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RISK ANALYSIS IN MANUFACTURING FOOTPRINT DECISIONS

Carin Rösiö
Industrial Engineering and Management
School of engineering
Jönköping University
Jönköping, Sweden
carin.rosio@jth.hj.se

Magnus Wiktorsson
Dep. of Product Realisation
School of Innovation, Design and Engineering
Mälardalen University
Eskilstuna, Sweden
magnus.wiktorsson@mdh.se

Jessica Bruch
Dep. of Product Realisation
School of Innovation, Design and Engineering
Mälardalen University
Eskilstuna, Sweden
jessica.bruch@mdh.se

Monica Bellgran
Dep. of Product Realisation
School of Innovation, Design and Engineering
Mälardalen University
Eskilstuna, Sweden
monica.bellgran@mdh.se

ABSTRACT

A key aspect in the manufacturing footprint analysis is the risk and sensitivity analysis of critical parameters. In order to contribute to efficient industrial methods and tools for making well-founded strategic decisions regarding manufacturing footprint this paper aims to describe the main risks that need to be considered while locating manufacturing activities, and what risk mitigation techniques and strategies that are proper in order to deal with these risks. It is also proposed how the risk analysis should be included in the manufacturing location decision process.

Keywords: risk analysis, manufacturing location decision process, manufacturing footprint.

1 INTRODUCTION

Companies' manufacturing activities are increasingly based on a global manufacturing footprint i.e. utilizing a manufacturing network design strategy, in order to increase competitiveness (Shorten *et al.* 2005). However, the manufacturing footprint is becoming increasingly complex with the large number of interdependent activities, as well as increasingly uncertain with unpredictable direction of changes. The uncertainty and complexity of the manufacturing localisation task challenges the possibility to develop suitable models to support manufacturing footprint decisions. A supportive decision model requires information that includes both strategic and economic implications of different geographical locations and considers a number of factors linked to the countries' different conditions, the position in the product life cycle and what the production system concept should look like (Bruch *et al.* 2011).

A key aspect in the manufacturing footprint analysis is the risk and sensitivity analysis of critical parameters. In order to avoid negative consequences when locating manufacturing, companies need to estimate different uncertainties concerning the site location selection (Miller 1992). The risks must therefore be analysed in the manufacturing location decision process. A risk could be defined as *"the uncertainty of financial loss, the variation between the actual and expected results or the probability that a loss has occurred or will occur"* (Broder 2006, p1). A distinction should however be made between an uncertainty that could be seen as unmeasurable while a risk is rather seen as a measurable uncertainty (Knight, 1921).

In order to contribute to efficient industrial methods and tools for making well-founded strategic decisions regarding the manufacturing footprint, this paper aims to describe the main risks that need to be considered while locating manufacturing and what risk mitigation techniques and strategies that are proper in order to deal with these risks. It also proposes how these risk mitigation techniques and

strategies could be included in the manufacturing location decision process. The scope of the paper is the manufacturing industry and a delimitation is made to large global manufacturing companies.

2 METHOD

The paper is based on empirical as well as theoretical findings. The empirical data was collected by a multiple case study with a holistic design (Yin 2009) were the risk analysis activities in two manufacturing location projects were studied also including the documentations and evaluations made after the project was carried out. The study was carried out during 2012 in two global manufacturing companies headquartered in Sweden. The companies are large industrial companies (>2000 employees) with a global customer base and R&D and production sites globally located. The data was collected by document studies and semi structured interviews (Yin 2009), see table 1.

Table 1: Data collection.

Case studies	Techniques	Details
Case A	Documents	Manufacturing location decision process
	Interviews	Senior project manager, Senior manager
Case B	Documents	Cost benefit analysis
	Interviews	Manager global production support

A review was made of literature and models for categories of risks to consider, as well as risk mitigation techniques and strategies relevant for manufacturing location decisions. The literature review included a broad range of literature such as production development and supply chain literature.

3 LITERATURE REVIEW

3.1 Main risks to consider in manufacturing location decision processes

The failure of a technical system can have roots in hardware, software, organization or the humans involved (Haimes 2009). Consequently a holistic approach of risks needs to be taken. The risks that need to be considered in manufacturing location decisions projects could be categorized differently. Dunning (1994) categorizes the risks of moving production into groups of economic uncertainty and currency exchange, coordination and environmental volatility, different business cultures and various political regimes. In addition, low technology capacity (e.g. Lan and Young 1996), political instability (e.g. Thomas and Worral 1994), natural disaster (Kusuda 1994), and competitive risks (Miller 1992) are categories of risks often mentioned. Supply chain risks is another category were an abundance of research is made (e.g Tang and Tomli 2008, and Kaku and Kamrad 2011). Fredriksson et.al (2008) make a distinction between risks within the own supply chain and risks outside the own supply chain and specifies several manufacturing related risks that are not included in the above mentioned categories. The theoretically identified risks are here summarized and exemplified in table 2.

Table 2. Categories of risks to be considered in manufacturing location decisions projects.

Category	Example of risks
Manufacturing related risks -current site (e.g. Fredriksson, 2008)	Production loss. Unused area. Unused production equipment. Reduced work load for shop floor manager. Supervisors. Maintenance. Overhead costs that are distributed on less produced volume/ product entities. Amortisation costs for remaining unused production equipment. Support for the new site, i.e. resources which cannot be used at the current site.
Manufacturing related risks - new site (e.g. Fredriksson, 2008)	Long production ramp-up time. Long learning curve. Quality deficiencies before right level of quality is achieved. Extra costs for new production equipment. Up-dating and modification of documents. Disposal/ closing down costs. Level and accessibility.
Financial uncertainty (e.g. Dunning 1994)	Custom duties. Inflation. Interest rates/exchange controls and GDP/GNP growth. Income per capita. Infrastructure.
Social and	Language. Communication problems. Access to skilled workforce. Competence losses. Roles of

cultural differences (e.g. Fredriksson, 2008)	women and minorities. Religion. Average education. Ethics and moral. Reliability. Importance to do a good job. Importance to keep times. Residents: Age. Health. Distribution. General rate of wage change. High mobility. Urbanization.
Political instability (e.g. Thomas and Worral, 1994)	Stability of government. Ideology. Legal systems. Tax structure and tax incentives. Business climate. Country's debt. Regulations and restrictions that can affect operation.
Natural disasters (e.g. Kasuda, 1994)	Earthquakes. Rain periods. Hurricanes.
Competitive risks (e.g. Miller, 1992)	Quality of work. Lack of skill. Communication infrastructure. Robustness of public utility. Inadequate transportation.
Supply chain risks (e.g. Tang and Tomli, 2008)	Supply risks. Demand risk. Process risk. Intellectual property risks. Behavioural risks. Receivable risks. Inventory risks. IT system risks. Forecast risks. Procurement risks. Receivables risks. Inventory risks. Risks linked to competitor's actions and environmental legislations.

Prioritization of risks to handle is a central question. Risks less likely to occur and initially not deemed as a major economic risk, might at the end be more costly and dangerous than others. It might be more important to handle the risk which have significant consequences and low likeliness than to focus on risks with small consequences but high likeliness (Fredriksson *et al*. 2008). However, risks that are typically underestimated are e.g. communication problems at different levels based on absence of a common language, tacit knowledge which is not documented, out-dated documentation (e.g. product, production equipment routines), un-used capacity and supply base. It is therefore recommended to have routines that in a consistent way value potential business damages when e.g. considering commercial losses, loss of goodwill or un-used man- and machine capacity (Fredriksson *et al.* 2008).

3.2 Risk mitigation techniques

In order to handle risks and to deal with them in a holistic manner, risk mitigation techniques and strategies are required. In risk assessment normally three main questions are posed (Haimes 2009); *What can go wrong? What is the likelihood that it would go wrong? What are the consequences?* Techniques or strategies to deal with these questions are e.g. failure mode and effects analysis (FMEA), life cycle costing (LCC), multi objective analysis and analytic hierarchy process (AHP) (Haimes, 2009).

In an FMEA the most critical potential design and process failure modes are identified before they occur in order to eliminate their effect on early stages (e.g. Onodera 1997). The main elements that are identified are the seriousness or the effects of the failures (severity), the frequency of the failure (occurrence) and the ability to detect the failure (detection). When multiplying these factors, the risk priority number (RPN) is determined to pinpoint the critical failure modes associated with the process. FMEA guides in finding the optimum solution between alternatives by ranking the risks related to each alternative (Onodera 1997). The LCC method can be used for manufacturing location decisions by the identification of high cost areas and thus high risk areas (Woodward 1997). LCC is an economic evaluation tool that determines the sum of initial and future costs related to production operation; from the production location decision is made to the delivery of the product to the customer (Fabrycky and Blanchard 1991). Locating manufacturing in a foreign country often involves the investment of a large amount of money in the target country. Thus, FDI international statistics support the decision of which places have the most return on investment for foreign industries (Dunning, 1994). Another technique, Multi-objective decision trees, guide decision makers when handling several and often conflicting objectives of location alternatives (Haimes 2009). The decision tree approach uses a graphical representation and is efficient for analysing complex problems (Fultun 1971). AHP is a method for enabling the decision makers to structure a complex problem as a simple hierarchy. It evaluates a large number of often conflicting factors in a systematic manner.

What technique to use differ depending on the category of risk as well as the aim of the analysis. The techniques and strategies complement each other and could be considered in the manufacturing location decision process.

3.3 Risk analysis in the manufacturing location decision process

The identification of risks and the analysis of its consequences and likelihood to appear are essential to conduct in the manufacturing location decision process. In the production location field an abundance of literature concerning concepts and models for production location decision are suggested (e.g. Thanh *et al*. 2008; Frediksson *et al*. 2008*;* Pongpanich, 1999), and summarized (e.g. ReVelle *et al.* 2008). Risk assessment is considered to different extension in these models. In a manufacturing location decision model proposed by Pongpanish (1999) the phases of investigation, identification, evaluation and selection are described where the risk analysis is mainly focused in the last phase where the location is selected. In a conceptual model of the process for efficient manufacturing location decisions proposed and presented in Bruch *et al.* (2011), a risk and sensitivity analysis is proposed to be made in the final part of the process. This analysis aims at identifying critical factors concerning risk, uncertainty and impact for each alternative, also considering the phases of investment, ramp-up, operations and phase-out. The outcome of this analysis supports the development of the business case, which should be the basic decision data for the decision making process. Despite the large amount of models suggested and the fact that the field of location theory and modeling is an area that traces its roots back to the first half of the 20th (ReVelle *et al.* 2008) the support used in industry often is insufficient. In addition, it is still not clear how and when risk assessment should be considered in a consistent way during the manufacturing location decision process.

4 EMPIRICAL FINDINGS

In order to study how risk assessment could be made in the manufacturing location decision process two case studies were conducted. It was studied how the risk assessment was performed in two manufacturing location projects at two different companies as well as what documented support that was used.

4.1 Case A

The manufacturing location project in Company A was initiated due to a need to expand the company's market, decrease the loss of market share and locating close to market and key customers.

When the project was carried out the company did not have a documented support for manufacturing location decisions. The knowledge was collected based on the gained experience from a number of previous projects. By the analysis of the interviews and document studies a location decision process emerged including the phases: identification of drivers for relocation, strategic decision, consequence analysis, and final decision. In the first two phases, potential risks were not identified or analysed. However, the consequence analysis included a risk evaluation. The risk factors identified in the process were related to:

- *Manufacturing related risks:* Delay on equipment release, Investment limitations, Keeping the employees motivated on the current manufacturing site, Ensure continuous flow of products, Higher demands on profitability (KPI), New work organisation on the new manufacturing site particularly on the maintenance side.
- *Social and cultural differences:* Collaboration between different sites, Language and cultural barriers, Transfer of knowledge from the current to the new manufacturing site, Available time and resources, Skills of the people involved in the project management, Preparation of documents.
- *Product development:* Under-estimation of the time and effort needed to get the approval of the customer for the modifications in the product design, Introducing new products and achieving reliable forecasts.

After the project was carried out a documented process was developed to even better support manufacturing location decision projects in the future. In this support a holistic approach was taken involving identification of risk level concerning knowledge transfer, organization, cultural aspects, sales, product development, production development and operations, local rules and regulations and security. In the developed process the phases idea, feasibility study, pre-study, realization and closure were included. Risks were treated in all phases except the final closure phase. In the idea phase the

idea was verified and a risk assessment concerning e.g. knowledge transfer was performed. In the feasibility study phase the risk level with the project was identified on a general level. A scenario-based risk and value evaluation was performed in the pre-study phase. Finally, in the realization phase, the main activities concerning risk handling were performed. In this document no additional instructions of how to handle the risk assessment were given. The company argued that every project is different from each other and the intention with their documentation was to avoid upcoming potential risk rather than being a complete list or exactly state how to make the risk value.

4.2 Case B

The aim with the manufacturing location project in Case B was to reach a new market. The company intended to start produce their mature products in the BRIC countries and therefore this project was initiated. When the case study was carried out the localization was still not carried out.

The company in case B had no documented support for manufacturing location decisions. The decision was based on strategic reasoning with a focus on cost but not based on the risks involved. The cost calculations were made based on several assumptions. No risk analysis was made before the location decision was taken. According to the manager for global production support, a risk assessment should have been done much earlier, before the decision was taken, and also during the location decision process. Problems identified in a later stage, after the decision was made, was mainly linked to the supplier interaction. The company had a difficulty to find suppliers that could offer a good price with a high quality. The knowledge transfer to suppliers was another difficulty since there was a risk to spread sensitive information concerning the products. In order to better support manufacturing location decision projects the company had started to develop a support model of a stage/gate character, complementing existing processes.

5 RESULT AND CONCLUSION

In literature there are several risk mitigation techniques presented to handle risks and to deal with them in a holistic manner. There are also an abundance of models concerning concepts and models for production location decision. However, it is still not clear how to carefully consider risks within these models. This paper describes main risks that need to be considered while locating production activities and introduce risk mitigation techniques to deal with these risks. In order to contribute to efficient industrial methods and tool for making well-founded strategic decisions regarding the manufacturing footprint risks must be identified and assessed in the manufacturing location decision process. The empirical findings illustrate that a support for this is needed and that it preferable is of a stage/gate character since this is a format often used in industry. Figure 1 illustrates how to involve risk analysis in a manufacturing location decision process, based on the process described by Pongpanich (1999), Bruch *et al.* (2011), and in case study A as well as the risk mitigation techniques and the risks categories based on the literature review and case study A.

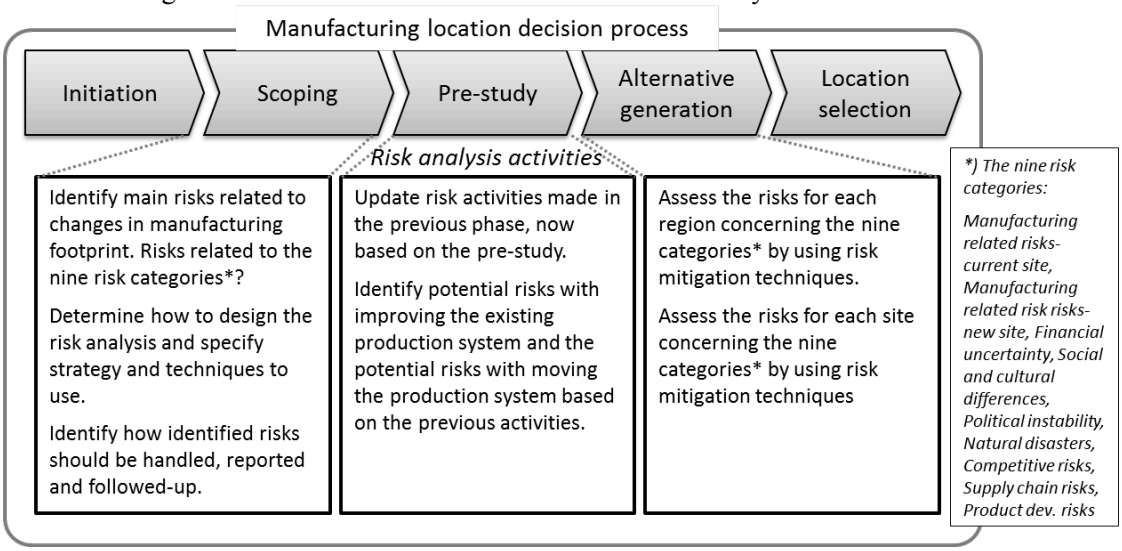

Figure 1: Risk assessment in manufacturing location decision process

The result of the paper give input to future research aiming to develop a supportive decision model of manufacturing localization. A process for including risk assessment activities is suggested involving both identifying potential risks as well as techniques needed to deal with the risks.

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