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Towards Decision Support Automation for Supply Chain Risk Management among Logistics Network Stakeholders

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Abstract: This paper is one pillar of a research project aimed to design a decision support system supporting collaborative Supply Chain Risk Management among logistics network stakeholders. It presents the motivation behind this objective, and the contribution towards this objective: a methodology to automatically deduce all the supply chain options enabled by a logistics network to fulfil the demand. This methodology is introduced as part of a decision support automation framework for Supply Chain Risk and Opportunity Management among logistics network stakeholders. The methodology focuses on strategic and tactical supply chain decisions, and on manufacturing stakeholders.

Keywords: Supply Chain, Supply Chain Risk Management, Decision Support, Logistics Network, Strategic Business Planning, Supply Chain Design, Risk Management, Opportunity Management.

1. INTRODUCTION

There was a time when businesses were designing their supply chains almost only when a product was added to their portfolio, without reconsidering their structure over time if no major issues were encountered. The supply chain community observed and analyzed over the past decades the evolution of how businesses are designing and challenging their supply chains (Abadi and Deghani, 2009; Mehmeti, 2016; Rasool et al., 2009). The supply chain environment progressively evolved from a stable ecosystem to a very dynamic, complex and competitive ecosystem nowadays (Ballou, 2007; Christopher, 2000).

For businesses, evolutions in their supply chain environment (evolution of stakeholders, services, products, market demand, policies, etc.) mean the potential appearance of new risks and opportunities about their performance and ability to reach their objectives. To be competitive, businesses try to identify and assess risks and opportunities, so as to identify and make decisions to mitigate the risks taking advantage of the opportunities. As an example, risks can correspond to the inability to fulfil the demand, as well as the inability to reach competitive prices, and an opportunity could be a new equipment bought by a stakeholder that enable cost efficiency improvements and production capacity increase. So, one factor of success for businesses is their ability to keep a complete, accurate and up-to-date vision of their supply chain environment, and the risks and opportunities related to their supply chains (Bartlett et al., 2007; Joshi, 2000).

This paper, starts with a literature review on Supply Chain Risk Management (SCRM) that highlights the need for additional research about collaborative SCRM, dynamic

SCRM, and SCRM information systems. Then, it introduces a framework outline for designing a decision support system supporting collaborative SCRM among logistics network stakeholders. Based on this introduction, a proposal is made to implement a part of this framework: a methodology and associated algorithm to automatically deduce all supply chain options enabled by manufacturing stakeholders of a logistics network to produce a set of products. This proposal can be used either for designing a more complete SCRM decision-support system, or untouched to simply automatically discover all the possible supply chains made available by a set of manufacturing stakeholders to make a set of products. Finally, the paper concludes with the proposal limitations and avenues for future research.

2. SUPPLY CHAIN RISK MANAGEMENT LITERATURE REVIEW: RESEARCH AVENUES FOR SUPPORTING COLLABORATIVE SCRM AMONG LOGISTICS NETWORK STAKEHOLDERS

The supply chain community did a lot of research on SCRM during the past decades and the interest is still growing, as it is shown by the number of papers and by literature reviews. Some simple examples shown this trend: 650 papers containing “supply chain risk management” in their title were found on September 2017 using the Google Scholar search engine with the request “allintitle: “supply chain risk management”” (citations not included). 411 papers containing “supply chain risk management” in their title, abstract or keywords were found on September 2017 using the Web of Science search engine and database with the request “TOPIC: (“supply chain risk management”)”. 35 surveys were found on September 2017 using the Google Scholar search engine with the request “allintitle: (“supply

chain risk management" OR SCRM) (review OR art)".11 surveys were found using the Web of Science search engine and database with the request "TITLE: (("supply chain risk management" OR SCRM) (review OR art))".

Over the past few years, several surveys have pointed out the lack of research efforts about collaboration among supply chain stakeholders for managing risks (Colicchia and Strozzi, 2012; Prakash et al., 2017; Vanany et al., 2009). Their reviews clearly express the need for future research exploring collaborative risk management among supply chain players. Colicchia and Strozzi (2012) also insist on the importance of dynamicity of risk management to always stay up-to-date with the business context.

In addition of highlighting the need for collaboration and dynamicity, some reviews insist on the need for the prescription of practical information system solutions to be implemented within the industry (Chen et al., 2013; Prakash et al., 2017; Singhal et al., 2011). Singhal et al. (2011) recommend that research be extended on more focused prescriptive studies applicable to industry. Chen et al. (2013) focused on the Agent-Based Modeling and Simulation approach, they identified the development of decision support systems for SCRM that sit on the top of ERPs as a promising research directions. Prakash et al. (2017) found a lack of research on information system implementation for managing risks in supply chains.

These gaps identified within the SCRM literature correspond to the origin of the research objective presented in this paper: designing a decision support system supporting collaborative Supply Chain Risk Management among logistics network stakeholders.

3. A DECISION SUPPORT AUTOMATION FRAMEWORK FOR SUPPLY CHAIN RISK MANAGEMENT AMONG LOGISTICS NETWORK STAKEHOLDERS

Previous research works have considered different options to decompose SCRM into several activity domains (Chen et al., 2013; Cruz and Ferreira, 2016; Ho et al., 2015). This paper refers to the SCRM activity domains synthesized by Ho et al. (2015) and named by the authors "SCRM processes":

- Risk Identification, defined as the process to identify risk types and factors.
- Risk Assessment, defined as the process to evaluate probability of an event occurring and the significance of the consequences.
- Risk Mitigation, defined as the process to mitigate either the probability of an event occurring or the significance of the consequences.
- Risk Monitoring, defined as the process to detect a disruption occurrence.
- Risk Recovery, defined as the process to enable the supply chain to quickly return to its original state during the occurrence of a disruption.

Ho et al. (2015) have shown that most SCRM frameworks have been focusing on two of these SCRM processes, and say that the next focus should be to integrate more than two processes.

The following lines will introduce the framework suggested to enable decision support automation for SCRM among stakeholders of a logistics network. It describes the scope of the framework ambitions and position the main components. As the framework is not the main focus of this paper, only a high-level description is presented.

3.1 Framework scope

The framework focuses on stakeholders of a logistics network and their knowhows, including manufacturing, transportation and distribution. The ambition of the decision support system framework is to support strategic and tactical business planning decisions.

According to the SCRM processes previously identified by Ho et al. (2015), the ambition is to cover the 5 highlighted SCRM processes, including the automation of the 4 following ones: "Risk Assessment", "Risk Mitigation", "Risk Monitoring", and "Risk Recovery". The "Risk identification" process would be part of the initial configuration of the decision support system.

However, potential evolutions in the logistics network environment imply the potential appearance of new risks that SCRM approaches try to manage. But a change is not necessarily negative and can also lead to opportunities (Olsson, 2007). It is important to highlight the fact that these potential evolutions also imply the potential appearance of new opportunities. The framework also aims to cover the opportunities in addition of the risks, so the processes covered are renamed as following: "Risk and Opportunities Assessment", "Risk Mitigation and Opportunities Readying", "Risk and Opportunities Monitoring", and "Risk Recovery and Opportunities Exploitation". The "Risk Identification" process becomes "Risk and Opportunities Identification", part of the decision support system initial configuration.

These processes could extend the usual SCRM approach to a Supply Chain Risk and Opportunities Management (SCROM) approach integrating the five previously suggested processes.

3.2 Framework processes

The suggested decision support system framework is structured according to the suggested SCROM processes, with an additional step for information system automation purpose: "Data Gathering and Consolidation".

The "Risk and Opportunities Identification" process would take part during the configuration phase of the decision-support system. Then, during the run-time, there is the "Data Gathering and Consolidation" step that continuously feeds the four SCROM processes (Figure 1) with information that enable their automation.

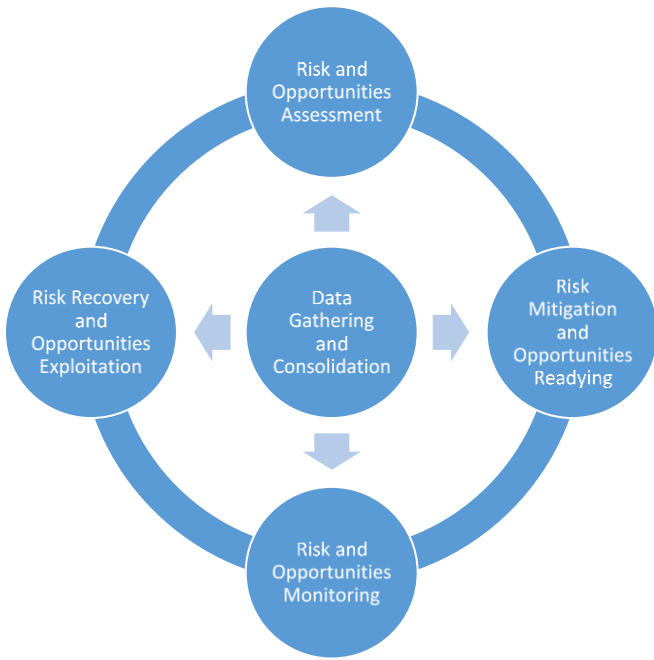


Figure 1: Processes of the framework suggested to enable decision support automation for SCRM among stakeholders of a logistics network

The next section of the paper focuses on this “Data Gathering and Consolidation” step, so more details about it are given hereinafter. This process is aimed to automatically collect data from the logistics network stakeholders and their environment, and transform and structure these data into relevant information for the four SCROM processes it feeds. It especially implies to have an interconnexion between stakeholders’ information systems thought information sharing infrastructure, policies and protocols.

This paper proposes a first contribution to the “Data Gathering and Consolidation” step towards providing information that enable the automation of the four SCROM processes. The proposal corresponds to a methodology to automatically deduce all the supply chain options enabled by the logistics network to fulfil the demand, using the logistics network stakeholders’ data. The deduction of these available supply chains would be the starting point enabling to manage risk and opportunities thought the four SCROM processes. The next section of this paper focusses on this available supply chains deduction step.

4. A PROPOSAL TO AUTOMATICALLY IDENTIFY ALL SUPPLY CHAIN OPTIONS ENABLED BY MANUFACTURING STAKEHOLDERS OF A LOGISTICS NETWORK

This section presents a methodology to structure data gathered from logistics network manufacturing stakeholders so as to be able to use this structured data to deduce all the supply chain options enabled by these manufacturing stakeholders to fulfil the market demand. A supply chain option corresponds to a possible supply chain configuration among all possibilities. It is important to note that in this

study, we only consider manufacturing stakeholders and not the transportation and distribution ones.

To structure the data gathered from logistics network manufacturing stakeholders, a metamodel has been developed. A metamodel corresponds to a model describing the structure and behavior of models, all models following a metamodel will have to respect the structure defined by the metamodel (Ramu and Prabhu, 2013; Wu et al., 2012). The design of the metamodel is know-how oriented to make the logistics network stakeholders’ know-hows the cornerstone of this methodology. The metamodel is based on the CORE metamodel created by Bénaben et al. (2016) to support collaborative situations. To make the logistics network metamodel as clear as possible, it has been simplified in Figure 2 keeping only the relevant elements for this paper. It originally contained packages specific for the logistics network around the CORE metamodel, as described by Bénaben et al. (2016) in the context of the crisis management, but they are not presented in this paper.

As described by Figure 2, the metamodel contains concepts and links between concepts that will both be used by the deduction algorithm. The concepts are: “Collaborative Network” that corresponds to the logistics network, “Stakeholders” that corresponds to logistics network stakeholders, “Know-How” that corresponds to the manufacturing services provided by the logistics network stakeholders, “Resource Category” that can correspond to products or equipment, and “Objective” that corresponds to the logistics network sales plan. The links between concepts are described as the following: A collaborative network “contains” stakeholders and “aims” to fulfil objectives, a stakeholder “provides” know-hows, a know-how “consumes”, “creates” and “requires” resource categories, and an objective “consumes” resource categories.

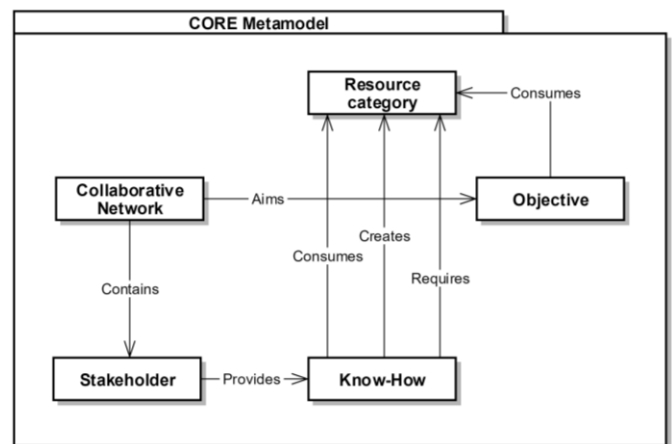


Figure 2: A metamodel to structure the data gathered from logistics network manufacturing stakeholders (showing only the elements being relevant for supply chain deduction)(inspired by Bénaben et al. (2016))

The data from the logistics network manufacturing stakeholders are collected and consolidated within a model that follows the structure of the previously presented

metamodel. This model structure makes possible for the deduction algorithm presented below to automatically deduce all the possible supply chains options enabled by the logistics network to fulfil the objective (sales plan). To be more precise, the algorithm deduces the, defined right after, Available Supply Chain Processes (ASCP) on the base of the model of the logistics network. For each product that the logistics network plans to sell to end consumers (*i.e.* each “Resource Category” having at least one link “consumes” from an “Objective”), we define the corresponding ASCP as the succession of all possible activities, instances of the logistics network stakeholders’ know-hows, which enable to realize the product. In other words, it corresponds to a unique supply chain process containing all the possible ways (all the supply chain options) making possible the considered product production. An ASCP gives the vision, to the logistics network stakeholders, of all the supply chain options, however it doesn’t imply that all must be implemented.

The ASCP are represented using a process modeling language inspired from the Business Process Model and Notation (BPMN) (Object Management Group, 2011; White, 2004), with some specificities. The deduction algorithm uses the following BPMN elements to represent the ASCPs: *start event*, *end event*, *activity*, *parallel gateway* (named in the algorithm “AND Opening gateway” or “AND Closing gateway”), and *inclusive OR gateway* (named in the algorithm “OR Opening gateway” or “OR Closing gateway”). The distinction between opening and closing gateway is one specificity of the process modeling language used to represent the ASCPs, it is an enabler of the deduction automation used within the deduction algorithm.

To make the ASCP deductions, we propose the following algorithm taking advantage of the logistics network model to create ASCP models using the BPMN language. This algorithm has been initially designed to answer one of the business needs identified during interviews with a pharmaceutical company: to automatically discover all supply chain options enabled by a set of manufacturing stakeholders to fulfil a sales objective.

Algorithm to deduce Available Supply Chain Processes:

Find all objectives within the logistics network model.

Find all resource categories concerned by the objective.

For each resource category concerned by at least one objective, create an ASCP model:

Create the “end event” of the ASCP model (according to the BPMN language).

[Line A] Find all know-hows able to create the resource category.

If there are two or more know-hows able to create the resource category, then:

Create an “OR Closing Gateway” and create a link oriented from this gateway to the last created element

(“end event”, “activity”, or “AND Closing gateway”).

For each know-how able to create the resource category:

[Line B] Create an “activity” being an instance of this know-how, and create a link oriented from this “activity” to the “OR Closing Gateway” previously created.

Find the resource categories consumed by this “activity” (according to the know-how).

If there are at least two different resource categories consumed by this “activity”, then:

Create a “AND Closing gateway” and create a link oriented from this gateway to the last “activity” created (line B).

For each resource category consumed by this know-how:

Continue going back to “line A” considering this resource category and the “activity” which needs it.

If there is one resource category consumed by this “activity”, then:

Continue going back to “line A” considering this resource category and the “activity” which needs it.

If there is no resource category indicated as consumed by this “activity”, then:

Following the created process, starting from the current considered “activity”, find the closest closing gateway (“OR Closing gateway” or “AND Closing gateway”).

If a closing gateway was found and does not already has its corresponding opening gateway, then:

Create the corresponding opening gateway (“OR Opening gateway” or “AND Opening gateway”) and create a link oriented from this gateway to the considered “activity”.

[Line C] Following the created process, starting from the current considered closing gateway, find the next closest closing gateway (“OR Closing gateway” or “AND Closing gateway”).

If a closing gateway was found and does not already has its corresponding opening gateway, then:

Create the corresponding opening gateway (“OR Opening gateway” or “AND Opening gateway”) and create a link oriented from this

gateway to the previously considered opening gateway.

Continue going back to line C considering this new closing and opening gateways.

If no closing gateway was found, then:

Create the “start event” and a link oriented from this “start event” to the lastly created opening gateway.

If a closing gateway was found and already has its corresponding opening gateway, then:

Create a link oriented from this gateway to the considered “activity”.

If no closing gateway was found, then:

Create the “start event” and a link oriented from this “start event” to the current considered “activity”.

If there is only one **know-how** able to create the **resource category**, then:

Continue going to line B considering this **know-how**.

A software has been developed to demonstrate the proper functioning of the deduction algorithm. From modeling the logistics network to visualizing all the supply chain options made possible by the logistics network manufacturing stakeholders. The main technologies used are the programming language Java and the databases MongoDB and GraphDB. It is composed of the following 3 major elements:

- Web-based user interfaces (“Stakeholders & Know-hows”, “Resource Categories”, and “Objectives”) to manually model the logistics network (step needed because the data gathering automation isn’t part of the scientific contribution of this paper) (Figure 3).
- The implementation of the deduction algorithm to automatically deduce the ASCPs from the logistics network modeled by the user.
- A graphical interface to visualize the ASCPs and so all the supply chain options (Figure 4).

The effectiveness of the algorithm has been confirmed checking the validity of the deduced ASCPs in one real and one fictive use cases. The real case has been done considering a network of existing and potential suppliers of a pharmaceutical company according to one of their product category. The fictive case has been realized considering a network of manufacturing stakeholders enabling the production of bread (Figure 3 and Figure 4). So, a business can use this approach to automatically deduce all possible supply chain options (ASCPs), enabled by a set of manufacturing stakeholders, to fulfil a production or sales objective. It must be noted that the efficiency, in terms of speed performance, of the algorithm has not been a point of interest in this research work.

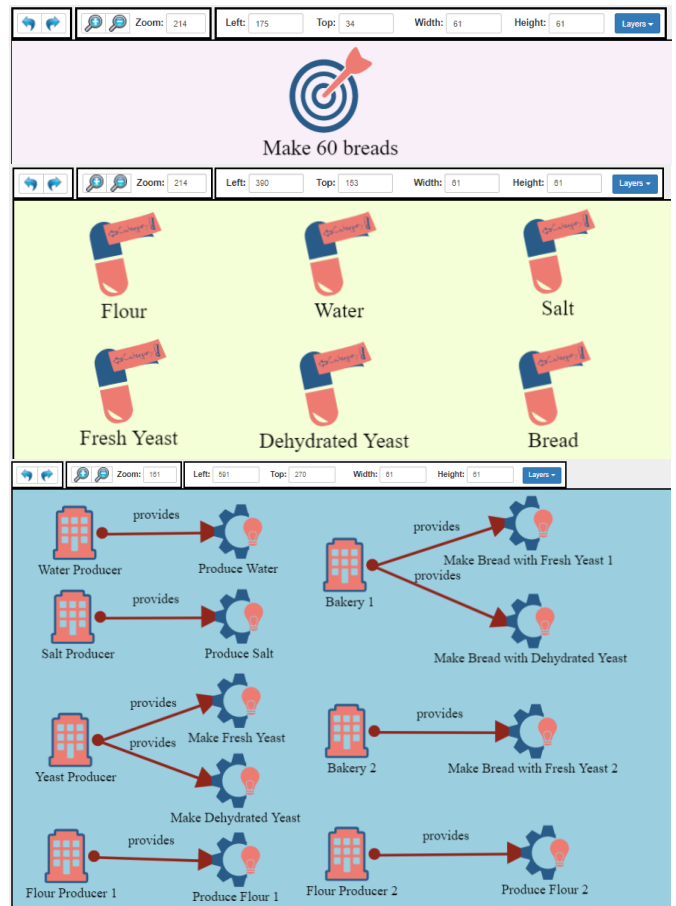


Figure 3: Web-based user interfaces to manually model the logistics network information according to the metamodel presented in Figure 2

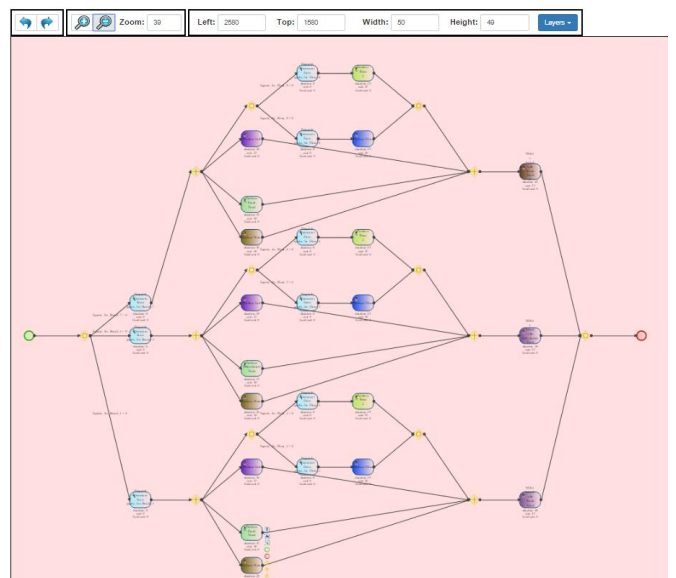


Figure 4: Graphical interface to visualize ASCPs: An example of a deduced ASCP enabling to visualize all the supply chain options enabled by the set of manufacturing stakeholders to fulfil the production objective (modelled in Figure 3)

5. CONCLUSION, LIMITATIONS AND AVENUES FOR FUTURE RESEARCH

In this paper, a methodology has been suggested to automatically deduce all the supply chain options enabled by manufacturing stakeholders of a logistics network to fulfil the demand. This methodology has been introduced as part of a decision support automation framework for Supply Chain Risk and Opportunity Management (SCROM) among logistics network stakeholders. And more precisely as a proposal for the consolidation part of the suggested “Data gathering and consolidation” step, towards providing information that enable the automation of the SCROM processes. The methodology includes a metamodel and a deduction algorithm proposal that only consider manufacturing stakeholders, so, future research work will have to extend it to transportation and distribution. In addition, the framework needs to be consolidated with more details about its practical implementation. From another perspective, risks and opportunities regarding human factors and data integrity have not been considered in this paper, so it would be relevant to supplement these results with additional research on these aspects. Finally, from an information system perspective, the five considered SCROM processes still need to be designed and developed to really provide businesses with a complete and practical decision-support system.

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