Software Supported Risk Management for the Global Production Networks Configuration

A. Niknejad*, K. Popplewell*, D. Petrovic*

**Faculty of Engineering, Computing and Environment*
Priory Street,
Coventry CV1 5FB,
United Kingdom

ali.niknejad@coventry.ac.uk
k.popplewell@coventry.ac.uk
d.petrovic@coventry.ac.uk

ABSTRACT: *Production networks are becoming more and more complex, as they are rapidly expanding to every corner of the world. While global commerce brings many opportunities and benefits, it also increases the impact and variety of risks. For example, a natural disaster affecting a region that hosts a majority of suppliers for a certain component can have devastating impact on the producers that rely on that component to manufacture their products. Such disruptions have become a rather common threat to Global Production Networks (GPNs).*

The EU FP7 funded FLEXINET project looks at the process of decision making for GPN configuration, from ideation to realization of the network. In this process, many different alternatives will be considered and should be evaluated from different perspectives, including risk. FLEXINET provides a set of software applications that can facilitate the process and provide better and faster analysis of the alternatives. This paper considers how these software tools will be used for the purpose of risk management and how the decision makers should engage them to enjoy the benefits.

KEYWORDS: *Decision Support Systems, Resilient Production Networks, Risk Management, Global Production Networks, Uncertainty Management, Fuzzy Arithmetic*

1. Introduction

A Global Production Networks (GPN) is established to deliver products and services to customers through a network of globally interconnected nodes, typically including manufacturing facilities and logistics providers etc. Such networks are susceptible to risks due both to external and environmental factors, and to the internal characteristics of the nodes. Disruptions can propagate throughout these networks,

exacerbating the impact of risks. The FLEXINET project is aimed at facilitating the configuration and reconfiguration of GPNs. Particularly, it examines the impact of risks on GPNs and how strategic decisions can be made to reduce it.

Global supply and production network risk management, particularly with software support, has been sparsely investigated in the literature. Basole and Bellamy (2014) examined visual analysis of GPN risks in the electronics industry and how that can support network design decisions. Tse and Tan (2011) explored product quality risks in global supply networks and a decision support framework is proposed to improve the visibility of product quality risks. Furthermore, Sydow and Frenkel (2013) investigated the labor related risks and uncertainties in GPNs and discussed the implications for risk management. Here we will utilize the risk documentation, assessment and analysis framework developed as part of the FLEXINET project (Edelbrock et al. 2015; Niknejad et al. 2016) to propose the FLEXINET software platform that can support risk management in GPNs.

The paper is arranged as follows. In Section 2, we discuss the overall structure of the GPN risk management proposed by the FLEXINET project. Section 3 will introduce the uncertainty management process for GPNs and how we can use information about uncertainty to improve the decision making process. Following this discussion, in Section 4, the two main software applications developed as part of the FLEXINET project for the purpose of risk management are presented. Finally, the paper is concluded by discussing the outcomes in Section 5.

2. Global Production Network Risk Management in FLEXINET

The risk management module of the FLEXINET project focuses on enabling the analysis and evaluation of risks in GPNs, where external, internal and network related risks are to be considered, to support selection of the configuration to be implemented.

To allow for an analysis of risk to be carried out, we first need to document and assess the risks in GPNs. The documentation step is concerned with the continuous monitoring and recording of events affecting the focal company and its GPN adversely. However, such raw information about events should be aggregated, refined and categorized to provide an assessment of the relevant risks that are likely to reoccur in future GPN configurations. The documentation and assessment of risk is supported by the Initial Risk Assessment and Specification Application (IRASA) in FLEXINET, which allows for documentation of incidents as well as construction of risk factors and risk scenarios, based on historical knowledge from incidents, data from external sources and direct experts' judgements.

When a viable business idea is proposed, the company develops alternative GPN configurations based on business model information such as the product requirements,

relevant technologies, key partners and markets. This process is supported by the GPN Configuration Application, where alternative GPNs are defined by selecting the relevant facilities, systems, locations and flows. It is then possible to carry out an analysis of the impact of risks on the alternative GPN configurations.

At this stage, the interdependency between the linked nodes in the GPN configurations are estimated, using experts' judgements. Then, using the novel Fuzzy Dynamic Inoperability Input/output Model (FDIIM) it is possible to analyze the propagation of risks within the GPN configurations and calculate the impact of risk as the expected cost of risks. This allows the decision maker to evaluate the feasibility and competitiveness of the GPN configurations from the risk perspective, and, by jointly considering it with other key indicators such as profit and revenue, a GPN configuration can be selected for implementation. The interdependency analysis and GPN risk analysis are both supported by the Strategic Risk Analysis Application (SRAA) in FLEXINET which relies on experts' opinion to determine the interdependency and provides summarization and visualizations of the analyses' results.

If it is identified, through the uncertainty analysis, that the results are not reliable enough to draw a conclusion, SRAA provides sensitivity analysis to determine the most influential parameters in the uncertainty, which can be targeted for further clarification and data gathering. This method is discussed in detail in Section 1.3.

All of the above mentioned steps are supported by a knowledge base, based on an ontology model developed in FLEXINET. The knowledge base facilitates interoperability within the separate software applications and also with legacy systems or other possible extensions of software applications.

An overview of the steps necessary for the risk management in GPNs using the FLEXINET provided tools is illustrated in Figure 1.

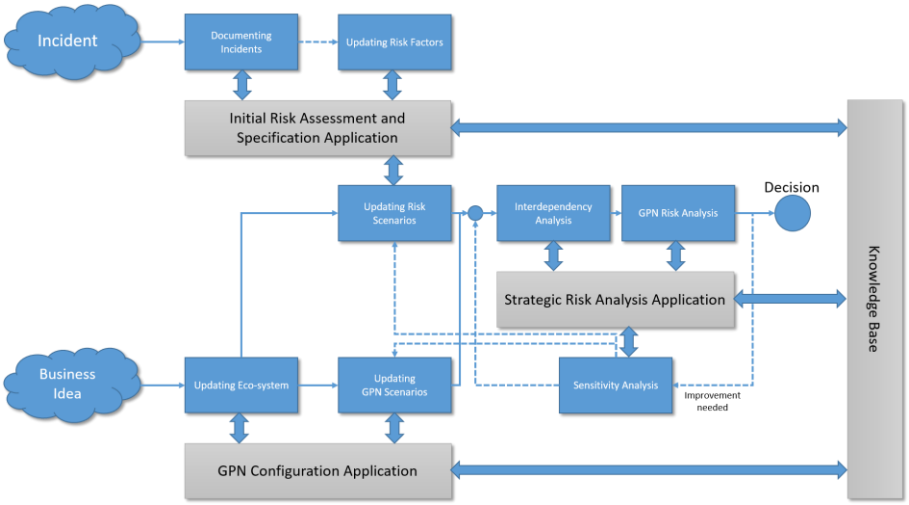

Figure 1. *Overview of the Risk Management Process Supported by the Software Applications*

As many of the necessary data for risk analysis at the strategic level are not available (for example, the interdependencies between the nodes, the reliability of new suppliers, etc.), we rely on company experts and their judgement. They can provide their opinion on various parameters using linguistic values, such as 'low reliability for Supplier A', 'high dependency of Manufacturing Plant on Supplier B'. This information, and the confidence of the experts in the opinion can be translated into fuzzy numbers, and thus allow the analysis of uncertainty by assigning different degrees of belief to a value, which can be tracked through the analysis to determine the reliability of the results.

3. Management of Uncertainty in FLEXINET

Uncertainty measurement facilitates an understanding of the information's reliability and accuracy. However, in FLEXINET, in addition to this general benefit, we aim to utilize uncertainty measurement to guide data collection and clarification, with the goal of focusing effort on the most important and influential parameters, whilst eliminating or postponing collection of precise data where impact of uncertainty is marginal. An overview of the evolution of data and uncertainty management in the GPN analysis is provided in Figure 2. The figure describes the necessary steps to utilize uncertainty measurement for reducing information collection efforts.

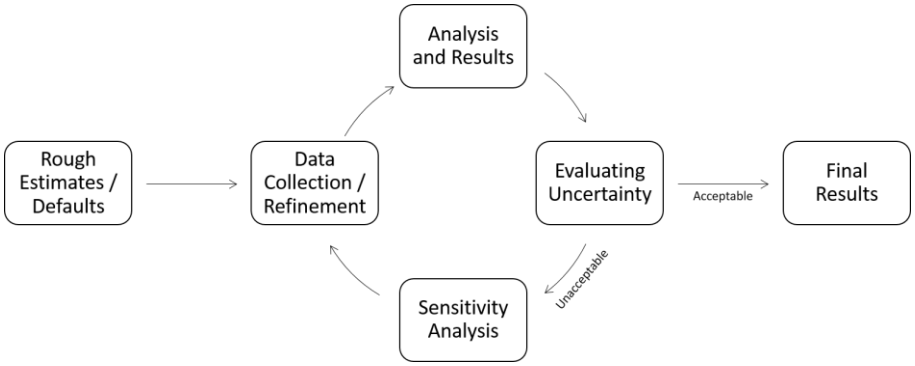

Figure 2. *Evolution of uncertainty for GPN risk evaluation using the FLEXINET tools*

This process is initiated with a rough estimation of the required parameters, typically provided by experts using linguistic terms, although it is also possible to use default values to supplement expert opinion, where even these are not readily available: default values are accompanied with maximum uncertainty to mark the fact that they are not based on empirical data. In the next step, where necessary, the initial information can be further enhanced by minimal data collection and refinement. At this point, it is now possible to carry out the analysis with the risk analysis methods provided by FLEXINET and retrieve the relevant results. The next step is to examine and evaluate the uncertainty within the results, and, check if the uncertainty can influence the final decision. If the uncertainty is not high enough to be able to change the outcome, there is no need for further data refinement and the results are considered to be the final results.

However, if the decision cannot be made confidently, the uncertainty in the obtained results is unacceptable and further investigation is necessary. For this purpose, we can utilize sensitivity analysis to find the most influential parameters in the results and the uncertainty of the results. Then, the most influential parameters are targeted for further data refinement efforts. This cycle can be repeated with the clarified parameters until an acceptable level of uncertainty in the results is achieved.

It is worth mentioning that data refinement can refer to refining and clarifying the data gathered through experts' opinion. For example, instead of relying on the opinion of a single expert, we can use the knowledge of multiple experts from different backgrounds and skillsets, by allowing them to discuss the subject and form a consensus within a meeting. In this way, the uncertainty of such subjective information can be reduced.

4. Risk-related Software Applications in FLEXINET

Two FLEXINET applications are exclusively targeted at risk management, and support the functionality described above. The Initial Risk Assessment and Specification Application (IRASA) supports the documentation of company knowledge and experience of risks factors and scenarios, embodying this in the FLEXINET knowledge base, and making these available for strategic risk. This analysis is supported by the Strategic Risk Assessment Application (SRAA), which can, for each proposed GPN configuration, analyze the expected impact of risk scenarios, to provide performance comparisons to decision makers.

Both these applications recognize that population-based statistics are likely to be unavailable to support formal evaluation of risk probabilities in the context of GPN configuration, so take the approach that expert estimates, made in linguistic terms (Zadeh 1975), of both likelihood of risk arising and their own confidence in the estimate can be used to evaluate GPN expected performance, delivering results interactive visualizations of the impact of risk, and average and time-based costs of risk. Sensitivity analysis supports focus on refinement of information and understanding on estimates most critical to performance, and so allow iterative refinement of analysis.

5. Conclusions

We have introduced the process of risk and uncertainty management in GPN design, proposed as part of the FLEXINET project. The proposed process is supported by the FLEXINET software services and applications, including those specifically designed to support GPN design and risk management. These applications allow for the documentation of incidents, to generate a company-wide knowledge base about the exposure of the company to risks. Such information, in addition to knowledge brought in from the experts and external sources, can be summarized and categorized by risk experts to form the risk factors and scenarios, which provide a benchmark for risk analysis of GPN configurations. This benchmark, along with the relevant information about the GPN configurations and interdependencies, is used to make an analysis of the impact of risk on GPNs, and, ultimately to make a decision about the best GPN configuration. In cases where the uncertainty of the results are high, FLEXINET applications provide support to identify the culprit parameters and target them for further data refinement and clarification.

Acknowledgments

This work has been funded by the European Commission Seventh Framework Programme within the FLEXINET project: Intelligent System Configuration Services for Flexible Dynamic Global Production Networks (Grant Agreement No. 608627), which is gratefully acknowledged.

6. References

Basole, Rahul C., and Marcus A. Bellamy. 2014. "Visual Analysis of Supply Network Risks: Insights from the Electronics Industry." *Decision Support Systems* 67. Elsevier B.V.: 109–20. doi:10.1016/j.dss.2014.08.008.

Edelbrock, Matthias, Ali Niknejad, Simon Schlosser, Dobrila Petrovic, Boris Otto, and Keith Popplewell. 2015. *Deliverable 2.3 of EC FP7-2013-NMP-ICT-FOF Project FLEXINET (Grant No. 608627): Design Specification for Business Model Innovation*.

Niknejad, Ali, Dobrila Petrovic, Keith Popplewell, Frank-Walter Jaekel, and Sonja Pajkovska-Goceva. 2016. "A New Framework for Strategic Risk Analysis in a Global Pump Manufacturing Network." In *Proceedings of the 8th International Conference for Interoperability for Enterprise Systems and Applications*. Guimarães, Portugal.

Sydow, J, and S J Frenkel. 2013. "Labor, Risk, and Uncertainty in Global Supply Networks-Exploratory Insights." *Journal of Business Logistics* 34 (3): 236–46. doi:10.1111/jbl.12022.

Tse, Ying Kei, and Kim Hua Tan. 2011. "Managing Product Quality Risk in a Multi-Tier Global Supply Chain." *International Journal of Production Research* 49 (1): 139–58. doi:10.1080/00207543.2010.508942.

Zadeh, Lotfi a. 1975. "The Concept of a Linguistic Variable and Its Application to Approximate Reasoning-I." *Information Sciences* 8 (3): 199–249.