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A Supporting Model for the Dynamic Formation of Supplier Networks

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Abstract. Supply chains have become an important focus for competitive advantage. The performance of a company increasingly depends on its ability to maintain effective and efficient relationships with its suppliers and customers. The extended enterprise (i.e. composed of several partners) needs to be dynamically formed in order to be agile and adaptable. According to the Digital Manufacturing paradigm, companies have to be able to quickly share and disseminate information regarding planning, designing and manufacturing of products. Additionally, they must be responsive to all technical and business determinants, as well as be assessed and certified for guaranteed performance. The current research intends to present a solution for the dynamic composition of the extended enterprise, formed to take advantage of market opportunities quickly and efficiently. A protocol model has been elaborated and inspired in the OSI reference model with reference to the Supply Chain Operations Reference model (SCOR®). This model provides a framework for linking customers and suppliers. It is presented in the form of seven layers that relate to steps for negotiating the participation of candidate companies in the dynamic establishment of a network for responding to a given demand for developing and manufacturing products, as follows: request for information; request for qualification; alignment of strategy; request for proposal; request for quotation; compatibility of process; and compatibility of system. An information model has been defined based on the concepts of SCOR® as well. The protocol model has been implemented by means of process modeling according to the BPMN standard and, in turn, implemented as a web-based application that runs the process through its several steps, which uses forms to gather data. An application example in the context of the oil and gas industry is used for demonstrating the solution concept.

Keywords. Supply chain. SCOR. Model-based enterprise.

1. Introduction

Supply chains have become an important focus for competitive advantage. The performance of a single company increasingly depends on its ability to maintain effective and efficient relationships with suppliers and customers [1]. Extended Enterprise is the most descriptive term highlighting managerial aspects of

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intraorganizational collaboration [2]. In this context, the Intelligent Manufacturing Research Program, inspired in IMTI's challenges for manufacturing in the 21st century [3] and implemented at UTFPR, has pointed out several demands, among which the need to develop models for dynamically establishing supplier networks is dealt in the current research project. It proposes a scenario of great agility and adaptability, where an extended enterprise is evaluated, certified for assured performance and built from numerous best-in-class suppliers. Its operation would allow information sharing, cost-effective and accelerated design, and optimized manufacturing processes.

One of the core problems in the dynamic formation of supply chains is the proper selection of partners to realize the goal of the whole network. Developing appropriate supply chain strategies that align effective supply chain practices with information quality can be challenging [1], as stakeholders from the supply and demand side are brought together to share and understand design information [4].

Most of the research studies conducted with in the major topic of supply chain formation focus on costs. Kim and Cho [4] present a method for the supply chain formation problem by using negotiation agents for information sharing. Both internal and external factors are considered for making a decision. All members are rewarded simultaneously and thus consequently accelerate performance of the whole supply chain. This enables resource allocation and pricing to be made more efficiently. Negotiation is grounded in costs, which is verified with suppliers and manufacturers. Best combinations are chosen as to obtain lower cost values. Kim and Segev [5] propose a mechanism, named Multi-Component Contingent Auction (MCCA) for combining the suppliers with the minimum total cost. A major problem in MCCA is the number of computations required for winner determination.

The current research intends to present a solution for the composition of the extended enterprise, formed to take advantage of market opportunities quickly and efficiently. The research aims to answer the following question considering the above problems: what would a model, which can be used for dynamically forming supplier networks, look like? This work has as contribution a proposal of protocol model, information model and process model.

The present article is structured as follows: Section 1 presents introduction, Section 2 shows theoretical background, Section 3 details the methodological aspects, Section 4 shows results and discussion and Section 5 presents conclusion.

2. Theoretical Background

The extended enterprise (EE) framework arose in high-tech industries with large chains of suppliers to face the current challenges related to innovation and competition in complex scenarios [6]. EE is defined as a long-term cooperation and partnership based on information and knowledge exchange and the coordination of the manufacturing activities of collaborating independent enterprises and related suppliers. Enterprise modeling is considered as the process of building models from the whole or part of the enterprise such as process models, data models, resource models etc [7].

In this context, different modeling approaches such as OSI, SCOR and BPMN can be combined and applied. OSI is a standard description or a reference model. It is a conceptual blueprint of how communication should take place. On the other hand, SCOR is a supply chain reference model with standardized terminology and processes.

And BPMN is a standard notation for capturing business processes and graphically representing them. These approaches are detailed in the following sections.

2.1. OSI Model

ISO (International Organization for Standardization) introduced the OSI (Open System Interconnection) standard in 1984. The model is thought to contribute to make network troubleshooting faster and easier [8].

OSI is a standard description or a reference model for defining how messages should be transmitted between any two points in a telecommunication network. A reference model is a conceptual blueprint of how communication should take place. It addresses all the process required for effective communication and divides these processes into logical grouping called layers. When a communication system is designed in this manner, it is known as layered architecture. OSI isn't a physical model, though. Rather, it's a set of guidelines that application developers used to create and implement application that run on a network. It also provides a framework for creating and implementing networking standards, devices, and internetworking schemes [9].

2.2. SCOR

The Supply Chain Operations Reference model (SCOR®) is the product of Supply Chain Council, Inc. (SCC) a global non-profit consortium whose methodology and benchmarking tools help organizations make dramatic and rapid improvements in supply chain processes. SCC membership is open to all companies and organizations interested in applying and advancing the state-of-the-art and practices [10].

SCOR is a reference model with standardized terminology and processes. It was first defined in 1996. Since then, several companies have adopted the SCOR model and methodology [11]. SCOR provides a unique framework that links business process, metrics, best practices and technology into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities [10].

Currently, SCOR is in Version 11.0. Revisions of the model are made when it is determined by SCC members that changes should be made to facilitate the use of the model in practice. The SCOR model has been associated with phases for fulfilling a customer's demand and is organized around six primary management processes: Plan, Source, Make, Deliver, Return and Enable [10].

2.3. BPMN

Business Process Model and Notation (BPMN) is the *de facto* standard for representing, in a very expressive graphical way, the processes occurring in virtually every kind of organization [12]. BPMN is a standard notation for capturing business processes, especially at the level of domain analysis and high-level systems design [13].

To get more agility and efficiency, a higher degree of automation is required [14]. Software Tools are used for the representation of BPMN. Bonita, a software suite, has been pointed out as one of the best open-source software for modeling and publishing BPMN 2.0 processes, based on a survey conducted with members of a LinkedIn group related to BPMN [12].

3. Methodological Aspects

The present work has been conducted in three phases, as described by the flowchart in Figure 1. In phase 1, literature research was carried out on topics OSI model, SCOR and BPMN.

In phase 2, a protocol model was drawn up. This protocol model is a diagram that indicates the steps to be followed in order to select companies as suppliers. Next, requirements and information important to assess suppliers were defined, based on SCOR, resulting in an information model. Still in this phase, the negotiation process was modeled in BPMN with the community edition of software tool Bonita [15], which allows its implementation in a web-like environment.

In phase 3, a product related to the oil and gas industry was selected as an application example. Information regarding the singularity of this context was gathered, to be used as an application example. A simulation of the modeled process was carried out using the automated process created in Bonita, from the moment a given demand is initiated by the customer, until the selection of suppliers is accomplished. In phase 4 the analysis of results was carried out.

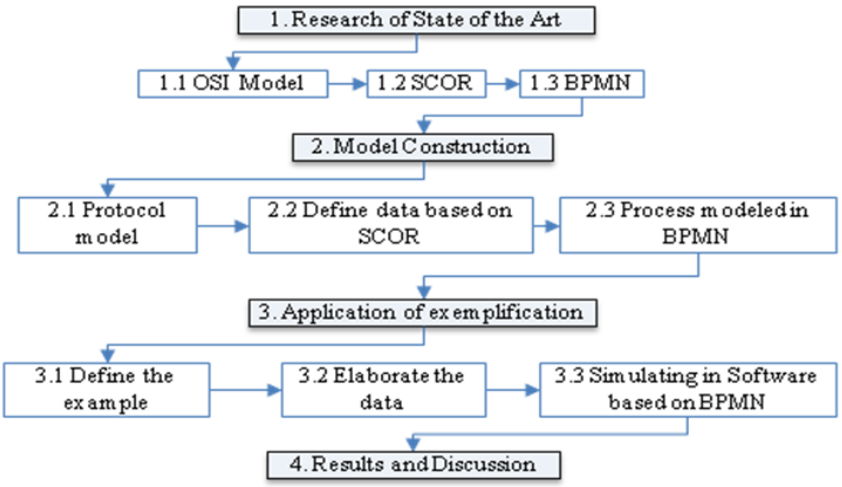

Figure 1. Flowchart of research activities.

4. Results and Discussion

The resulting protocol model provides a framework for linking customers and suppliers. This protocol model, as represented in Figure 2, has been elaborated and inspired in the OSI reference model. In this model, 7 layers were defined: Request for information; Request for qualification; Alignment of strategy; Request for proposal, Request for quotation, Compatibility of process; and Compatibility of system.

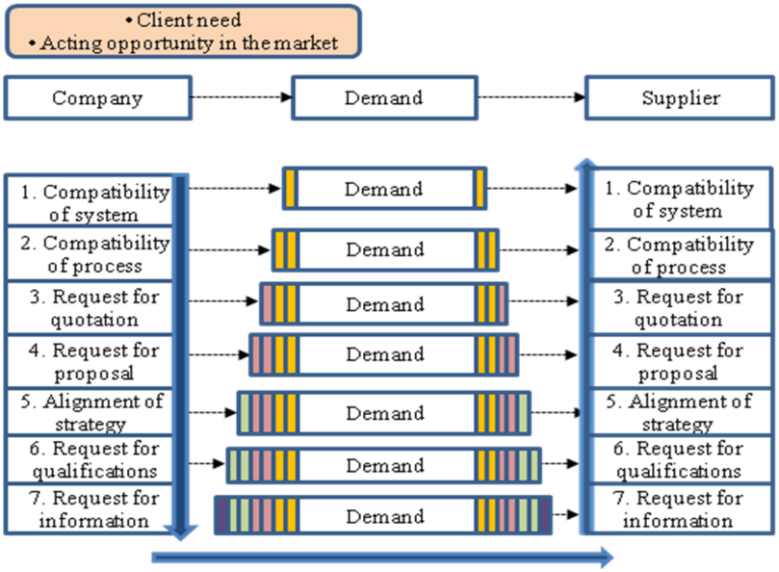

Figure 2. Protocol Model.

The layers in the protocol model represent the steps for negotiating the participation of candidate companies in the dynamic establishment of a network for responding to a given demand for the development and manufacturing of products. Candidate companies can move on to the next step each time they are approved, until they are finally approved to fulfill demand. A brief explanation of each layer follows:

- Request for information (RFI): in this step information is collected about which products and services are to be provided, in order to verify whether they meet a business need;
- Request for qualification (RFQ): in this step, information is collected on the qualifications of suppliers, specifically certifications for the production processes; and if environmental issues are to be fulfilled;
- Alignment of strategy: in this step information is verified about mission, vision and values of the supplier, and if they are aligned with the customer company;
- Request for proposal: in this step information is verified about the companies' history, financial information, expertise, compliance with technical specifications and time-to-supply requirements;
- Request for quotation: in this step, prices of products or services are checked;
- Compatibility of process: in this step, information is collected on the compatibility of production processes;
- Compatibility of system: in this step, information related to the compatibility between IT systems is checked.

The contents of the negotiation with the supplier are based on the Supply Chain Operations Reference model (SCOR®). As a result, an information model for all negotiation steps has been built. For example, Table 1 describes the information model developed for layer Alignment Strategy.

Process mapping was performed according to BPMN. The following activities were modeled: Demand presentation by the client; Receipt and analysis of demand; Definition of specifications related to product and process; as well as the steps involved in the supplier selection.

Table 1. Information model of the layer named Alignment Strategy.

Alignment Strategy				
SCOR	**Subject**	**Description of the question**	**Question**	**Options Answer**
HT.0026	Company Policies	Describe the company policies	Company Policies	Text
	Mission	Describe the mission	Mission	Text
	Vision	Describe the vision	Vision	Text
HS.0045	Environmental Requirements	Requirements implementation consist of familiarity and understanding of internal and external goals, objectives, rules and laws pertaining to the operation of the Source function within the organization.	Are the Environmental Requirements implemented?	* Yes, the system is implemented; * It is used some principles; * No, but it is in process of implementation; * No, it isn't implemented.
HS.0041	EHS Regulations	EHS Regulations involve actions, tasks, and responsibilities concerned with the observance and application of the environment, health, and safety rules and standards.	Are the EHS Regulations implemented?	
HS.0157	Warranty Process And Policy	Warranty Process And Policy involve actions, processes, rules aiming at regulating the commitment of a party about the performance/quality features of its products and services to its customers.	Are the Warranty Process And Policy implemented?	
SE1	Manage Supply Chain Business Rules	Manage Supply Chain Business Rules is the process of establishing, documenting, communicating and publishing supply chain business rules. Business rules can apply to people, processes, corporate behavior and computing systems in an organization, and are put in place to help the organization achieve its goals.	Is the Manage Supply Chain Business Rules implemented?	
HS.0050	Import Export Regulations	Import Export Regulations involve the knowledge and understanding of the laws and regulations governing the import and export requirements of materials including working with the states, other federal agencies, and foreign governments to ensure compliance with them.	Are the Import Export Regulations implemented?	
HS.0139	Supplier Relationship Management	Supplier Relationship Management is the process of working collaboratively with suppliers vital to the organizational success to maximise the potential value of those relationships.	Is the Supplier Relationship Management implemented?	

The overall process was then broken into subprocesses: Demand; RFI; RFQ; Alignment Strategy; Request for Proposal; Request for Quotation; Compatibility of Process; and Compatibility of System. The resulting business process model is presented in Figure 3.

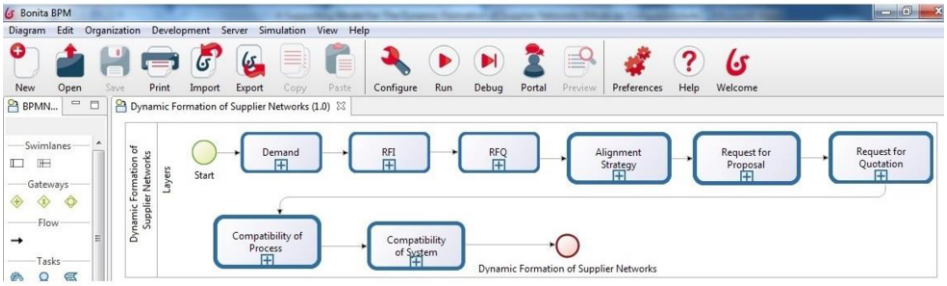

Figure 3. Overall process model.

Next, the subprocesses were detailed and are the individual tasks are assigned to actors, as represented in Figure 4. It is the possible to include forms related in the tasks, Figure 5, which directly map to the information model created previously.

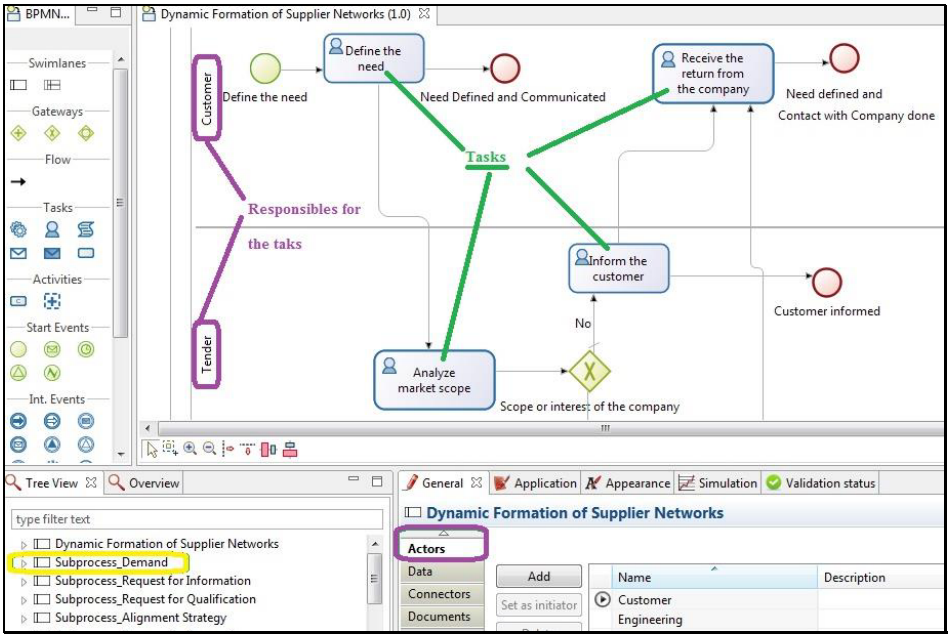

Figure 4. Representation of tasks, actors in a subprocess.

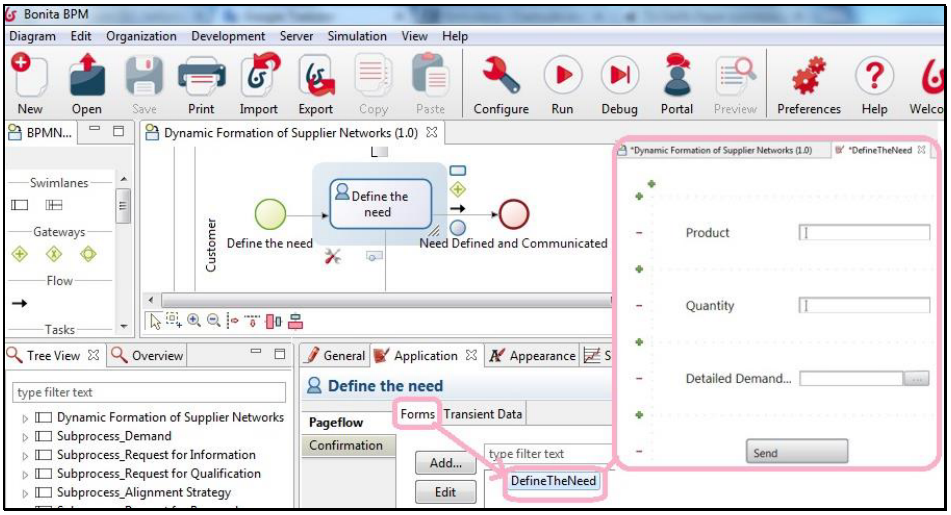

Figure 5. Inclusion of forms associated with tasks.

After the process and subprocesses are modeled, and tasks, actors and forms are defined, it is possible to “run the process” in the form of a web portal as depicted in Figures 6 and 7.

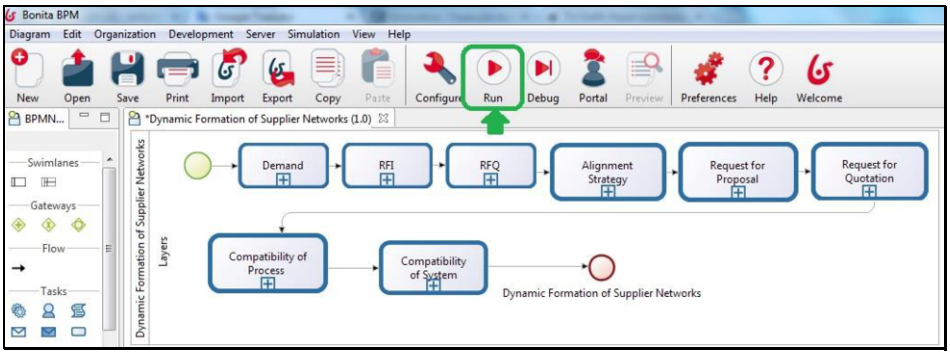

Figure 6. "Running" the process.

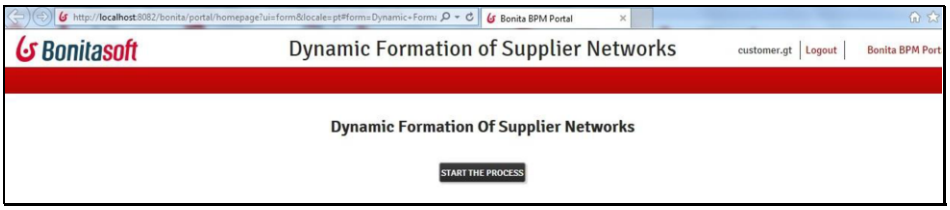

Figure 7. Starting the process.

An application of the process and information model was conducted. For that purpose, a common product in the oil and gas industry was selected: a transportation skid. In this case, a transportation skid is to be designed to interface with the Ocean Epoch's skidding system [16].

In the first step of the example, the customer accesses the web portal and defines the demand. The customer can describe the product, quantity and upload a file with details of the demand in order to assist the analysis that will follow.

The next task is performed by the tender professional, who examines whether the customer proposal is part of the company's scope of action. The actor, tender professional, accesses the data and indicates if the opportunity is related to the scope of the company. If the opportunity isn't related to the company then the tender professional sends a message to the customer through the portal and the customer can access the answer. If the opportunity is related to the company, the next task is sent to Engineering, who decides if it is technically feasible. If so, then the process proceeds through the tasks related to product and process specifications as accountable actors get engaged and respond.

With the defined specifications, the company starts to contact candidates to become suppliers. The negotiation is performed through tasks and access through the web portal. In this step the supplier fills in the forms with the required information for each step. And after a procurement professional examines the information, selects the option if the supplier is approved for the next step or not. If the supplier isn't approved for the next step, the procurement professional sends a message to the supplier that can be accessed via the web portal. If the supplier is approved for the next step, a new task becomes available for accomplishment.

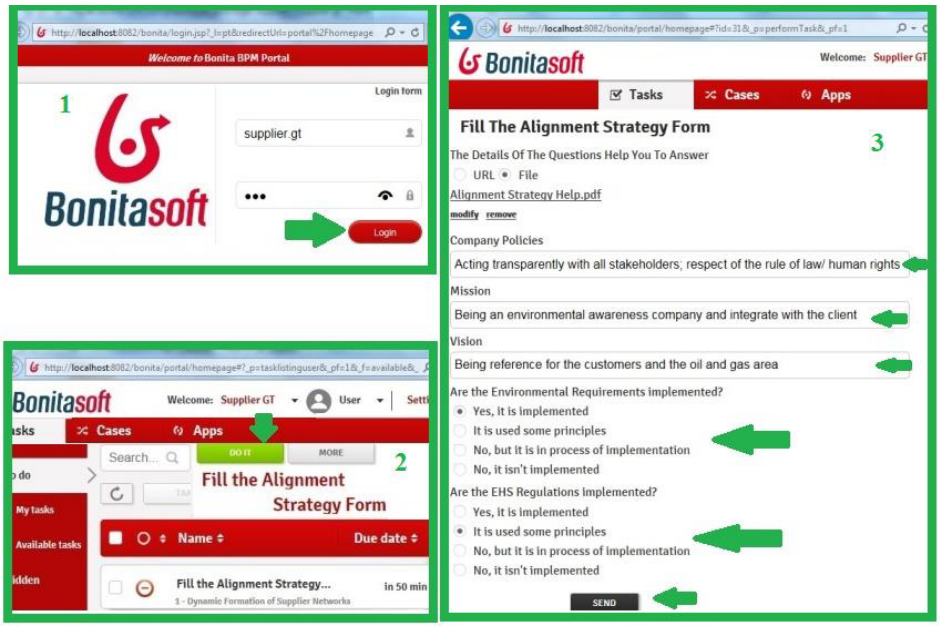

Figure 8. Tasks related to Supplier - Subprocess Alignment Strategy.

Figures 8 and 9 show the negotiation of step Alignment Strategy. Figure 8 shows tasks (1, 2, 3) accomplished by the supplier, whereas Figure 9 shows tasks (4, 5, 6, 7, 8) accomplished by the procurement professional. After all subprocesses are completed and a given supplier may actually be considered part of the network to be engaged in a given demand.

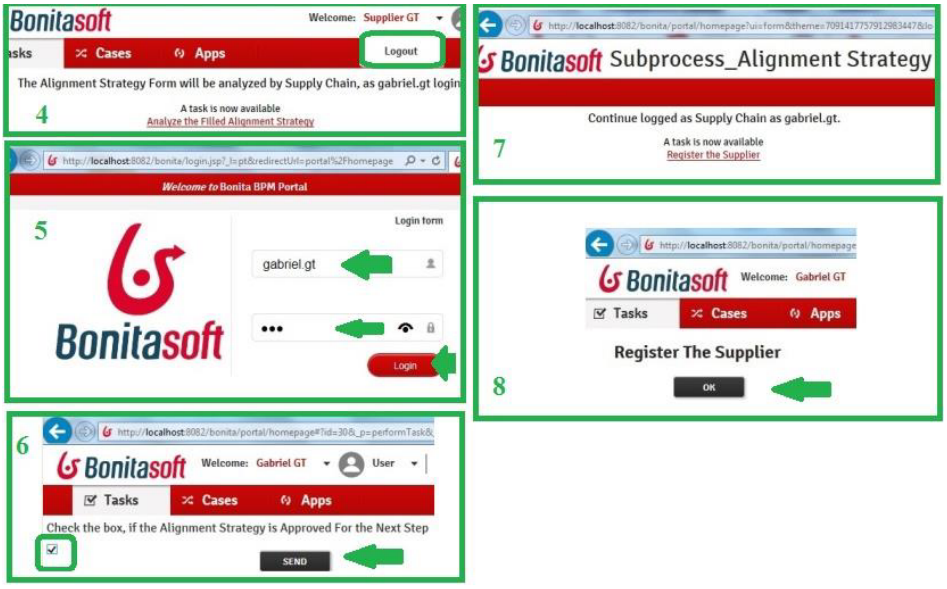

Figure 9. Tasks in subprocess Alignment Strategy, to be assigned to Procurement.

5. Conclusion

In the present work, a layered protocol model has been developed to support the dynamic formation of supply networks, triggered by a given demand. As negotiation advances in steps, information about the demand is only revealed as needed, and completely exposed once the selection of suppliers is complete.

Using SCOR as a basis for building the information model allows companies to develop internal procedures that support standards for supply chain operations. In addition, BPMN can support such standards and allow integration of processes in customers and suppliers within the Extended Enterprise. Modeling business processes in tools like Bonita also allows the direct creation of software applications that are driven by customized processes.

Nevertheless, some limitations have been identified as to how adherent to BPMN tools such as Bonita are presently. For example, simulating negotiation processes with several suppliers simultaneously (i.e. multiple instances) is an issue yet to be solved. In the case of the application example used for validation, each supplier would have to run separate instances of the process, not necessarily simultaneously. For future work, this interaction of competing suppliers would be desirable.

References

[1] J.Leukel, V. Sugumaram, Formal correctness of supply chain design, *Decision Support System,* vol. *56, 2013, pp. 288-299.*

[2] N. A. Dobrynin, Extended enterprise as a new context for manufacturing, *Vestnik Samara State University of Economics*, vol. 5, 2010, pp. 15-16.

[3] IMTI, *Manufacturing Success in 21 st century: A Strategic View*, Oak Ridge, Tennessee: IMTI, Inc, 2000.

[4] H. S. Kim, J. H. Cho, Supply Chain formation using agent negotiation, *Decisions Support Systems*, vol. 49, 2010, pp. 77-90.

[5] J. B. Kim, A. Segev. Multi-component contingent auction (MCCA): a procurement Mechanism for dynamic formation of supply networks, *International conference on Electronic commerce,* vol. 5, 2003, pp. 78-86.

[6] S. Alguezaui, R. Filieri, A knowledge-based view of the extending enterprise for enhancing a collaborative innovation advantage, *Int. J. Agile Systems and Management*, vol. 7, 2014, pp. 116-131.

[7] E. I. Neaga, J. A. Harding, An Enterprise Modeling and Integration Framework based on Knowledge Discovery and Data Mining. *Int. Journal of Production Research*, vol. 43, 2005, pp. 1089-1108.

[8] M. Kayri, I. Kayri, A proposed "OSI Based" network troubles identification model, International *Journal of Next-Generation Networks (IJNGN)* , vol. 2, n°. 3, September 2010.

[9] G. Bora, S. Bora, S. Singh, S.M. Arsalan, OSI Reference Model: An Overview, *International Journal of Computer Trends and Technology (IJCTT*, vol. 7, n° 4, January 2014.

[10] Supply Chain Council, Inc. *SCOR: The Supply Chain Reference*, United States of America, 2012.

[11] F. Persson, SCOR template - A simulation based dynamic supply chain analysis tool, *Int. J. Production Economic,* , vol. 131, 2011, pp. 288–294.

[12] M. Chinosi, A. Trombetta, BPMN: Na introduction to the standard, *Computer Standards & Interfaces*, vol. 34, 2012, pp. 124–134.

[13] R.M. Dijkman, M. Dumas, C. Ouyang, Semantics and analysis of business process models in BPMN, *Information and Software Technolog*, vol. 50, 2008, pp. 1281–1294.

[14] P. Moynihan, W. Dai, Agile supply chain management: a services system approach, *Int. J. Agile Systems and Management*, vol. 4, n° 3, 2011, pp. 280-300.

[15] Software Bonita. 2015, Bonitasoft Open Source Workflow & BPM software, http://br.bonitasoft.com/, Acessed: 22 Oct 2014 .

[16] AME. 2015, AME Offshore Solutions. http://www.amepl.com.au/theme/ameplcomau/assets/public/File/pdf/c4ca4238a0b923820dcc509a6f75849b_1.pdf, Acessed: 1 March 2015.