An Agent Based Tool to Support Tactical Dialogues in Industrial Enterprise Networks: model and experimental campaign

MARCO BOTARELLI §, PAOLO TATICCHI §, ROBERTO REVETRIA *, FLAVIO TONELLI *
§ Department of Industrial Engineering
University of Perugia
Via Duranti 17, Perugia
ITALY
* Department of Production Engineering, Thermo-energetic and Mathematical Models
University of Genoa
Via All'Opera Pia 15, Genoa
ITALY
flavio.tonelli@diptem.unige.it

Abstract: - The globalization of competition has entailed that organizations of developed countries have to face new kind of competitors with low labour cost, and often-advantageous exchange rates (resulting in favourable export selling prices). In such a scenario, innovation and organizational flexibility are becoming fundamental levers to enable enterprises to increase their competitiveness. For this reason, the need arises of a formalized methodology that enables organizational flexibility and capacity of performing innovation. This work originates from the analysis of a case study which highlighted that enterprise networks can enable organizational flexibility, and defined the formalization of the VDO concept – Virtual Development Office – a network organizational model based on an independent subject which has the role of enabling innovation in a collaborative environment to reach world class manufacturing capabilities. A multi-agents system based architecture is proposed to model and support tactical dialogues inside the network. The VDO has been modelled as a supervisor and coordinator agent able to perform a selection process in order to create the best coalition for managing emerging business opportunities. The context analyzed in this research work assumes a virtual market place where enterprises, represented by agents, can ''meet each other'' and cooperate in order to achieve a common business goal given by a collaboration opportunity.

Key-Words: - Enterprise Networks , Virtual Development Office, Multi-Agent Systems, Decision Making, Case Study

1 Introduction

In the current competitive scenario, enterprises competitiveness is not based on company or industry, but on the value creating systems themselves, within which different agents work together to co-create value and build a network [1]. Researches in interconnected systems have contributed to characterize the benefits correlated to cooperation between companies [2,3,4]. These advantages could be particularly important for Small Medium Enterprises (SMEs) given the resource constraints and limitations they work within [5]. On the other hand, networking of enterprises entails new organizational problems [35], such as the decentralization of decision-making process and the horizontal coordination between different business functions as well as, outside the firm, between complementary activities performed by suppliers and customers [6]. The aim of this paper is to present a new organizational enterprise network model and a related multi-agent based support framework, developed within the Italian research project MIGEN[1], during which the authors supported the development of a network from its first steps. Specifically, the paper addresses the following questions: (1) Can an organizational model be developed which can foster a long term development of an SMEs network? (2) How can the interactions between the network partners be fostered? (3) How can business opportunities and innovation in the network be managed and promoted? (4) A Multi-Agent Based framework can support effectively the tactical decision process?

[1] MIGEN (the name comes from the Italian acronym for Innovative Models for Enterprises Network Management) is a research project supported by Italian government with the PRIN (Research Project of National Interest) program. The project involved the Universities of Perugia, Florence and Genoa and it focused on the development of specific models and tools for managing networks of enterprises.

This paper is organized as follows: firstly, a brief description of the industrial context in which this study has been carried out is described; secondly, based on the case study, a formal conceptual organizational model is offered and its main highlights are discussed. Thirdly, a description of a multi-agent based framework for supporting tactical decision processes is described considering the limitations and the issues of this approach.

2 The GPT Case Study

The scenario in which the presented study has been developed is the district of printing and packaging located in Umbria, Italy. Such a district, composed by over 160 enterprises, is characterized by a high technical-productive specialization due to an historical handicraft tradition in the mechanical and printing field. Today the competitive potential of the district is severely limited because it lacks the ability to spontaneously optimize its activities, a situation exacerbated by the absence of leader firms capable of providing direction for the system as a whole. Through a SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis, the researchers were able to identify the advantages, the weaknesses, the problems and the possible future turns of the SMEs of the district. One particular outcome from this exercise was the recognition that even those SMEs with good technological knowledge and decisional and adaptive rapidity are constrained by their small business dimensions that put them in a severe competitive disadvantage when compared to larger competitors. This makes the entry in the European and international markets difficult; a situation further exacerbated by the absence of an entrepreneurial culture, effective marketing capabilities and the pursuit of preset objectives through defined strategies. In this regard the Umbrian printing and packaging district can be seen to embody the problems of most Italian Small & Medium Enterprises (SME).

In such a scenario, three firms (Pasqui, Litop and Litograf), characterized by a range of complementary products and by a partnership based on a solid personal knowledge of the entrepreneurs, decided to form a new company: G.P.T., acronym of "Gruppo Poligrafico Tiberino" (that will constitute what the authors introduced in the model with the concept of VDO), with the first intent of integrating the commercial and marketing functions. Since the early stage of its life, GPT perceived the need of expanding its own mission and activities. From 2005 to 2008 GPT grew from the 3 initial partners to the 20 current members, extending its borders from the district localization, to the national territory. Partners are SMEs prevalently belonging to the printing and packaging sector, even if the group growth also involved financial and service companies in order to increase the network competencies and its ability to manage relevant innovation projects. Today's aggregate turnover is about $310 million, involving over 1000 employees, in 24 establishments, underlining the exponential network expansion. In this direction GPT is today pushing interesting strategies for the consolidation of the Italian market and it is now entering the South America and Northern Africa markets.

2.1 The organizational model of GPT network

In order to characterize the organizing scheme of a network we will use the dimensions proposed by [7]: (1) a governance structure, namely power relations arising from asymmetries in market base, resources and capabilities that determine how economic surplus is distributed within the chain and how activities are coordinated within and across firms; (2) an input-output structure, or sequence of interrelated value-adding activities, including production design and engineering, manufacturing, logistics, marketing and sales; (3) a geographical configuration, referring to the spatial dispersion or concentration of activities within and across locations; (4) a social and institutional context, formed by norms, value and regulatory frameworks of the various community within which firms operate.

The governance. The governance structure plays a key role not only in the creation and distribution of value, but also in the coordination of networks. From a strategic perspective, the coordination of a network requires some degree of centralization in order to ensure an efficient use of resources, rapid decision-making and the rising of a global vision driving the network. For these reasons management researchers stress the role of the "leading firm" [8], continuously engaged in attracting and selecting members, in sustaining network relationships by managing conflicts and learning, in positioning the network in the market and in building the structure and culture of the network [9]. In a network composed by SMEs we can't find a subject that can naturally play the role of lead actor over a long time horizon. In our case, GPT is a formally defined entity that plays the role of a permanent figure (lead actor) operating within an enterprise community that survives the single Virtual Enterprise (VE), defined as a temporary organization of companies that come

together to share costs and skills to address business opportunities that they could not undertake individually.
Another important aspect covered by GPT, as a permanent actor inside the network, is the problem of building trust between partners, which is considered a critical aspect within the network [10], and can result in lower transaction costs, easier conflict resolution, or lower need of formal contracting [11]. Trust, while advocated by many authors [12], was recognized as needing time and care to build [13] and can be difficultly developed in the typical horizon of a single VE. Similar consideration can be done about information sharing. In high level of interdependence environments, in order to manage the complexity of activities, procedures and interfaces have to be precisely defined, and a large investment in time and work is needed. This will result in a large complex system that can be justified only within a long-term strategy of the network [14].
The input-output structure. The main mission of GPT is to manage the organization of the VE when the business opportunity is activated and to coordinate innovation activities according to a long-term strategic decision, through a continuous monitoring of both partner resources and competencies [15] and market needs. Once the business opportunity is captured, GPT has to set up the specific virtual enterprise composed by members belonging to the community or even outside the community. One of the main features of GPT is that, even preserving the dynamism of a typical VE in responding to market needs, it allows to centralize and manage on a long time horizon, some critical "company" activities (i.e. the development of a well-known trademark, a long-term maintenance guarantee), without the limitations of a typical VE [16].

The geographical configuration. One of the current main trends characterizing manufacturing scenarios is represented by the internationalization of production processes; the geographical shape of global production networks results from a combination of local, regional and trans-regional dynamics [17]. We could think of the previous as different stages or aspects during the network life cycle; even if the first pool of enterprises participating the network will be probably located in a geographically limited community where those enterprises can already have proactive environment in terms of diffused trust, collaboration, knowledge, etc., the network can be then composed by companies coming from different regions or countries, where each region can be characterized by a specific competence. The same process can be found in the development of GPT, where the geographical closeness, with its advantages in terms of informal links and shared values, has balanced the lack of formalized processes, information technology tools, etc., while its structure allows to strategically manage the link between a VE composed by companies coming from different regions or countries. This has been happening during the GPT expansion, since some partner localization is out of the initial district, but they are distributed in various parts of Italy.
The social and institutional context. Katz and Darbishire [18] have shown that country specific labour market structures and institutions play a critical role in shaping employment relations systems, although they are affected by the spread of new practices in highly globalized sectors. One of the main advantages of the organizational model proposed is that it can formulate and manage over a single business opportunity a jointly development strategy within the community and drive networks of firms toward continuous improvement and learning. Furthermore, it can interact for the community with institutional subjects as a single entity promoting innovation activity with research centres or the support of financial institutions (banks, government offices, etc.). GPT has in fact good relation with local and national institutions as much as ministries, research centres and prestigious academies, that allow to perform important initiatives and innovative projects of high visibility.

3 The Concept of the Virtual Development Office (VDO)

Considering the attribute previously described, the aim of this work was to define a conceptual organizational model for enterprise networks. In particular we focused on Small Medium Enterprises (SMEs) that in most cases operate in a dense network or inter-firm relationships given that they represent an important aspect of the European economy. Therefore it's necessary to propose a collaborative model to SMEs to encourage the innovation and research capabilities, to standardize processes and to increase performances. Our approach is based on the creation of an independent subject, the Virtual Development Office (VDO), GPT in the case study, which act as a leading actor, and it has the role of creating, coordinating and managing a community of enterprises. Particularly, it should be the market intelligence of the network, continuously catching business opportunities in the

market and positioning the network on it. Moreover, the VDO is the permanent interface to public institutions [36], financial institutions and research centres. As described before, a proactive collaboration with such subjects is a leverage factor in today business. The VDO activities presented above are "external" to the network. However, the VDO also has a crucial role inside the network life. First of all, it has the role of maintaining and consolidating the trust of companies involved in the network by generating and promoting a long-term alliance. By acting as a central player on respect of the "business ecosystem", it promotes both the willing of cooperation, both the readiness to collaborate each time a business opportunity, which for a network can be defined as a "collaboration opportunity" (CO) arises.

The efficacy of this subject, called VDO – Virtual Development Officer, is composed by the following phases:

- Analytic Phase; it involves a continuous monitoring of the environment and the competitive position of enterprises belonging to the community in terms of resources and competencies. One of the core activities of the VDO is the definition of the strategic positioning of the community and the creation/promotion of business opportunities. Moreover it is important to remark that based on this approach it is possible to define developmental lines for innovation projects and it is possible to identify criteria for opening the community to different actors.
- Planning Phase; after the target definition (business opportunity, new product development projects, etc.), the VDO should manage the following activities: (1) plan activities, identifying the necessary resources/capabilities to reach the targets; (2) select the enterprises in the community that will create the VE to fulfil the CO derived from the identified BO; (3) establish the contribution of every actor in the VE and the cooperation rules based on Service Level Agreements (SLAs). The last is a very critical activity in the management of the VE, given that it requires the definition of organizational models, revenue sharing contracts, transaction costs, etc. i.e. the "rules of the game" that will guide the activities of the single enterprise.
- Operating phase; it implies the control of the quality of the products/services provided (safety, availability, reliability, etc.) and the solution effectiveness; these data represent fundamental feedbacks for the analytical phase.

During the planning phase the VDO has to face several tactical decision problems [37] to be able to effectively fulfil a CO, operating as a single VE. When the CO is found, the enterprises within the business network must be chosen for producing the final product or service to satisfy it. Each enterprise is just one node adding some value to the chain and the most suitable enterprises have to be chosen by the VDO according to some Key Performance Indicators (KPIs) such as costs, product quality, and customer service level. The optimal bids are selected based on a multi-criteria mechanism and constraint-based negotiation (i. e. owner-cost, higher quality, lower delivery time, etc…). Through the selection process, new temporary supply chains are created; these virtual coalitions (or VEs) need then to be managed, supervised, and coordinated from the operational point of view. Decision support systems tools can perform concurrent, synchronized, and distributed simulations sharing information within the VE. Hence, a multi-agent-model to support VDO decision-making has been developed.

4 Multi-Agent Systems Survey

Several Software Engineering practices have been proposed to model distributed software systems in a useful manner and to handle the complexity that stems from a real software project: component programming and object oriented frameworks have proven to be an effective methodology to address complex problems [19]. Agent Oriented Technology and Agent Oriented Software Engineering (AOSE) [20] can be an interesting and effective alternative to provide interoperation among software artefacts. Agents are intelligent software entities that expose flexible behaviours and they cooperate, compete, and coordinate in order to achieve their goals [21]. Such features are basic requirements for modelling scenarios in which single entities interoperate constituting (rising up) a complex organization. Agents are commonly organized through Multi-Agent Systems (MAS), where they can best exploit their social ability. Agent technology is well suited for the design of distributed and concurrent applications requiring a high degree of cooperation, or in certain cases competition, with asynchronous communication [22]; hence agents represent an effective solution for designing and implementing a VE scenario. MASs are more than interesting candidate to implement complex and evolvable organization according to environment changes. MASs are dynamic by their nature, new agents, acting like proxies of new joined partners, can be easily added or removed from the system without modifying the pre-existing agent infrastructure. By using their social skills and by exploiting MAS services, the newly added agents are able to

seamless integrate into the agent community. The services provided by all the partners in the system can be accessed through the agents representing them. Developing multi-agent systems is a complex task; it implies the implementation of concurrent software environment constituted by autonomous entities. These entities should rely on communication and directory services, offered by the hosting environment in order to easily interoperate. Agent programming frameworks commonly address these issues: an agent framework can support developers in the entire MAS life-cycle, providing them with tools for analysis, design, implementation, and deployment [23,24]]. Jade [25], developed by the TILab, is one of the most used and diffused. AgentService [26] is an agent framework which provides, in addition to the common MAS features, the ability to distribute the agent system (distributed communication infrastructure and agent mobility) and a high level of extendibility through the adoption of a modular architecture. An interesting application of the framework can be found in [27]. A system based on a customized version of the AgentService environment was able to provide a very flexible and open solution from different points of view (agent model, scheduler engine, architecture) as required by this work.

5 MAS for Enterprise Networks (ENs)

There are a number of characteristics in the EN domain that make it a suitable candidate for the application of MAS approach [28]. Examples of such characteristics include:

- ENs are composed of distributed, heterogeneous and autonomous components, a situation that can be easily mapped with MAS.
- Coordination and distributed problem solving also tackled by MAS are critical problems in ENs management.
- Decision-making with incomplete information, and involvement of network members as autonomous entities, that although willing to cooperate in order to reach a common goal might be competitors regarding other business goals, is another common point.
- The phase of VE formation in which it is necessary to select partners from the EN and distribute tasks, shows market characteristics and negotiation needs that have been research issues for years in the MAS community (coalition formation).
- A VE consortium is a dynamic organization that might require re-configurations, i.e. replacement of partners, changes in partners' roles, etc., for which a flexible modelling paradigm is required.

Since agents can be designed and developed independently, from the technology point of view, it is important to adopt common rules ("social laws" and standards) for MAS interoperation. In this context the work performed by FIPA [29] and the efforts provided by agent researchers in the fields of communication ontology [30] are effective solutions to agent interactions.
In next sections the agent-based approach for modelling the proposed case study is detailed described.

6 The Multi-Agent Framework For VDO Decision Support

This paper focuses on the phase of a VE constitution alias the planning activity of the VDO. Collaborative designing and engineering activities, carried out by the VE coalition according to VDO coordination, represents an innovation in management models. The making/manufacturing process must be organized in order to create the required physical supply chain, able to manufacture products according to design and engineering specifications and CO requirements.
The process of selecting the best enterprises for the formalized CO, identified by the VDO, is based on the performance assessment concept. Thereby, a Collaboration Opportunity Scorecard (COS) is defined for associating the CO with a set of metrics and indicators to drive the selection of enterprises within the network. Three perspectives have been identified to feature each CO: Cost-Focused, Product-Focused, and Customer-Focused [31]. A specific weight is defined in relation to each perspective and functionally to an objective function. VDO is in charge of finding the possible configurations of VE able to respect the CO requirements through the enterprise selection process. The CO, from the manufacturing point of view, involves the definition of a Bill of Materials (BOM). In relation to this aspect, a set of target costs are associated to each item of the BOM and according to CO cost target; these costs should be taken into account in the creation of the physical supply chain.
In order to evaluate the capabilities of each enterprise belonging to the coalition, a set of KPIs have been defined. The introduction of these KPIs allows an effective management of the COs and provides a mechanism for benchmarking the enterprises involved in the network.

Four indicators are defined, see Table 1, for describing each CO perspective (Cost, Product, Customer); in addition, in the proposed model, a reputation index (RI) has been introduced for evaluating the activities done by enterprises in previous COs. Once a CO is defined along with its parameters such as weights and target costs, the VDO has to select the most suitable enterprises to build the physical supply chain in terms of specified KPIs.

Cost-Focused KPIs	**Product-Focused KPI**	**Customer-Focused KPIs**
Cost	Number of new products in the pipeline	Responsiveness
Cycle Time	Time to market	Complaint Handling
Conformance to Standards	Customization	Customer Based Technology
Production Capability	Flexible Technology	Product Knowledge

Table 1: Key Performance Indicators – Enterprise Network Profile

Following the above considerations the VDO has to manage a complex and transversal decisional process starting from the collaboration on design activities and ending with the delivery phase. The entire decision process should be decomposed in order to deal with its complexity. The proposed way for performing this process involves the adoption of agents as stated in the above sections. The agent architecture fulfils these needs allowing a quick simulation of different and complex scenarios in order to evaluate different alternatives and make the most convenient decision. In the following sub-sections the basic features of the proposed support system are detailed.

6.1 Multi-Agent Framework Software Architecture

Fig.1 describes the software architecture of the proposed tool following the well-known three-tier model. On the client side a dedicated Graphical User Interface (GUI) is provided to VDO personnel for managing the simulation system; in addition, different kinds of client applications are supported by the adoption of web standards. On the server side, a dedicated Web Service gives access to the multi-agent system managing the enterprise network. The multi agent system is hosted by one or more instances of the AgentService platform, which can be distributed over a computer network. This MAS uses a Relational Data Base Management System (RDBMS) to store all the data related to the enterprises profiles, the COs, and the bidding systems. All the features offered by this system are accessible through web service technology.

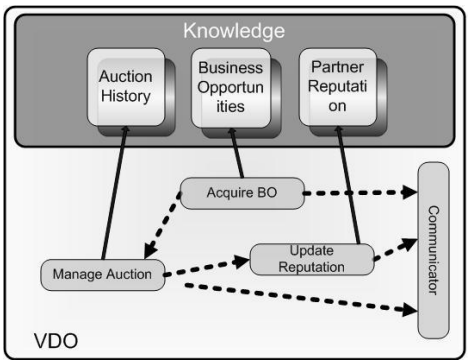
Fig.1: Software Architecture of the System.

6.2 The Enterprise Network Multi-Agent Model

The multi-agent system hosts the community of agents managing the ENs and is implemented by using one or more instances of the AgentService platforms. The proposed solution adopts a multi-agent model with a one-to-one correspondence agent-enterprise along with one agent representing the VDO. VDO agent manages CO data and arranges the auctions while Enterprise Agents (EA) take care of the enterprise indicators and manage the bidding process. According to the AgentService framework, each agents of the EN is modelled through concurrent behaviours whose activities are based on the agent knowledge as described by the following pictures.

The set of knowledge units describing the VDO agent's knowledge base are the following:

- Auction History: contains the data about the auctions enterprise participated to as bidder. This can be useful for statistics and to tune up winning function parameters.
- Collaboration Opportunities: contains all the COs detailed with BOMs, weights, and target costs. This information is used for supplier selection.
- Partner Reputation: contains the reputation indexes of all the partners.



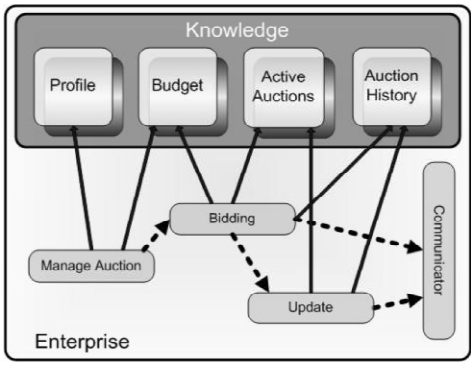


Fig.2: VDO and enterprise agent internal structure.

Each VDO agent is characterized by four different types of behaviour objects:
- Manage Auction: it is in charge of setting up auctions and interpreting the role of auctioneer. An external winning function is adopted in order to select best suppliers.
- Acquire CO: takes input data about new COs from a database or directly from a user thought a specific interface.
- Update Reputation: when new data about the work done by suppliers are available, it updates their reputation indexes.
- Communicator: is in charge of collecting and delivering messages among agents.

In the same way, Enterprise Agents can handle details about their capabilities (Profile), data and indication for bidding (Budget), actual and historical information about auctions (Active Auctions and Auction History knowledge items). On the basis of Profile and Budget information, Enterprise agents decide, by means of the Manage Auction behaviour, if it is convenient to participate to a given auction; as consequence they can drive bidding activities through the Bidding behaviour. At the end of each auction, result details are stored in the agent knowledge (Update). In next sub-sections the selection process and the auction interaction mechanism are detailed.

6.3 Enterprises Selection Process

In the proposed system the process for assigning a task to an enterprise is performed in an automatic way. The phase may involve two different main steps: an enterprise selection based on enterprises' indicators and a multi-step reverse auction. As described in section 2, three indicators characterize the CO along with the relative bill of material with its target costs. Starting from the CO definition enterprises are selected on the basis of their capabilities, KPIs, and reputation index. At first a preliminary selection on the internal suppliers is performed discarding all the enterprises which do not deal with any of the services indicated in the BO or any of the items involved in the COs' BOM. If no internal supplier is founded for covering a ring of the CO supply chain, a reverse auction is performed among external enterprises; the target cost indicated in the CO is the base price for the auction. After that, for each internal supplier, a function, (1), based on their KPIs is calculated and a top list of the best enterprises for the given CO is defined. The required steps for this evaluation phase are:

- For each supplier, sum of all the KPIs related to each dimension (cost, product, and customer). Notice that all the indicators are integer values in the range 1-10.
- Calculate the function F (1) which considers the supplier reputation index (RI), the KPIs, and the weights of the CO.

$$F = RI\ (w_{cost} \cdot kpi_{cost} + w_{product} \cdot kpi_{product} + w_{customer} \cdot kpi_{customer}) \quad (1)$$

- Rank the enterprises on the basis of F value and extract the list of the top n enterprises.

Once the top list is defined, VDO has the opportunity to make an additional selection involving also enterprises external to the network. This can be done through a reverse auction, which adopts as base price the target cost of the item. The auction process is detailed in the next section. At the end of the COs, the indicators and the reputation index are re-evaluated for each involved enterprises.

6.4 Agents Activities and Negotiation Process

Starting from a set of processes defined within a given CO, the VDO agent selects a list of enterprises following the selection process described in section 3.4. After that, the auction phase takes place. VDO agent makes a proposal for assigning COs' manufacturing activities to enterprises indicating the required the target costs along with the level of quality and the prospective deadlines. Each Enterprise agents can bid for a single process steps (single item of the BOM associated to the CO) or make a more complex offer, which include more processes. VDO agent is in charge of selecting the set of most suitable offers composing the received proposals. Each offer has to be evaluated considering the interested KPI and the reputation of the bidder enterprise. Initial enterprise reputation and key performance indicators are input information for the system, but can evolve according

to enterprise agent actions and real enterprise activity. The proposed negotiation protocol is an extension of the contract net [32] and envisages the presence of two kinds of roles the requestor - the initiator of the contract - and the participant – an enterprise having the capability required by the interested CO. VDO plays the role of requestor and drive the negotiation. The negotiation protocol is depicted in Fig.3. The analysis of all the steps forming the process for arranging a meeting follows:

- Step 0: the requestor sends to participants a CO proposal with the required target costs and indicators, and starts waiting for responses.
- Step 1: the selected enterprises and the external suppliers interested in participating in the CO check their available capacity, their costs, and make a proposal.
- Step 2: the requestor waits for proposals until the auction deadline, and then evaluates the received offers.
- Step 3: the requestor can accept a selected offer, ask for new offers or reject all proposals.
- Step 4: each participant can confirm the accepted offers, exclude these from the auction in case of rejection, or participate to a new bidding.

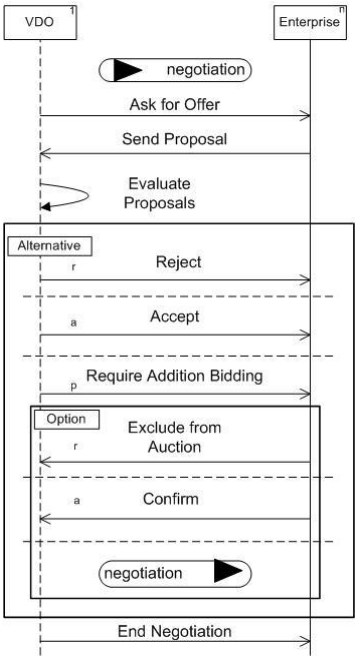


Fig.3: Negotiation Protocol

The bidding strategy for Enterprise Agents and the winning function of the VDO agent are open and can be customized in order to be compliant to the further objective function to be evaluated. The agent society within the framework is dynamic: new Enterprise Agents can join or leave the community at any time they want making the network auto-adaptive. The algorithm defining the protocol is implemented in the Manage Auction behaviour of the VDO and drives the negotiation accessing the CO knowledge. This negotiation protocol is a feasible and effective solution but it is possible to define new contract mechanisms for specific scenarios without changing the agent structure and the MAS architecture.

7 Case study definition and experimental campaign

The case study is based on a particular industrial enterprise network working in the printing and packaging sector in Italy. In this case study a VDO, named GPT, has been created. The aim of the experimental campaign is the validation of the decision support system and the tuning of parameters used inside the aforementioned enterprises selection functions according to bargaining mechanisms. In particular, two different CO derived from real opportunities arose in the network, have been analyzed. The first one is related to University Diplomas (UD) while the second one is related to an Art Catalogue (AC).

7.1 Collaboration Opportunity – University Diplomas

CO features: Italian Universities use to produce Diplomas internally. They are filled manually and signed by the Rector. This procedure is not a value added activity and it is time consuming for University staff. Moreover the student has to retire the Diploma personally at the University offices. The VDO-GPT identified such issue as a BO and decided to propose a new product/service system characterized as follow:

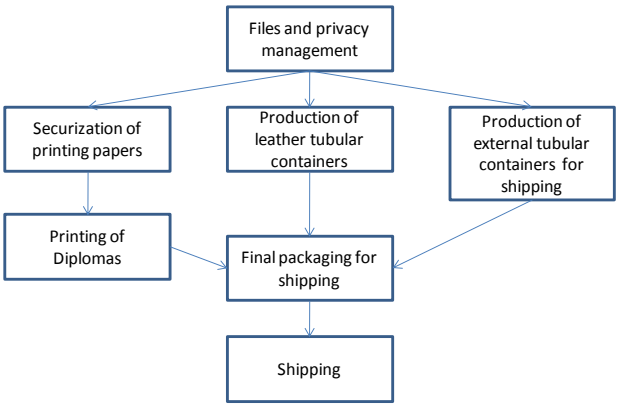


Fig. 4: UD/CO structure

This CO can be classified as follows:

- Product Focused 0,8
- Customer Focused 0,1
- Cost Focused 0,1

The proposed product/service is featured by some innovative components (digital printing, secured paper with logo, leather tube, privacy management, postal service management).
According to the proposed approach, in order to select the Enterprises participating the VE, the following factors have to be evaluated:

- Privacy management (Boolean),
- Secured ink printing on secured paper (Boolean),
- Cylindrical tube production; minimum cost bidding,
- Postal service; minimum cost auction,
- Secured paper; minimum cost auction.

7.2 Collaboration Opportunity – Art Catalogue

This CO is featured by the design and realization of an Art Catalogue starting from indications provided by the customer in a not formalized form. The VDO-GPT identified such issue as a BO, characterized by the following activities:

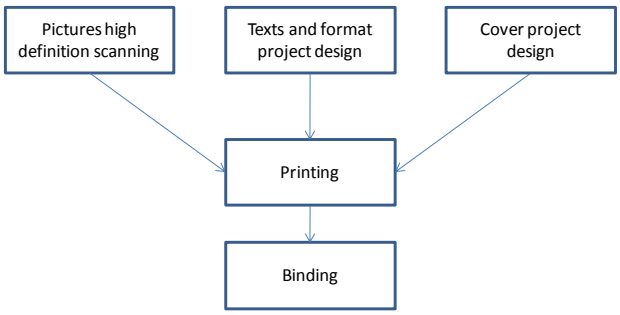


Fig. 4: AC/CO structure

The printing process is based on two possible technologies: the offset printing and the digital printing. The first one has a greater printing quality but costs and difficulties are higher for small lots. The second one has a minor printing quality but it can be executed even for one-piece lot. Considering the EN only three enterprises have the capabilities to perform these technologies.

- Company A: digital printing technology.
- Company B: offset printing technology and good competitiveness for large production lots.
- Company C: Offset printing technology and good flexibility with respect to Company B and more competitive on medium size lots.

Theoretically speaking the most suitable Company to execute the printing phase is Company C. From the market point of view the CO can be classified as follows:

- Product Focused 0,8
- Customer Focused 0,1
- Cost Focused 0,1

7.3 Enterprises selection procedure

The following steps describe the selection procedure:

1. The selection is made, initially, inside the EN.
2. Boolean values can be used like Boolean constraints to perform a pre-selection of those Enterprises invited to participate to the bidding phases and to identify product/services to be performed internally or externally the EN.
3. For those Enterprises belonging to the EN the sum of cost, product and customer orientation KPIs is calculated[2].
   a. For the internal Enterprises previously selected, the value of the different KPIs is multiplied for the RI in order to calculate F according to the (1).
   b. Enterprises are re-ordered according to a descending value of F and from this ranked list a top list is created. The Enterprises included in this top list are invited to participate to a dutch auction.
4. The VDO starts the dutch auction phase for internal and external Enterprises (e.g. in the AC/CO an external Company D participates the auction) proposing a target cost for the required product/service.
5. The VDO decides for the winning bidder.
6. The VDO assigns the task.
7. At the end of the task execution the VDO checks, and eventually redefines, the RI and declared KPIs, for each Enterprise that performed the task.

7.4 Results

The performed tests have been reported and compared with the expected ones; the first three

[2] The identification of a value between 1-10 for each KPI is a critical step because no objective criteria have been defined in order to assign that value functionally to real features and metrics of each subject. The subjectivity of these values makes the subject, assigning the score, a determinant player capable to influence partially the decisional process. In the reality, this process has been performed by management people of the VDO.

tests refer to the UD/CO while the last one refers to the AC/CO. The tests have been structured as follows.

Test 1: Analysis of the result of the selection process and specifically the variance of the BO realization cost with respect to the variability of CO parameters (focus on Product, Customer, Cost). The range of weight values has been set to high when greater than 0,9, medium when greater than 0,5, and low when smaller than 0,1. To this end the test outlines the relations between CO parameters weights and the results obtained from the selection process. For example changing the orientation of the CO toward the cost it is expected to privilege those Enterprises featured by low costs. In table 1 (see appendix A), have been outlined the KPIs of the Enterprises showing differences of orientation with respect to the three factors: cost, customer and product. In Table 2, instead, the relationship between CO weights and realization cost is reported.

Test 2: Analysis of the Enterprise selection process results and in particular the realization cost of a CO by varying the market competitiveness (high, average, low). This test tries to validate the relationship between market competitiveness, selected Enterprises, and CO realization cost. In this case by increasing the market competitiveness a greater selection of external Enterprises is expected with the lowering of the CO realization cost. These results are reported in Table 3.

Test 3: Analysis of the Enterprises selection process by varying the RI value to validate the exclusion mechanism for those Enterprises featured by low RI values. In Table 4 all the Enterprises have a RI value equal to 5 while in Table 5, COMPANY A and COMPANY B have the RI value equal to 1.

Test 4: Analysis of the Enterprises selection process by varying the RI only for some of them. This variation, differently from the previous tests, simulates the ex-post evaluation of the quality and conformity of the supplied product/service. For this particular test the AC/CO is used. The realization of the AC requires a printing phase that can be executed by using two different technologies. A first simulation of the selection process shows a preference in choosing Enterprises capable to perform a digital printing (economically expensive but with greater quality), also when the CO is configured to favour the quality instead of the cost. This situation can be explained because some Enterprises can perform both technologies (digital and offset), see Table 6. By the way, the second simulation corrects this problem as expected, by varying the RI of COMPANY A (first proposal of digital printing), from the original value of 5 to the new value of 1, accordingly to the low quality certified at the end of the first realization. In this second simulation the COMPANY C is the winning bidder (see Table 7).

8 Discussion and strategic issues

The situation is such that the actors (firms, and some form of centralized "authority", with coordination goals, the VDO) will have a lot of strategic variables on which they can operate. In particular it is difficult to see which could be the overall goal of the VE: otherwise said, it is not clear which is the social welfare choice that should be implemented (considering simply the profit means that one does not take into account the diverse strategic goals of the different firms involved in the VE). Some more flexible and decentralized systems should be used: information available on the strategic choices, on the unknown parameters, on the long term and strategic goals of the firms is not enough to develop a reasonably efficient scheme. The typical possibility is to mix some kinds of centralized discussion (bargaining) together with some bidding system, tailored as much as possible for the situation under exam. The main idea could be the following. Assume, for sake of simplicity, that some BO has been found by the VDO, and converted in CO (we assume that there is a given mapping of available capabilities). This means that, based on the knowledge of the EN system, there is the possibility of joining efforts to achieve some specified goal (e.g.: produce a specific product for a specific market). We imagine that there is an initial open discussion whose outcome is the listing of some (at least one) possibility of arranging the existing expertise to exploit the CO. Based on this, a bidding procedure is open. It would be a combinatorial auction, where each firm will make an offer for a "piece" of the production process, stating the relevant characteristics of its contribution, including the price that it demands for it. At the end, offers are examined and it is seen whether there is at least one combination of offers that makes possible the exploitation of the CO. If yes, the best (according to some pre-specified criterion) offer is selected. If not, some further open discussion is opened, to see whether, on the basis of the available information, some new possibility to catch the CO is open.

From the practical point of view, it is being improved the proposed tool to better help the VDO in its decision making process.
The improvements would consist in common operative capabilities to perform three different, related, tasks:

- Facilitation of the preliminary negotiation process;
- Operating automatically the aforementioned combinatorial auctions;
  Modifying, adding, and evolving the agents, modelling the Enterprise Network, that interested enterprises can use to simulate the two previous tasks.

The VDO decisional process is based on relationships of authority and a priori defined hierarchy. Particularly the authority transfer to other subjects in terms of typology and responsibility greatly influences the cooperation and the negotiation process. In order to reduce the authority conferred to decision-makers are required exit rules to quit the virtual community. An other possibility is to promote collaboration proposals trough criteria such as consensus, majority, and negotiation. This last aspect gives greater warranties to the single Enterprise but increases the transaction cost. The proposed business model is based on relationships stability and in particular focuses on the following aspects:

- A priori duration and entering/quitting rules,
- Safety and privacy of specific investments,
- Individual discount factor for each Enterprise,
- Enterprise composition in the EN,
- Complementary degree with respect to products, services, processes, selling markets, human capital and relationships,
- Organizational, productive, and financial structure.

The decisional process is based on a knowledge that can be more or less symmetric about some strategic information like:

- Reference markets,
- Long/medium/short term objectives.

The symmetry/asymmetry of information derives from the diffusion modes as well as from its verification, and warranty. These are all aspects not considered by the proposed system, only influenced in terms of informative availability used to support the decisional process. Using the game theory, in an appropriate way, it is possible to provide useful strategic information to define and conduct the process to face the strategic negotiation phases. The interaction system described in this work is related to the "bargaining problems". The classic approaches, from axiomatic classification of solutions proposed by Nash [33] to the alternative offers model of Rubinstein [34], don't seem appropriate tools for this context, because these models have been formulated supposing a complete information of the system (this information instead, is incomplete or asymmetric in the proposed work). Furthermore, because the Enterprises belonging to the EN show complementary and competitive aspects at the same time, it would be ingenuous to assume that Enterprises would provide freely private information about their activities (i.e. production processes, know-how, marketing opportunities, …).
For these reasons incentive standard problems should be included to build a theoretically correct structure. An adequate incentives schema should be applied in order to reduce the temptation to declare false capabilities or performance.

9 Conclusions

In this paper we pointed out the increasing importance of an interconnected business environments, especially to foster SMEs competitiveness. After an introduction to the issue, presented in the form of a case study, Authors analysed some key dimensions that can be used to classify networks: an input-output structure; a governance structure; a geographical configuration; a social and institutional context. Using these dimensions we proposed a new organizational model based on the figure of the VDO, an institutional subject, acting as a lead actor in an enterprises community. The organizational model proposed aim to go over the typical limitations of a VE while maintain its main strength. At the same time it opens a new critical aspect for its management and for the definition of the optimal environment in which it should and could be adopted. The VE coordination and collaboration activities require complex decision-making process. Hence, Authors developed a decision support tool based on a multi-agent system able to collect and store the contribution of every actor in the EN after a control of the execution of the planned activities. Multi Agent-Based Systems showed many interesting features for modelling open and distributed systems like enterprise networks. By referring to the new approach proposed in the paper the VDO could accomplish this task through the selection and negotiation activities starting from different perspectives (Cost, Product, and

Customer). The developed model allows a scenario analysis with respect to enterprises' features, capabilities, performance, and facilitates VDO personnel in making a convenient choice timely and reliably. The experimental campaign shows that this decision support system is capable to address real and practical problems thanks to the CO definition and the Enterprises selection process simulation. The possibility to interact with the system over more sequential simulation allows a tactical control of the subjects modelled and their interactions. Interesting strategic issues related to knowledge and profit sharing arose from the modelling and the in-progress application phase. From the strategic point of view this approach should be further studied in order to improve bidding mechanism and negotiation approach.

APPENDIX A

Table 1 – Enterprises KPI

Name	Cost	Cycle Time	Compliant To Standards	Production Capability	Responsiveness	Claims Handling
COMPANY A	8	8	8	8	1	1
COMPANY B	1	1	1	1	8	8
COMPANY C	1	1	1	1	1	1

Name	Customer Based Technology	Product Knowledge	Num Of New Products In The Pipeline	Time To Market	Customization	Flexible Technology	Reputation Index
COMPANY A	1	1	1	1	1	1	5
COMPANY B	8	8	1	1	1	1	5
COMPANY C	1	1	8	8	8	8	5

Enterprise_ID	Risk Index	VC Inv Level	VDO Inv Level	Production Saturation Level
COMPANY B	1	1	1	10
COMPANY C	3	3	3	3
COMPANY A	10	10	10	1

Table 2 – Relationship between CO weights and realization costs

Cost	Customer	Product	Total Unit Cost
0,1	0,1	0,1	108,2842105
0,1	0,1	0,5	108,2842105
0,1	0,1	0,9	108,2842105
0,1	0,5	0,1	43,48421053
0,1	0,5	0,5	108,2842105
0,1	0,5	0,9	108,2842105
0,1	0,9	0,1	43,48421053
0,1	0,9	0,5	108,2842105
0,1	0,9	0,9	108,2842105
0,5	0,1	0,1	43,48421053
0,5	0,1	0,5	43,48421053
0,5	0,1	0,9	43,48421053
0,5	0,5	0,1	43,48421053
0,5	0,5	0,5	108,2842105
0,5	0,5	0,9	108,2842105
0,5	0,9	0,1	43,48421053
0,5	0,9	0,5	108,2842105
0,5	0,9	0,9	108,2842105
0,9	0,1	0,1	43,48421053
0,9	0,1	0,5	43,48421053
0,9	0,1	0,9	43,48421053
0,9	0,5	0,1	43,48421053
0,9	0,5	0,5	43,48421053
0,9	0,5	0,9	43,48421053
0,9	0,9	0,1	43,48421053
0,9	0,9	0,5	43,48421053
0,9	0,9	0,9	108,2842105

Table 3 – Enterprises selection functionally to the market competitiveness

Market Competitiveness	CO_ID	Product	Enterprise_ID	F-Value	Offer
Average	UD/CO	Internal Container	COMPANY C	16,9	2
Average	UD/CO	Internal Container	Market	0	1,5869465
Average	UD/CO	Diplomas	COMPANY A	27,1	0,96
Average	UD/CO	Diplomas	COMPANY B	28,3	0,1578947
Average	UD/CO	Diplomas	Market	0	0,7934733
Average	UD/CO	External Container	COMPANY C	16,9	1
Average	UD/CO	External Container	Market	0	0,7934733
Average	UD/CO	Secured Paper	Market	0	2,3804198
Average	UD/CO	Postal Service	Market	0	6,3477861
Average	UD/CO	Label	COMPANY A	27,1	0,96
Average	UD/CO	Label	COMPANY B	28,3	0,1578947
Average	UD/CO	Label	Market	0	0,7934733
TOTAL COST					***17,931362***
Low	UD/CO	Internal Container	COMPANY C	16,9	2
Low	UD/CO	Internal Container	Market	0	2,8181745
Low	UD/CO	Diplomas	COMPANY A	27,1	0,96
Low	UD/CO	Diplomas	COMPANY B	28,3	0,1578947
Low	UD/CO	Diplomas	Market	0	1,4090872
Low	UD/CO	External Container	COMPANY C	16,9	1
Low	UD/CO	External Container	Market	0	1,4090872
Low	UD/CO	Secured Paper	Market	0	4,2272617
Low	UD/CO	Postal Service	Market	0	11,272698
Low	UD/CO	Label	COMPANY A	27,1	0,96
Low	UD/CO	Label	COMPANY B	28,3	0,1578947
Low	UD/CO	Label	Market	0	1,4090872
TOTAL COST					***27,781185***
High	UD/CO	Internal Container	COMPANY C	16,9	2
High	UD/CO	Internal Container	Market	0	0,8174312
High	UD/CO	Diplomas	COMPANY A	27,1	0,96
High	UD/CO	Diplomas	COMPANY B	28,3	0,1578947
High	UD/CO	Diplomas	Market	0	0,4087156
High	UD/CO	External Container	COMPANY C	16,9	1
High	UD/CO	External Container	Market	0	0,4087156
High	UD/CO	Secured Paper	Market	0	1,2261468
High	UD/CO	Postal Service	Market	0	3,2697247
High	UD/CO	Label	COMPANY A	27,1	0,96
High	UD/CO	Label	COMPANY B	28,3	0,1578947
High	UD/CO	Label	Market	0	0,4087156
TOTAL COST					***11,775239***

Table 4 – Enterprises selection functionally to the Reputation Index (case with RI=5 for all the Enterprises)

CO_ID	Product	Enterprise ID	F-Value	Offer
UD/CO	Internal Container	COMPANY C	84,5	2
UD/CO	Internal Container	Market	0	2,451382
UD/CO	Diplomas	COMPANY A	135,5	0,96
UD/CO	Diplomas	COMPANY B	141,5	0,157895
UD/CO	Diplomas	Market	0	1,225691
UD/CO	External Container	COMPANY C	84,5	1
UD/CO	External Container	Market	0	1,225691
UD/CO	Secured Paper	Market	0	3,677073
UD/CO	Postal Service	Market	0	9,805528
UD/CO	Label	COMPANY A	135,5	0,96
UD/CO	Label	COMPANY B	141,5	0,157895
UD/CO	Label	Market	0	1,225691

Table 5 – Enterprises selection functionally to the Reputation Index (case with COMPANY A and COMPANY B with RI=1 and COMPANY C with RI=5)

CO_ID	Product	Enterprise ID	F-Value	Offer
UD/CO	Internal Container	COMPANY C	84,5	2
UD/CO	Internal Container	Market	0	2,448212
UD/CO	Diploma	COMPANY A	135,5	0,96
UD/CO	Diploma	COMPANY B	100	1,333333
UD/CO	Diploma	Market	0	1,224106
UD/CO	External Container	COMPANY C	84,5	1
UD/CO	External Container	Market	0	1,224106
UD/CO	Secured Paper	Market	0	3,672318
UD/CO	Postal Service	Market	0	9,792849
UD/CO	Label	COMPANY A	135,5	0,96
UD/CO	Label	COMPANY B	100	1,333333
UD/CO	Label	Market	0	1,224106

Table 6 – Enterprises selection functionally the RI with alternative capabilities (case with all Enterprises featured by a RI = 5)

CO_ID	Product/Service	Enterprise ID	F-Value	Offer
AC/CO	High resolution scanning	Market	0	1,4
AC/CO	Contexts Definition	Market	0	1,4
AC/CO	Executive on CD	COMPANY C	111	0,15
AC/CO	Executive on CD	COMPANY B	100	1,333333
AC/CO	Executive on CD	Market	0	1,4
AC/CO	Catalogue Design and Printing	COMPANY D	92,5	0,176471
AC/CO	Catalogue Design and Printing	COMPANY A	135,5	0,96
AC/CO	Catalogue Design and Printing	Market	0	1,4
AC/CO	Printed Material	COMPANY B	100	1,333333
AC/CO	Printed Material	COMPANY A	135,5	0,96
AC/CO	Printed Material	Market	0	1,4

Table 7 – Enterprises selection functionally the RI with alternative capabilities (case with COMPANY A featured by a RI = 1 and COMPANY B, C, D with RI=5)

CO_ID	Product/Service	Enterprise ID	F-Value	Offer
AC/CO	High resolution scanning	Market	0	1,4
AC/CO	Contexts Definition	Market	0	1,4
AC/CO	Executive on CD	COMPANY C	111	0,15
AC/CO	Executive on CD	COMPANY B	100	0,166667
AC/CO	Executive on CD	Market	0	1,4
AC/CO	Catalogue Design and Printing	COMPANY D	92,5	0,176471
AC/CO	Catalogue Design and Printing	COMPANY A	27,1	0,96
AC/CO	Catalogue Design and Printing	Market	0	1,4
AC/CO	Printed Material	COMPANY D	92,5	0,176471
AC/CO	Printed Material	COMPANY B	100	0,166667
AC/CO	Printed Material	Market	0	1,4

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