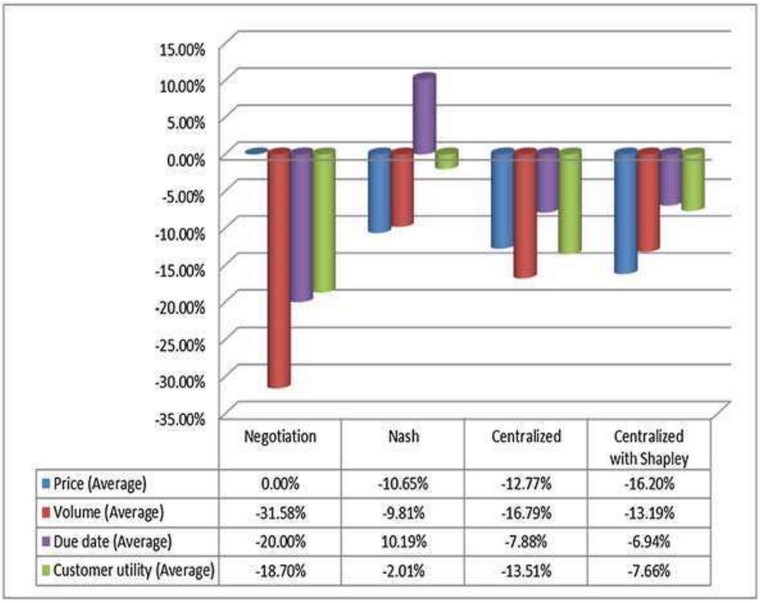


Fig. 7.16 Customer utility results

From the suppliers' point of view, all the approaches improve the performance measures with the eight plants of the network (the only exception is the negotiation approach). Nash approach and centralized approaches are closer in terms of total profit gained by the suppliers. The peak of demand has a very negative effect on the negotiation approach.

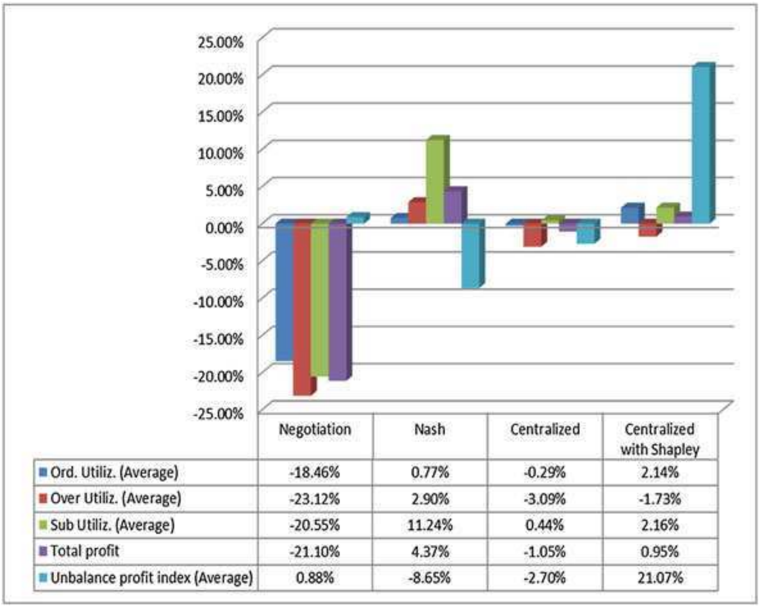
Figure 7.15 reports the performance measures from the e-marketplace' point of view.

The NASH approach operates in an efficient way. The performance of the NASH approach are obtained by a low reduction of the coalitions that reach an agreement. This is due to the higher number of coalitions in the market scenario without peak of demand for the NASH approach.

The Figs. 7.16, 7.17 and 7.18 show the simulation results in case of high market fluctuations (market case 2) but with some peak of demand for the network composed by eight suppliers. In particular, the percentage differences with the case without peak demand are reported.

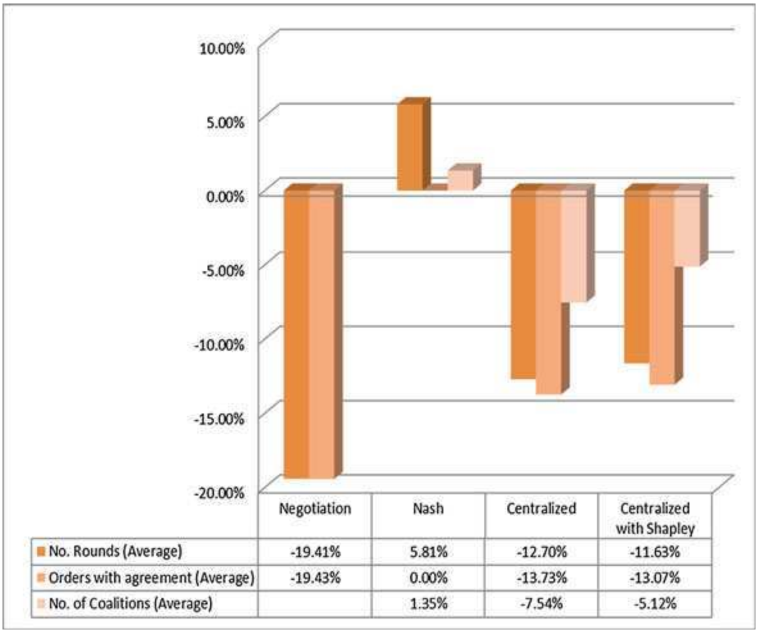
Figure 7.16 shows the performance from the customers' point of view. In this scenario, the NASH approach leads to the lower reduction of the average customer utility. From the customer's point of view the centralized approaches do not gain the same benefits of NASH approach from the eight suppliers when peak demand occurs.

Figure 7.17 reports the performance measures from the suppliers' point of view.



	Negotiation	Nash	Centralized	Centralized with Shapley
Ord. Utiliz. (Average)	-18.46%	0.77%	-0.29%	2.14%
Over Utiliz. (Average)	-23.12%	2.90%	-3.09%	-1.73%
Sub Utiliz. (Average)	-20.55%	11.24%	0.44%	2.16%
Total profit	-21.10%	4.37%	-1.05%	0.95%
Unbalance profit index (Average)	0.88%	-8.65%	-2.70%	21.07%

Fig. 7.17 Suppliers' utility results



	Negotiation	Nash	Centralized	Centralized with Shapley
No. Rounds (Average)	-19.41%	5.81%	-12.70%	-11.63%
Orders with agreement (Average)	-19.43%	0.00%	-13.73%	-13.07%
No. of Coalitions (Average)		1.35%	-7.54%	-5.12%

Fig. 7.18 E-marketplace results

Table 7.10 Simulation results—global average performances in case of a network of four suppliers

Global average performances in case of a network with four suppliers

Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	0.97	0.87	0.59	0.56
Av. volume	0.51	0.70	0.79	0.78
Av. due date	1.63	3.07	1.61	1.62
Av. customer utility	2.01	2.27	2.43	2.39
Total profit	29557.73	39198.05	51838.02	51372.54
Unbalance profit index	1.17	0.87	0.96	0.95
No. rounds	43.86	61.80	57.31	56.55
Orders agr.	0.70	0.96	0.86	0.85
Ord. utiliz.	1760.87	2586.09	2179.71	2147.59
Over utiliz.	1276.99	1909.40	2735.18	2702.34
Sub utiliz.	1789.83	1996.53	3037.29	3003.26
No. coalitions	–	5.91	5.10	5.04

From the suppliers' point of view, the NASH approach leads to the better results for the suppliers' performance measures. In this case, the result is obtained increasing the sub-furniture utilization. Moreover, the NASH approach obtains the better distribution of the profit among the suppliers.

Figure 7.18 reports the performance measures from the e-marketplace' point of view.

Also in this case, the NASH approach reacts better to the more possibility to make coalitions in a network with eight plants. The greater number of coalitions that reach an agreement underline the efficiency of this approach compared to the centralized approaches.

The Tables 7.10 and 7.11 report the simulation results as the average overall market conditions in case of both four and eight plants. This is equivalent to analyze a scenario in which each market condition above explained has the same probability to occur.

From the analysis of this data the following issues can be drawn:

- The NASH approach improves all performance indexes from four plants to eight plants network. This approach leads to the better compromise between customers and suppliers benefit. Moreover, the customer satisfaction is uniformly distributed among three considered indexes (volume, price and due date). This is due to the higher number of coalition reaching an agreement with the customers during the bargaining process. Therefore, it is easy to verify that the coalitions made with NASH approach could be really incisive in the market;
- The results of the centralized approaches confirm that they lead to main benefit for the players acting as suppliers. Moreover, the profit sharing methodology proposed is not substantially significant for the performance indexes evaluated in here.

Table 7.11 Simulation results—global average performances in case of a network of eight plants

Global average performances in case of a network with eight suppliers				
Performance	Nego	Nash	Centr	Centralized with Shapley
Av. price	0.97	0.75	0.58	0.58
Av. volume	0.52	0.73	0.84	0.84
Av. due date	1.37	0.61	1.43	1.42
Av. customer utility	1.65	2.60	2.28	2.28
Total profit	30430.83	52437.73	58101.82	57992.17
Unbalance profit index	1.46	1.16	1.16	1.24
No. rounds	43.56	50.19	59.15	59.35
Orders agr.	0.71	1.00	0.89	0.89
Ord. utiliz.	1797.87	2239.56	1958.77	1967.17
Over utiliz.	1324.58	2563.71	3147.98	3151.57
Sub utiliz.	1885.66	2354.63	3235.74	3247.31
No. coalitions	–	15.56	5.53	5.63

Table 7.12 Simulation results—global average performances in case of a network of four suppliers

Global normalized performances in case of a network of four suppliers				
Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	1.00	0.76	0.07	0.00
Av. volume	0.00	0.68	1.00	0.96
Av. due date	0.99	0.00	1.00	0.99
Av. customer utility	0.00	0.64	1.00	0.90
Total profit	0.00	0.43	1.00	0.98
Unbalance profit index	0.00	1.00	0.70	0.70
No. rounds	1.00	0.00	0.25	0.29
Orders agr.	0.00	1.00	0.62	0.58
Ord. utiliz.	0.00	1.00	0.51	0.47
Over utiliz.	1.00	0.57	0.00	0.02
Sub utiliz.	1.00	0.83	0.00	0.03
No. coalitions		1.00	0.08	0.00

- The simulation results show how the coalition approaches proposed could be really considered as value added services in all market conditions tested in here.

The Tables 7.12 and 7.13 report the values normalized of the global average performance as the normalization process explained in the Chap. 6 by the expressions 6.11 and 6.12.

Table 7.12 reports the normalized results in case of network composed by four suppliers. The better values are highlighted. The negotiation approach has some better results: average price, utilization in overtime and sub-furniture. However,

Table 7.13 Simulation results—global average performances in case of a network of eight suppliers

Global normalized performances in case of a network of eight suppliers

Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	1.00	0.43	0.00	0.00
Av. volume	0.00	0.66	1.00	1.00
Av. due date	0.07	1.00	0.00	0.01
Av. customer utility	0.00	1.00	0.66	0.66
Total profit	0.00	0.80	1.00	1.00
Unbalance profit index	0.00	1.00	1.00	0.73
No. rounds	1.00	0.58	0.01	0.00
Orders agr.	0.00	1.00	0.62	0.62
Ord. utiliz.	0.00	1.00	0.36	0.38
Over utiliz.	1.00	0.32	0.00	0.00
Sub utiliz.	1.00	0.66	0.01	0.00
No. coalitions		1.00	0.00	0.01

these results are caused by the reduced number of orders that reach an agreement compared to other approaches. The NASH approach distributes uniformly the profit among the suppliers and maximizes the ordinary utilization (this allows to reduce the production costs). Moreover, the NASH approach maximizes the number of the order with agreement and this is obtained because the number of coalitions that reach an agreement is greater than the other approaches. The centralized approach leads to better results for the suppliers (total profit) and the average customer utility. The centralized approach with SHAPLEY value has results very similar to the centralized approach.

Table 7.13 reports the normalized results in case of network composed by eight suppliers. The main difference with the case of four suppliers is the better performance of the NASH approach. In case of eight suppliers, the NASH approach has the better compromise between customer and supplier satisfaction. The centralized approach leads to better result for the supplier. Then, the NASH approach works well when the number of suppliers is higher.

Finally, Table 7.14 reports the normalized result as the average of the values reported in the Tables 7.12 and 7.13.

The normalized results allow to obtain a behavior map of the e-marketplace performance in several dynamic conditions, both for customers and for suppliers. As a matter of fact, one of the main barriers to e-marketplace adoption by SMEs is their incapacity to understand the related benefits and risks, particularly in changing market conditions. The development of a behavior map can be used as a support to the decision-making process: a generic actor (buyer or seller) can evaluate if it participates or not in an e-marketplace, considering the actual market conditions, and it can easily estimate the performance variation when the market conditions change (risks evaluation).

Table 7.14 Simulation results—global normalized performance

Global normalized performances

Performance	Negotiation	Nash	Centralized	Centralized with Shapley
Av. price	1.00	0.60	0.04	0.00
Av. volume	0.00	0.67	1.00	0.98
Av. Due date	0.53	0.50	0.50	0.50
Av. Customer utility	0.00	0.82	0.83	0.78
Total profit	0.00	0.62	1.00	0.99
Unbalance profit index	0.00	1.00	0.85	0.72
No. rounds	1.00	0.29	0.13	0.15
Orders agr.	0.00	1.00	0.62	0.60
Ord. utiliz.	0.00	1.00	0.44	0.43
Over utiliz.	1.00	0.45	0.00	0.01
Sub utiliz.	1.00	0.75	0.01	0.02
No. coalitions		1.00	0.04	0.01

This reduces the risk of the investment related to the participation in an e-marketplace because the platform is close the real behavior of enterprises. This issue is related to several factors influencing diffusion rate of e-marketplaces (White et al. 2007; Renna and Argoneto 2010).

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Chapter 8
Conclusions and Future Developments

8.1 Summary

The book presents a study that has been conducted about the opportunity to utilize a set of methodologies to face the problem of reach an agreement among customer and suppliers in an e-marketplaces environment. The first methodology to support the development of tools in e-marketplace is the multi-agent architecture. The multi-agent architecture was formalized from the static and dynamic point of view in order to support the development of the architecture in real application and the simulation environment.

The second tool regards the bargaining model. A bargaining model is one of the main key steps in e-marketplace transaction. The satisfaction of buyers and sellers strongly depends on models of negotiation performed by the e-marketplace. The approach proposed is based on the negotiation mechanism. Moreover, the bargaining approaches are based on the information provided by production planning tool. A Production planning tool allows to create a link between commercialization and production activities improving the satisfaction and the performance of the bargaining protocol. The production planning algorithm proposed is the third tool to support the e-marketplace.

The fourth tool developed to support the e-marketplace is the possibility to make coalition among the suppliers. Two approaches have been proposed. The first approach regards the application of NASH equilibrium theory to decide the partners of a coalition. This approach is characterized by limited information sharing among the suppliers. The second approach proposed is a centralized approach with complete information sharing. The centralized approach can be used as a benchmark for the NASH approach. Finally, a centralized approach with a profit sharing mechanism based on SHAPLEY value has been proposed. In order to test the proposed approach, a simulation environment based on the proposed multi-agent architecture has been developed. The proposed approaches have been tested in different market conditions of price and volume fluctuations.

P. Argoneto and P. Renna, *Innovative Tools for Business Coalitions in B2B Applications*, DOI: 10.1007/978-0-85729-707-5_8,

This research is one of the very few studies that utilizes the application of game theory linked to negotiation and production planning tool to provide real value added in e-marketplaces.

In what follows, we summarize the main scientific contributions of this book and some directions for future work.

8.2 Main Scientific Contributions

The main contributions of this book can be discussed at different levels. The high level concerns the framework of the multi-agent architecture. The research presents a framework of the multi-agent architecture to support the activities of the e-marketplace. The architecture was described from a functional and dynamic point of view using IDEF0 formalism (functional point of view) and UML activity diagrams (dynamic point of view). The proposed approach is able to support information sharing, bargaining process, production planning activities and even relationship between customer and supplier. Therefore, the proposed architecture is a tool able to coordinate the activities inside each customer and supplier and the relationship among them.

The medium level concerns the bargaining process. In this level, it has been developed a negotiation model in which the strategies of each actor (customer or supplier) can be easily defined. Moreover, a production planning algorithm has been proposed. The main contribution of the production planning algorithm is the methodology how the production planning alternatives have been built. The algorithm proposed defines the production planning alternatives based on the negotiation information with no parameters to set at priori. Moreover, the negotiation process is linked to the information provided by the production planning alternatives. This allows to obtain a negotiation process more efficient to pursue the agreement between customer and supplier.

The last level regards the tool to support the possibility to make coalitions among the suppliers. The problems addressed are the following:

- members available to make a coalition;
- methodology to select the partners of a coalition;
- counter-proposal formulation during the negotiation process;
- profit–sharing mechanism (in case the coalition wins the negotiation).

The NASH approach proposed concerns mainly the partners' selection by the NASH equilibrium concept. The approach based on SHAPLEY value has been proposed to support the profit–sharing mechanism for the centralized approach.

The simulation results highlight the following issues:

- As the results show, both supplier and customer gain benefits from the adoption of coalition approaches. All the coalition approaches allow to improve both customer's satisfaction and supplier's profit. The benefits are relevant in all market environments tested. Another benefit for the suppliers is the distribution of the profit among the partners of the network. In particular, the coalition approaches allow to distribute the profit more uniformly than the negotiation approach.

- The approach based on NASH equilibrium has two main characteristics. The coalitions made by this approach are more efficient than the other approaches. In fact, the coalitions that reach an agreement with the customer are always greater than the other approaches. This is particularly true when the market has high fluctuations of price and volume. The second relevant result concerns who gain major benefits between customer and supplier. This approach leads to better compromise between the customer and supplier satisfaction. In particular, NASH approach works better when the network of plants is composed by numerous partners. As the results show, the NASH approach improves significantly the real value added to customers and suppliers.
- The centralized approaches are characterized by the following characteristics. The benefit of these approaches is very high for suppliers who respect the customers. The centralized approaches do not improve the value added when the partners of the network increase. Although the coalitions made by the centralized approaches can be composed by two or three partners, the NASH approach leads to better result when the network is composed by eight plants. NASH approach made coalitions of two partners. This confirms the goodness of the NASH approach.
- The SHAPLEY value approach proposed to share the profit among the partners for the centralized approach does not improve the performance of the centralized approach. This result highlights that the greater importance of the partners selection process than the profit sharing process. The influence of the profit sharing mechanism is very low.
- The simulation environment developed can be used to support the decision maker in the decision process of the opportune negotiation and coalition strategies. Moreover, the simulation tools can be used to evaluate the real value added of the strategies before the implementation in real case applications.

8.3 Future Development Paths

The future research paths of this book concern the following issues.

At the level of multi-agent architecture the future research concerns the selection of the opportune strategy. A knowledge base will be provided to each agent and an inferential engine will be developed to select dynamically the strategy to use. The knowledge base will be developed by the simulation results that highlight the characteristics of each strategy. The use of fuzzy logic or neural network can be proposed to develop the inferential engine. This allows the agent to adapt when the market conditions change or the network characteristics change.

The second future research path concerns the bargaining process. It will be tested different bargaining process to measure the performance indexes with the integration of coalition methodology and bargaining characteristics. It might be possible to consider auction methodologies instead of negotiation. The interaction between bargaining process and coalition will be deeply investigated.

The methodologies proposed in this book for coalition approach are focused on one process: selection of the partners or profit sharing. A future work regards the integration of the methodologies proposed to obtain a coalition mechanism with the development of each stage. This study will highlight, if the integration of each methodology can improve the performance of the coalition possibility. Moreover, this approach can increase the computational complexity of the coalition approach reducing the potential practical application.

Another problem did not address in this book concerns the possibility to make coalitions among the customers. Therefore, it will develop when and how the customers decide to make a coalition and how the benefit of the coalition will be distributed among the partners of the coalition. These processes can be solved using game theory. Moreover, the negotiation among coalitions (customers and suppliers) will be deeply investigated.

Finally, the NASH equilibrium approach proposed in this book presents a weakness that will be improved. The volume allocated to each partner is evaluated with a discrete part between the two partners (25–75%; 50–50%; 75–25%). This strategy was chosen to minimize the computational time of the process. A future study will be focused on the determination of the allocation mechanism of the volume between the two partners keeping low the computational time.

Appendix

Table A.1 Simulation results—negotiation 4 suppliers

Volume low—price low (market case 1)			
Performance	Overlap 0	Overlap 5	Overlap 10
Average price	0.93	0.95	0.95
Average volume	0.88	0.88	0.86
Average Due date	1.44	2.05	2.67
Average customer utility	2.31	2.36	2.37
Total profit	19970.21	27.750.36	34.647.92
Unbalance profit index	1.31	1.00	1.12
No. rounds	61.51	58.65	56.77
Orders agr.	0.97	0.98	0.96
Ord. utiliz.	1882.46	2435.02	3036.93
Over utiliz.	1039.90	1903.47	2620.24
Sub utiliz.	1728.59	2571	3448.05

Table A.2 Simulation results—negotiation 8 suppliers

Volume low—price low (market case 1)			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.94	0.95	0.95
Av. volume	0.89	0.89	0.88
Av. Due date	1.45	2.00	2.53
Av. customer utility	2.28	2.35	2.38
Total profit	20225.01	28217.73	35721.01
Unbalance profit index	1.45	1.40	1.31
No. rounds	60.67	58.74	57.42
Orders agr.	0.98	0.99	0.99
Ord. utiliz.	1876.18	2438.25	3023.05
Over utiliz.	1126.93	1944.08	2774.67
Sub utiliz.	1808.97	2638.17	3498.30

P. Argoneto and P. Renna, *Innovative Tools for Business Coalitions in B2B Applications*, DOI: 10.1007/978-0-85729-707-5,

Table A.3 Simulation results—negotiation 4 suppliers

Volume high—price high (market case 2)			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.38	0.37	0.37
Av. Due date	1.22	1.74	2.33
Av. customer utility	2.26	2.26	2.29
Total profit	26956.01	38970.10	50782.27
Unbalance profit index	1.38	1.30	1.00
No. rounds	39.51	38.45	36.91
Orders agr.	0.59	0.58	0.58
Ord. utiliz.	1119.62	1497.36	1873.71
Over utiliz.	615.24	999.05	1873.71
Sub utiliz.	1027.47	1497.83	1980.21

Table A.4 Simulation results—negotiation 8 suppliers

Volume high—price high (market case 2)			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.39	0.39	0.36
Av. Due date	0.72	1.10	1.33
Av. customer utility	1.33	1.35	1.31
Total profit	27460.82	41410.07	50635.00
Unbalance profit index	1.63	1.47	1.43
No. rounds	38.56	38.64	36.58
Orders agr.	0.58	0.60	0.57
Ord. utiliz.	1145.24	1562.27	1852.97
Over utiliz.	627.63	1088.90	1423.75
Sub utiliz.	1064.71	1603.44	1982.49

Table A.5 Simulation results—negotiation 4 suppliers

Volume low—price low—peak orders			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.94	0.95	0.95
Av. volume	0.54	0.54	0.56
Av. due date	1.47	2.02	2.1
Av. customer utility	2.32	2.37	2.36
Total profit	16333.52	22207.79	22791.59
Unbalance profit index	1.33	1.00	1.00
No. rounds	48.57	46.81	47.45
Orders agr.	0.77	0.78	0.79
Ord. utiliz.	1527.86	2004.25	2056.52
Over utiliz.	876.33	1476.93	1537.27
Sub utiliz.	1389.29	2058.55	2126.43

Table A.6 Simulation results—negotiation 8 suppliers

Volume low—price low—peak orders			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.94	0.95	0.95
Av. volume	0.55	0.55	0.51
Av. due date	1.17	1.64	2.00
Av. customer utility	1.83	1.88	1.88
Total profit	16354.64	22662.07	28194.73
Unbalance profit index	1.47	1.42	1.37
No. rounds	48.44	46.56	45.36
Orders agr.	0.78	0.79	0.79
Ord. utiliz.	1510.65	2018.86	2428.42
Over utiliz.	893.13	1521.30	2080.37
Sub utiliz.	1455.25	2131.90	2749.61

Table A.7 Simulation results—negotiation 4 suppliers

Volume high—price high—peak orders			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.25	0.25	0.25
Av. due date	0.58	0.83	1.06
Av. customer utility	1.07	1.04	1.07
Total profit	21326.97	31603.19	41352.78
Unbalance profit index	1.40	1.17	1.03
No. rounds	31.46	30.20	30.00
Orders agr.	0.47	0.46	0.47
Ord. utiliz.	898.39	1235.13	1563.13
Over utiliz.	485.99	791.20	1104.53
Sub utiliz.	822.54	1213.98	1613.99

Table A.8 Simulation results—negotiation 8 suppliers

Volume high—price high—peak orders			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.26	0.26	0.26
Av. Due date	0.58	0.86	1.08
Av. customer utility	1.07	1.09	1.084
Total profit	21451.98	32205.68	40631.24
Unbalance profit index	1.64	1.48	1.45
No. rounds	31.23	30.45	30.02
Orders agr.	0.47	0.47	0.47
Ord. utiliz.	905.44	1271.20	1541.96
Over utiliz.	490.52	817.32	1106.40
Sub utiliz.	837.8	1255.46	1601.77

Table A.9 Simulation results—coalition NASH 4 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.97	0.97	0.98
Av. volume	0.87	0.87	0.86
Av. due date	1.79	2.77	3.51
Av. customer utility	2.28	2.31	2.32
Total profit	19979.59	26797.43	32537.01
Unbalance profit index	1.31	0.99	0.98
No. rounds	65.05	62.49	60.74
Orders agr.	0.97	0.98	0.97
Ord. utiliz.	3589.91	2396.88	2538.59
Over utiliz.	1030.86	1672.48	1972.26
Sub utiliz.	1471.32	2337.51	2733.29
No. coalition	0.51	0.49	0.66

Table A.10 Simulation results—coalition NASH 8 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.90	0.90	0.89
Av. volume	0.84	0.84	0.83
Av. due date	0.58	0.78	0.84
Av. customer utility	2.57	2.60	2.61
Total profit	19713.53	28160.69	35656.45
Unbalance profit index	1.18	1.18	1.20
No. rounds	52.19	50.19	48.17
Orders agr.	0.99	1.00	0.99
Ord. utiliz.	1639.53	2246.54	2689.17
Over utiliz.	1239.41	2267.64	2847.73
Sub utiliz.	709.45	1279.43	2754.31
No. coalition	12.94	12.25	12.41

Table A.11 Simulation results—coalition NASH 4 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.45	0.52	0.62
Av. due date	0.51	2.27	4.82
Av. customer utility	2.37	2.34	2.30
Total profit	23121.66	44068.77	70326.23
Unbalance profit index	0.50	0.63	0.79
No. rounds	57.99	59.22	61.48
Orders agr.	0.98	0.98	0.98
Ord. utiliz.	2121.26	2863.15	3339.51
Over utiliz.	1687.33	2285.67	2716.35
Sub utiliz.	657.69	1495.74	2534.43
No. coalition	13.91	11.38	9.13

Table A.12 Simulation results—coalition NASH 8 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.73	0.73	0.70
Av. volume	0.73	0.72	0.69
Av. due date	0.38	0.39	0.31
Av. customer utility	2.65	2.66	2.64
Total profit	52198.15	76453.05	93952.59
Unbalance profit index	1.34	1.32	1.04
No. rounds	49.28	46.82	46.40
Orders agr.	1.00	1.00	1.00
Ord. utiliz.	1702.70	2259.27	2833.84
Over utiliz.	2133.12	2891.03	3576.81
Sub utiliz.	1671.56	2617.27	3606.47
No. coalition	18.09	17.73	17.67

Table A.13 Simulation results—coalition NASH 4 suppliers

Volume low—price low—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	1.00	1.00	1.00
Av. volume	0.81	0.78	0.80
Av. due date	3.53	4.61	4.63
Av. customer utility	2.20	2.24	2.24
Total profit	21727.93	28731.92	28358.34
Unbalance profit index	1.18	0.93	0.93
No. rounds	67.01	63.81	63.93
Orders agr.	0.96	0.95	0.96
Ord. utiliz.	1774.12	2346.01	2356.28
Over utiliz.	1058.08	1637.95	1675.87
Sub utiliz.	1543.16	2232.30	2304.5
No. coalition	1.26	1.54	1.41

Table A.14 Simulation results—coalition NASH 8 suppliers

Volume low—price low peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.78	0.75	0.73
Av. volume	0.74	0.72	0.69
Av. due date	0.87	0.94	1.00
Av. customer utility	2.54	2.58	2.57
Total profit	21768.77	30951.42	38075.06
Unbalance profit index	1.10	1.09	1.08
No. rounds	54.94	51.72	51.82
Orders agr.	0.99	0.99	0.99
Ord. utiliz.	1669.78	2201.28	2784.70
Over utiliz.	1421.4	2438.79	3098.49
Sub utiliz.	1068.7	2406.15	3359.34
No. coalition	13.89	14.19	13.29

Table A.15 Simulation results—coalition NASH 4 suppliers

Volume high—price high peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.38	0.51	0.60
Av. volume	0.74	0.49	0.58
Av. due date	0.25	2.75	5.42
Av. customer utility	2.23	2.26	2.20
Total profit	50786.45	46855.74	77085.48
Unbalance profit index	0.91	0.57	0.76
No. rounds	56.72	60.46	62.72
Orders agr.	0.79	0.98	0.97
Ord. utiliz.	1505.97	2890.27	3311.10
Over utiliz.	2043.16	2378.45	2754.31
Sub utiliz.	2113.13	1775.18	2760.13
No. coalition	8.83	12.16	9.64

Table A.16 Simulation results—coalition NASH 8 suppliers

Volume high—price high peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.66	0.65	0.62
Av. volume	0.66	0.65	0.62
Av. due date	0.42	0.44	0.33
Av. customer utility	2.59	2.61	2.59
Total profit	55295.57	77684.42	99343.02
Unbalance profit index	1.12	1.18	1.08
No. rounds	51.79	49.64	49.35
Orders agr.	1.00	1.00	1.00
Ord. utiliz.	1690.87	2236.44	2920.60
Over utiliz.	2190.76	2884.86	3774.44
Sub utiliz.	1885.45	2839.06	4058.32
No. coalition	18.28	17.94	17.99

Table A.17 Simulation results—coalition centralized 4 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.88	0.90	1.14
Av. volume	0.90	0.89	0.89
Av. due date	1.45	2.13	2.40
Av. customer utility	2.37	2.41	2.40
Total profit	18992.24	27497.04	34918.85
Unbalance profit index	1.21	0.98	0.97
No. rounds	58.75	56.10	55.51
Orders agr.	0.95	0.95	0.95
Ord. utiliz.	1140.1	1977.1	2705.35
Over utiliz.	1898.13	2481.19	3068.82
Sub utiliz.	1734.52	2639.21	3542.15
No. coalitions	0.67	0.66	0.99

Table A.18 Simulation results—coalition centralized 8 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.89	0.91	0.90
Av. volume	0.89	0.90	0.90
Av. due date	1.35	2.02	2.53
Av. customer utility	2.25	2.29	2.37
Total profit	18447.90	26170.08	34603.18
Unbalance profit index	1.38	1.34	1.19
No. rounds	58.45	55.60	54.45
Orders agr.	0.95	0.95	0.96
Ord. utiliz.	1030.08	1547.06	2234.75
Over utiliz.	1903.34	2818.84	3625.01
Sub utiliz.	1767.30	2628.01	3565.19
No. coalitions	0.67	0.54	0.68

Table A.19 Simulation results—coalition centralized 4 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.45	0.47	0.48
Av. volume	0.94	0.85	0.81
Av. due date	0.45	1.50	2.23
Av. customer utility	2.60	2.52	2.46
Total profit	57009.64	78957.58	99252.62
Unbalance profit index	0.92	0.92	0.91
No. rounds	67.79	64.88	62.16
Orders agr.	0.94	0.88	0.85
Ord. utiliz.	1670.34	2417.9	3202.34
Over utiliz.	2298.4	2982.8	3661.84
Sub utiliz.	2351.81	3420.17	4556.11
No. coalitions	9.7	8.87	8.48

Table A.20 Simulation results—coalition centralized 8 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.45	0.48	0.48
Av. volume	0.97	0.92	0.91
Av. due date	0.36	1.16	1.78
Av. customer utility	2.52	2.40	2.41
Total profit	61322.98	89940.47	116529.68
Unbalance profit index	1.26	1.05	1.02
No. rounds	68.92	70.15	68.31
Orders agr.	0.95	0.95	0.94
Ord. utiliz.	1400.26	2238.38	3081.38
Over utiliz.	2547.42	3551.26	4556.36
Sub utiliz.	2433.08	3700.26	4991.84
No. coalitions	10.36	10.17	9.44

Table A.21 Simulation results—coalition centralized 4 suppliers

Volume low—price low—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.49	0.52	0.56
Av. volume	0.70	0.68	0.67
Av. due date	1.19	2.07	2.75
Av. customer utility	2.82	2.57	2.59
Total profit	17696.19	27086.57	29763.02
Unbalance profit index	1.10	0.87	0.90
No. rounds	49.87	49.94	49.78
Orders agr.	0.81	0.81	0.82
Ord. utiliz.	1091.31	1946.44	2616.79
Over utiliz.	1752.01	2460.52	3010.40
Sub utiliz.	1652.56	2656.36	3478.36
No. coalitions	1.9	1.97	2.01

Table A.22 Simulation results—coalition centralized 8 suppliers

Volume low—price low—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.52	0.53	0.52
Av. volume	0.73	0.74	0.79
Av. due date	1.03	1.70	2.22
Av. customer utility	2.22	2.27	2.31
Total profit	18591.67	28028.95	38608.11
Unbalance profit index	1.22	1.15	1.10
No. rounds	50.16	50.57	52.11
Orders agr.	0.82	0.84	0.87
Ord. utiliz.	1061.04	1707.12	2504.63
Over utiliz.	1847.58	2818.02	3782.50
Sub utiliz.	1780.72	2800.08	3988.55
No. coalitions	2.08	2.19	2.57

Table A.23 Simulation results—coalition centralized 4 suppliers

Volume high—price high—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.39	0.39	0.39
Av. volume	0.73	0.72	0.74
Av. due date	0.33	1.15	1.61
Av. customer utility	2.17	2.04	2.18
Total profit	50795.02	76199.26	103888.2584
Unbalance profit index	0.90	0.89	0.9
No. rounds	57.11	57.72	58.12
Orders agr.	0.79	0.78	0.82
Ord. utiliz.	1524.65	2422.33	3441.86
Over utiliz.	2056.18	2984.66	4167.21
Sub utiliz.	2146.60	3442.44	4827.12
No. coalitions	8.68	8.50	8.81

Table A.24 Simulation results—coalition centralized 8 suppliers

Volume high—price high—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.41	0.42	0.40
Av. volume	0.76	0.77	0.80
Av. due date	0.26	1.11	1.67
Av. customer utility	2.16	2.10	2.08
Total profit	53873.37	87255.73	123849.69
Unbalance profit index	1.22	1.02	1.00
No. rounds	56.46	60.45	64.13
Orders agr.	0.79	0.82	0.84
Ord. utiliz.	1237.30	2190.18	3273.06
Over utiliz.	2216.95	3403.85	4704.66
Sub utiliz.	2175.61	3643.51	5354.74
No. coalitions	8.90	9.05	9.76

Table A.25 Simulation results—coalition centralized shapley 4 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.88	0.90	0.88
Av. volume	0.89	0.89	0.89
Av. due date	1.40	2.06	2.74
Av. customer utility	2.35	2.39	2.42
Total profit	18669.53	26700.57	34184.71
Unbalance profit index	1.23	0.98	0.98
No. rounds	59.13	56.23	55.34
Orders agr.	0.95	0.95	0.95
Ord. utiliz.	1119.68	1923.17	2679.35
Over utiliz.	1879.28	2450.73	3051.97
Sub utiliz.	1709.87	2579.12	3507.57
No. coalitions	0.64	0.65	0.87

Table A.26 Simulation results—coalition centralized shapley 8 suppliers

Volume low—price low			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.91	0.91	0.90
Av. volume	0.89	0.90	0.90
Av. due date	1.41	1.99	2.55
Av. customer utility	2.23	2.31	2.38
Total profit	18865.31	26562.80	34463.01
Unbalance profit index	1.39	1.29	1.19
No. rounds	57.92	55.66	54.61
Orders agr.	0.95	0.96	0.96
Ord. utiliz.	1047.64	1595.66	2201.00
Over utiliz.	1931.58	2818.75	3608.33
Sub utiliz.	1789.48	2666.44	3541.07
No. coalitions	0.52	0.65	0.62

Table A.27 Simulation results—coalition shapley 4 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.44	0.47	0.39
Av. volume	0.94	0.86	0.69
Av. due date	0.47	1.42	2.26
Av. customer utility	2.59	2.52	2.26
Total profit	58102.92	79753.41	96038.60
Unbalance profit index	0.92	0.92	0.88
No. rounds	67.59	65.41	56.32
Orders agr.	0.93	0.90	0.75
Ord. utiliz.	1698.95	2445.05	3176.45
Over utiliz.	2351.57	3023.17	3738.17
Sub utiliz.	2394.01	3480.44	4535.47
No. coalitions	9.68	9.02	8.12

Table A.28 Simulation results—coalition shapley 8 suppliers

Volume high—price high			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.46	0.48	0.48
Av. volume	0.90	0.92	0.91
Av. due date	0.32	1.16	1.69
Av. customer utility	2.44	2.40	2.34
Total profit	60292.41	86726.35	116739.13
Unbalance profit index	1.28	1.07	1.02
No. rounds	67.78	69.47	69.38
Orders agr.	0.94	0.95	0.94
Ord. utiliz.	1386.14	2159.35	3094.91
Over utiliz.	2537.56	3467.08	4551.38
Sub utiliz.	2412.47	3595.35	5007.85
No. coalitions	9.99	10.02	10.06

Table A.29 Simulation results—coalition centralized shapley 4 suppliers

Volume low—price low—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.53	0.52	0.54
Av. volume	0.67	0.69	0.68
Av. due date	1.27	2.06	2.72
Av. customer utility	2.68	2.67	2.62
Total profit	17790.15	26241.64	34331.24
Unbalance profit index	1.07	0.89	0.88
No. rounds	50.19	49.00	49.22
Orders agr.	0.80	0.81	0.82
Ord. utiliz.	1087.27	1921.00	2619.30
Over utiliz.	1731.70	2439.89	3059.68
Sub utiliz.	1642.94	2632.60	3498.67
No. coalitions	1.81	1.84	2.07

Table A.30 Simulation results—coalition centralized shapley 8 suppliers

Volume low—price low—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.55	0.53	0.50
Av. volume	0.74	0.75	0.77
Av. due date	1.00	1.73	2.26
Av. customer utility	2.22	2.21	2.24
Total profit	18413.86	28303.54	39273.81
Unbalance profit index	1.22	1.26	1.11
No. rounds	50.64	50.83	53.32
Orders agr.	0.83	0.84	0.87
Ord. utiliz.	1043.68	1731.94	2563.22
Over utiliz.	1831.72	2857.37	3841.74
Sub utiliz.	1753.17	2863.41	4085.30
No. coalitions	2.00	2.25	2.92

Table A.31 Simulation results—coalition centralized shapley 4 suppliers

Volume high—price high—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.41	0.40	0.39
Av. volume	0.74	0.70	0.69
Av. due date	0.25	1.13	1.63
Av. customer utility	2.23	1.99	1.96
Total profit	50786.44	74327.86	99543.36
Unbalance profit index	0.91	0.90	0.88
No. rounds	56.72	56.62	56.83
Orders agr.	0.79	0.76	0.75
Ord. utiliz.	1505.96	2320.61	3274.32
Over utiliz.	2043.17	2891.74	3767.00
Sub utiliz.	2113.13	3288.54	4656.73
No. coalitions	8.83	8.46	8.48

Table A.32 Simulation results—coalition centralized shapley 8 suppliers

Volume high—price high—peak demand			
Performance	Overlap 0	Overlap 5	Overlap 10
Av. price	0.39	0.41	0.39
Av. volume	0.77	0.79	0.81
Av. due date	0.27	1.11	1.57
Av. customer utility	2.23	2.16	2.24
Total profit	55222.23	89297.48	121746.06
Unbalance profit index	2.07	1.01	1.00
No. rounds	57.82	61.01	63.76
Orders agr.	0.80	0.82	0.84
Ord. utiliz.	1282.57	2257.99	3241.98
Over utiliz.	2281.19	3464.34	4627.74
Sub utiliz.	2244.25	3731.39	5277.53
No. coalitions	9.31	9.30	9.92

Index

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