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Quantitative lifecycle risk analysis of the development of a just-in-time transportation network system

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ABSTRACT

The automotive manufacturing industry is under financial pressure due to massive cost structure, relatively small scale operation and strong global competition. In order to improve their operational cost efficiency, companies have adopt lean principles in all their manufacturing activities, in particular, just-in-time supply chain. However, a consequence of this policy makes the transportation network from the local supply chain time critical. This paper uses an enterprise system model integrated with a quantitative method to study a manufacturing company's logistics system re-development project. The quantitative risk analysis examines the project's systems engineering management plan to see if it is sufficiently to mitigate risks in design, monitoring and validation of the project's lifecycle processes. The computed risk profile shows a trend of decreasing risk and suggests areas of improvement in the systems engineering plan to ensure greater probability of success. The research assumes a single risk profile for the supply chain. Research is continuing in expanding to more accurate risk profile of the project when partners of the supply chain have individual profiles.

1. Introduction

For decades, automotive manufacturing has been regarded as a pillar of many countries' economy. However, as manufacturing systems become global, more competitors from different countries are entering the race. In some countries, the industry is regarded as extremely competitive [1]. In order to survive, automotive manufacturers have no choice but to find ways to reduce cost and increase efficiency.

Typically, the major vehicle manufacturers are responsible for the design and assembly of their products. However, the majority of components for the car are sourced from independent suppliers. For example, one of the major automotive manufacturers in Australia has 210 domestic suppliers with total 5177 parts supplied through its inbound materials operations. These suppliers are also located in three different states with the sources of parts evenly distributed among the states. This type of operation required for closed loop supply chain management, i.e. to deliver inbound domestic automotive parts from suppliers to the main assembly plant and to return the empty packaging from the assembly plant back to its suppliers [2].

Due to the diversity of the supply chain, one of the common problems in the automotive industry is to implement a lean material management system by minimizing its inventory cost. This policy puts pressure on the transportation network such that it has to operate on the principle of Just-In-Time (JIT), i.e. small quantities of inbound materials shall be delivered more frequently to the main assembly plant instead of receiving a once off delivery in bulk sufficient for weeks. Furthermore, the small delivery quantity shall be just enough to cover production requirements for a defined period so as to keep the plant running continuously without interruption.

Usually, third party logistics companies are responsible for providing fully integrated logistics services including the design and implementation of JIT transportation network. However, prior experience showed that although their transportation network design was seen as cost effective on paper (operational plan), a lot of disruption often occurred at the operational level due to the enormous number of ad hoc delivery services that were charged at the premium rate because those services were considered out of scope. This has blown off the purchasing department budget.

An improvement project was initiated within one of the major Australian automotive manufacturers to reduce its operation costs by adopting 'Just in Time' policy to the design of a new transportation network. Making system changes always carries risk, especially when the change involves significant unknowns and investment. In order to mitigate the risks, large scale system development projects are often managed with systematic processes that are designed to minimise the risk of making wrong decisions.

The purpose of this paper is to examine how a quantitative assessment methodology can be used to estimate the levels of risk throughout

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the project's lifecycle at the very early stage of the project's development. To do this, the following research questions are raised about the JIT supply chain:

1. What are the issues affecting design of the supply chain system?
2. How could the effect of these issues be quantified?
3. How can systems engineering approach assist in estimating risks in the lifecycle of the supply chain redesign project?
4. How are the risks assessed?

These research questions are investigated using the case study of the aforementioned automotive manufacturer embarking on a change of the just-in-time supply network. The JIT supply chain re-design project has proved successful in transforming the operation of the supply chain to suit the need for the company. During the transformation, the planned changes have been well-documented. This case provides a valuable set of evaluation data for examining new system development risks.

This paper describes a new method of assessing the risks of the supply network redesign project quantitatively. The method combines an estimated normal distribution of success index at each milestone of the project and computes the probability of success at that milestone. The risk quantification analysis allows decision makers to plan ahead for any mitigation actions required at various parts of the project lifecycle.

The remaining parts of this paper are divided as follows. Section 2 is literature review in relation to the four research questions and hence supports our proposed risk analysis methodology. Section 3 outlines the mathematical part of our risk assessment methodology. Section 4 uses the JIT supply chain system as an illustrative example. Section 5 concludes this paper.

2. Literature review

The four research questions provide a focus to review literature that are relevant to the purpose of this paper. The following sub-sections are organised according to these four research questions.

2.1. Logistics related issues in just-in-time supply chain system

Historically, supply chains are described as activities that involve the movement of materials from the point of origin to the final destination i.e. from manufacturer to customers. However, as the means of transportation are getting more efficient, e.g. due to the fast growing aviation industry, the logistics system design will need to take into account many different mixes of transportation modes and interfaces to different types of information. Zimmer [3] investigated the problem of coordinating producers and suppliers by a single-period order and delivery planning model within a Just-in-Time setting. The research found that a good coordination mechanism would perform just as good as a centralized supply chain. Ke et al. [4] found that industry characteristics had an impact on the transportation model mix in global supply chains. Manufacturing industries tended to use more air freight and less ocean freight when facing positive sales surprises, high-monthly demand variation, a high-contribution margin ratio, a high cost of capital, and increased competition. They proposed that the transportation model mix should align with industry characteristics with the strategies of the supply chains.

In automotive industry, JIT practice has significant influence to supply chain strategy. The main objective of transportation system is to meet the requirements of the customers, no more, nor less [5]. The JIT policy changes the way inbound materials are delivered. Instead of using bulk carriers, less-than-truckload carriers are used to deliver smaller quantity of materials to the destination more frequently.

Danese et al. [6] investigated whether just-in-time supply chains had direct relationship with just-in-time production. They found positive effects in some factors but there were also some adverse factors. They recommended when efficiency was the priority, companies should direct their efforts on JIT production. However, when their aim was to maximize delivery, they should invest on both JIT production and JIT supply chains.

Hence, resolving issues within a JIT supply chain would demand substantial investment to the design of supply chain in addition to internal production efficiency. The high investment nature of system changes poses high risks that must be analysed and mitigated prior to actual commitment.

2.2. Issues in supply chain system design

In a supply chain, it is the logistics engineer's routine work to resolve issues such as deciding actions dealing with complex problems, or negotiating with pluralist participants who are always in disagreement and unwilling to compromise. It is obvious that making changes to the logistics system is a significant challenge to both the system designer and all stakeholders in the system. Su et al. [7] used several cases in Taiwan's heavy vehicle supply chains to identify major risks and influencing factors that hindered the industry in adopting performance-based logistics. The research suggested that performance-based logistics development in Taiwan could be achieved if obstacles could be dealt with collaboratively. Baker [8] explored the role of inventory and warehousing within international supply chains. The result showed that inventory was a common risk mitigation design feature among supply chains being studied. On the contrary, the just-in-time automotive supply chain re-design project in this research intends to decrease inventory which increases risks instead.

To understand the issues in a generic perspective, Goetschalckx et al. [9] developed two models and associated solutions using economic inputs such as seasonal demands, configuration of production and distribution system, sales and profits. They demonstrated that potential savings could be achieved by the design of strategic global supply chain networks with the determination of tactical production-distribution allocations and transfer prices. Hoffman [10] examined the concept of alternative inventory financing by a logistics service provider in Switzerland. The research found that the profit of the logistics service providers depended mainly on the value and amount of the goods to be financed. These findings had strong implications to the costs of supply chain system involving inventory, financing, distribution network and sales.

Koh et al. [11] studied 203 manufacturing small and medium enterprises in Turkey in order to determine the underlying dimensions of supply chain management practices. They established an empirical test framework identifying the relationships between practices, operational performance and the organisational characteristcs.

Changing from an existing logistics system to a new logistics system is not a trivial task. Increasing complexity of the system and changing operating conditions require service personnel to have a higher level of analysis and judgment capability and skill. Unlike a product, a logistics system needs to adapt to the changing environment [12]. Current system change management processes focus on attaining the product requirements only. There is very little effort that considers the impact of retiring the old logistics agreement during the change over period. The challenge in this transition is to maintain a viable working support system while meeting the requirements of the integrated holistic capacity. Staff will have emotional responses that need to be recognised at different stages of changing system. Alcorn and Jarrand [13] witnessed the need of a new health care system being constructed with potential partnerships and cultures as integral parts of the operational plan. Rollenhagen et al. [14] measured plant cultures vs. professional subcultures in three Swedish nuclear power plants using six factors including change management, knowledge and participation. They showed that organisations of the same nature going through same process hence exhibiting similarity patterns but the process of