A Knowledge Based Approach for Handling Supply Chain Risk Management

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ABSTRACT

This paper discusses the concept of supply chain risk management (SCRM) in relation to the emerging challenges brought by globalisation and information and communication technologies (ICT) and the ability of SCRM frameworks to adapt to these latest requirements. As SCRM can be responsible for loss or gain of profit, the ultimate goal of enterprises is to have resilient supply chains with automated decision making that can deal with potential disruptions. In response to these, taking advantage of ICT developments such as knowledge and data discovery techniques and automated risk management frameworks have become a vital aspect for assuring business success. Having this context, this research has the following aims: 1) to perform literature review on identifying and categorising several types of supply chain risks in order to analyze their management strategies, 2) to perform a literature review on knowledge management frameworks and 3) to propose a knowledge management and a risk management framework that would be, at a further stage of this research, integrated in an agent based decision support system for supply chain risk management.

Categories and Subject Descriptors
H.3.0 [Information Storage and Retrieval]: General
H.4.0 [Information Systems Applications]: Logistics
I.2.6 [Artificial Intelligence]: Learning

General Terms
Management, Design, Reliability, Theory.

Keywords
Data mining, knowledge extraction and management, supply chain risk management.

1. INTRODUCTION

The increased competitive pressure in a stagnating and globalized market has led to the design of more efficient supply chains. Since supply chains are vulnerable towards many types of risks [18] that increase exponentially in a globalising and knowledge based economy, dealing with large amount of information available for taking the right decisions has become a real challenge. Decreased stocks, longer transports and increased dependency from fewer suppliers have led to an increased vulnerability of global supply chains. Local disruptions e.g. from disasters, terrorism or simply the failure of a supplier can have multiple consequences for a company and its customers all over the world. Apart from these, the environmental instability creates unpredictable disasters. The actual negative outcomes of risks could be: loss of profit, late deliveries, client dissatisfaction, temporary stop of production, damage to business’s reputation and decrease of shareholder’s value.

Furthermore, another factor that describes nowadays supply chain operational environment is uncertainty and also poorer process visibility [1], increasing thus the list of potential issues. Moreover, according to [3], these two factors coupled with a complex supply chain can lead towards chaos if excessive reactions, second time guessing, mistrust and modified information within the supply chain are being performed. Finally, according to [25], all these negative events that affect supply chains (supply chain risks) broadly fall into the following categories: operational disturbances, tactical disruptions and strategic uncertainties, however, a more detailed classification will be provided later on.

Thus, while supply chains are under the pressure of having to deal frequently with negative events, the key challenges of nowadays’ industry are to better predict these risks and to achieve supply chain resilience [7] as the financial downside in the case of risk occurrence is reaching unimaginable heights. More specifically, according to [4], supply chain resilience can be defined as the ability of a system to return to its initial state or to move towards a more desired state after a disturbing event took place. In order to understand the importance of having good prediction tools and an overall resilient framework, Table 1 presents several case studies of some big corporations that encountered huge financial issues as risks’ aftermath.
Hence, the need for effective risk management in supply chains is vital. To this extent, the reliance on information and communication technology has become a necessity. More specifically, modern supply chains should use automated decision support systems that would inform in real time the managers about the potential risk and their management strategies that could interfere within the normal flow of the supply chain. These tools rely extensively on knowledge extraction and management techniques in order to take raw data into useful resources that would allow effective decision making.

In response to this need, the current research advances the work of [28] in which a high level agent based knowledge management framework with an incorporated decision support system/framework was proposed. Accordingly, this paper presents a summary on the following aspects: provision of a thorough analysis and classification of general supply chains risks and risk management (in section two), investigation of several knowledge extraction and management strategies (in section three) and finally, it presents the structure of the proposed knowledge and risk management framework(s) which were devised from several existing models and adapted to suit the requirements of the broader framework debated in the work of [28]. The final objective of this paper is to make all the proposed deliverables to easily integrate in the framework proposed by [28].

### Table 1. Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Source</th>
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<tbody>
<tr>
<td>In 1996 General Motors faced supplier issues which temporarily stopped the production in 26 plants and resulted in a loss of $0.9 billion.</td>
<td>[5]</td>
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<tr>
<td>Ford met a loss of 4000 units (cars) due to a dispute with a diesel engine producer.</td>
<td>[26]</td>
</tr>
<tr>
<td>In 1997 Boeing experienced supplier delivery failure of two critical parts, which caused an estimated loss of $2.6 billion.</td>
<td>[5]</td>
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<tr>
<td>In 2001 Cisco lose $2.25 billion due to inventory issues.</td>
<td>[15]</td>
</tr>
<tr>
<td>Pfizer had a $2.8 loss due to manufacturing issues.</td>
<td>[15]</td>
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</table>

### Table 2. Risk Categories (Terminology)

<table>
<thead>
<tr>
<th>Source</th>
<th>Terminology</th>
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<tbody>
<tr>
<td>[12, 16, 20, 23, 24, 27, 34]</td>
<td>• process, control, demand, supply, environmental (risks)</td>
</tr>
<tr>
<td>[7]</td>
<td>• compensation risk, employment risk</td>
</tr>
<tr>
<td>[20, 31]</td>
<td>• disruption, price, inventories/schedule, technology, quality (risks)</td>
</tr>
<tr>
<td>[20]</td>
<td>• operational, network, and external (risks)</td>
</tr>
<tr>
<td>[18]</td>
<td>• demand, production, supply, interaction (risks)</td>
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### 2.2 Supply Chain Risk Management

Supply chain risk management (SCRM) provides a framework for dealing (or defending from) with the potential risks than could interfere. According to [19], risk management strategies in supply chains are determined by taking into consideration three directions: the utilized resources; network systems; and performance criteria. Alternatively, according to [17] a risk management approach addresses the following: the strategy (whether the existing infrastructure supports the risk management objectives), tactical considerations (identification of all possible risk and contingency planning) and execution (when to react and how to learn from past experiences). However, when it comes to the actual investigation of specific SCRM methodologies, the literature provides many examples.

One example described by [30] refers to a continuous risk management process that has the following stages: risk analysis (system bounds identification, critical events identification, risk events identification), risk assessment (valuation of risky events, their likelihood and impact) and risk control (appropriate procedures). Another comprehensive example is presented by [26] who categorises several approaches of dealing with risks. The first one is the introduction of operational buffers along the supply chain, the second refers to mitigation strategies (reducing the likelihood of occurrence) and the last one is contingency planning (alternative modes of operation if a risk occurs) towards reaching resilience. Consequently, [14] presents a six step process: supply chain analysis, identifying uncertainty sources, studying the corresponding risk, managing risk, differentiating the most adequate real option, and employing supply chain risk strategy.

Finally, [8, 21] agree on eleven factors that are involved in risk management: agility, information sharing, trust, collaborative relationships, information security, corporate social responsibility,
aligning incentives and revenue sharing policies, strategic risk planning, risk sharing, risks knowledge, and continual risk analysis. Finally, in order to design an efficient risk management framework for a nowadays supply chain, the key aspect is to allow the ICT component responsible for risk management to heavily interact with the knowledge management component in order to have all the time (but also to consolidate), up-to-date knowledge for effective decision making.

3. KNOWLEDGE MANAGEMENT
As the nowadays’ business environment is moving towards the knowledge based economy, the actual success of companies relies in how effectively they can use the knowledge emerged from their past, current and future operations. To this extent, according to [22], companies are heavily exploiting the knowledge management sector in order to efficiently deal with changes in their business environment, enhancing thus their competitive advantage. However, knowledge management in the current technologically advanced era is done automatically, using specialized ICT techniques that integrate several tools into automated decision support systems. More specifically, according to [34, 28], decision support systems are interactive software based programs used for information compiling that take advantage of data mining and knowledge and data discovery [26], with the ultimate goal of reaching a decision for a specific purpose. Basically, a decision support system incorporates automated knowledge management. However, since a general framework for a decision support system was presented in presented in a previous version of this broader research by [28], the current focus of the paper related to knowledge management will be directed towards the structure and stages of the knowledge management process which can generally be split up into knowledge discovery, utilization and consolidation.

To this extent, according to [9], “knowledge discovery is a nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns from large collections of data”, all these by applying data mining and post processing techniques to improve the knowledge [11]. Additionally, knowledge discovery is concerned with the preparation of data and with the utilisation of the knowledge gained from data. Furthermore, according to [2, 9 - 11], data mining is the core process/stage of knowledge discovery. More specifically, according to [9], data mining is concerned with the actual extraction of knowledge. Consequently, a more complex definition of data mining provided by [10] states that this is an interdisciplinary field that uses approached of several research areas (specially machine learning, statistics, artificial intelligence) to extract high level knowledge from real-world data sets. However, these real-world data sets are stored in databases [2] and thus, the actual data manipulation is done using the database. To this extent, in order to avoid the confusion between the general database manipulation (using query language) and applying data mining to a database, as well as to differentiate the terminology data, information and knowledge, the previous figure (Figure 1) provides a general overview to clear these aspects.

Alternatively, to make the difference between data mining and knowledge discovery, in can be briefly stated that data mining is a tool/stage for knowledge discovery. Additionally, in order to reveal the complexity and differences of these processes, according to [2], data mining involves the following considerations: handling of different types of data, efficiency and scalability of data mining algorithms, usefulness, certainty and expressiveness of data mining results, expressions of various kinds of data mining results, interactive mining knowledge at multiple abstraction levels, mining information from different sources of data and protection of privacy and data security. Consequently, [10] consolidates the definition with the actual functions of data mining: classification, regression, clustering, summarization, dependency modelling, link analysis, and sequence analysis.

Apart from the data mining process, knowledge discovery – the broader cycle that includes data mining has several stages as well. From the general models provided by the literature, Figure 2 presents the main stages that all models resemble.

![Figure 2. The Knowledge Discovery Process](image)

Additionally, the literature provides several derivations of the stages presented in Figure 2. To this extent, a model proposed by [6] and mentioned by [9] presents knowledge discovery as a series of the following six steps: understanding the problem domain, understanding the data, data preparation, data mining, evaluation of the discovered knowledge, and using the discovered knowledge. Furthermore, an alternative knowledge discovery model proposed by [10] identifies the following nine stages: learning the application domain, creating a target dataset, data filtering and pre-processing, data reduction and projection, choosing the function of data mining, choosing the data mining algorithm, data mining, interpretation, and using the discovered knowledge. Finally, the literature presents also several tools...
developed upon the theoretical frameworks that aim to deal with data mining and knowledge discovery. Some of these tools, are: Alice(Isoft), Brainmaker, Deltaminer [13]. Nevertheless, the main concern of this study is how to effectively use knowledge management frameworks for supply chain risk management and this is why the proposed frameworks which are based on the theoretical foundations presented in chapters two and three are going to be discussed in the next section.

4. THE PROPOSED FRAMEWORKS

4.1 The Risk Management Framework

As stated in the introduction, one of the aims of this paper was to present the summary of a proposed supply chain risk management strategy that could be easily integrated in an agent based decision support system for supply chain risk management that will be developed at a later stage. To this extent, the proposed risk management framework which is described in Figure 3 is very modular and provides sound interfaces that can be easily integrated later-on with an agent based framework due to the concept of using “handlers” which can be efficiently replaced by agents.

1. The request is passed to the Risk Processing Coordination Handler (RPCH) which accesses the Solution Generation Module (SGM).
2. The SGM assesses the risk and checks whether the risk KB contains a similar or previously encountered type of risk for which a solution exists.
3. If a solution for that risk exists in the KB, then step 5 is executed.
4. If a solution does not exist in the database, then the SGM generates a mitigation strategy by asking the RPCH to access the SC database and retrieve the specific data or knowledge needed for generating a solution.
5. When a solution is reached (either existing one or newly generated one) the Solution Assessment Handler (SAH) is requested.
6. The SAH requests the RPCH to check whether the proposed solution is in accordance with the business goals and if it is feasible to implement in the current context.
7. If the solution is not feasible, then step 4 is executed.
8. If the solution is feasible, then RPCH requests the SAH to update the risk KB with that solution.

Furthermore, a specific element of this framework is the inclusion of the knowledge management module which makes sure to provide valuable knowledge from all the data that is exchanged between the risk management processes and the supply chain database. The knowledge management module will be discussed in more details in section 4.2.

Finally, this risk management framework provides an effective tool for dealing with supply chain risks on one hand, and on the other it provides the basis for a constant update/consolidation of the risk knowledge base with new solutions to the potential risks that might interfere.

4.2 The Knowledge Management Framework

Continuing the previous section with the last main deliverable of this paper, namely the knowledge management framework, the following figure (Figure 4) presents the general functioning flow of the knowledge management framework.
This knowledge management framework provides great integration mechanisms with the risk management framework presented in Figure 3. First of all, the discovery of knowledge is done both from the supply chain database and from the data exchange with the risk management framework from which real time data is being extracted and processed. Secondly, the actual validation and acquisition of the knowledge is done again in cooperation with the risk management framework in order to make sure that the knowledge that is going to be incorporated in the risk knowledge base is consistent with the business goals that govern risk management. Thirdly, knowledge utilisation and consolidation are done as per request or per automatically identified need together with the experiences that the risk management framework faces (past experiences, real-time experiences, predicted experiences, etc). However, testing all these extensions to prove their effectiveness will be feasible only the entire system will be integrated and implemented (or theoretically simulated).

Finally, the proposed knowledge management framework integrates efficiently with the risk management framework, providing thus great interfaces for its incorporation in the agent based decision support system for supply chain risk management proposed by [28].

5. CONCLUSION

Overall, the importance of using knowledge management techniques within supply chain risk management has become a necessity in nowadays knowledge driven business environment. To this extent, having automated tools for knowledge management based on advanced information and communication technology platforms can bring an improved competitive advantage especially when having to deal with the complex spectrum of risks from the supply chain sector. Acknowledging this context, the current paper performed a literature review on supply chain risk categorisation and management, and on identifying several knowledge extraction and management models in order to propose a risk and knowledge management framework that would be easily integrated in an agent based decision support system for supply chain risk management which was developed in a previous version of this study. However, the focus of this study was mainly on the two main frameworks (risk and knowledge management) rather than on their integration with the wider decision support system which will represent a great perspective for future research. Additionally, another further enhancement of the current work will be the implementation and testing of the final model that will be devised, as currently, the proposed models’ main limitation is the lack of testing with quantitative data.

6. REFERENCES


