Managing Supply Chain Risks in Multi-site, Multi-partner Engineering Projects

Sami Kara, s.kara@unsw.edu.au
Berman Kayis, b.kayis@unsw.edu.au
Emilie Gomez, e.gomez@student.unsw.edu.au

School of Mechanical and Manufacturing, the University of New South Wales, Sydney, Australia

Abstract

Identification and managing of variety of risks during the complete product design, development and delivery process are challenging. It covers the 'product value stream' in engineering projects including partners, suppliers, research and development, design and manufacturing, marketing, purchasing, service and support personnel and customers. This, coupled with the relationships that have developed between a purchasing company and its suppliers as well as with its customers, resulting in networks or supply chains that are more exposed and vulnerable to detrimental events. In this paper, a process of supply chain risk management literature is reviewed with an emphasis given to the risk identification process. Accordingly a framework is developed to categorize the sources of risks into three main areas – environment, supply chain and organization with unique risk classifications. This framework can be used as a risk identification tool as well as a route to establish inter- and intra-relationships between various risk factors.

1. Introduction

The management of risks in multi-site, multi-partner (MSMP) engineering projects has attracted interest from both academia and practitioners. In Project Management Body of Knowledge (PMBOK), Risk Management has been indicated as one of the eight main areas to consider (1). Risk Management is a process which covers the life cycle of Product Design, Development and Delivery (PD3). Project planning, organising, managing and controlling phases must cover (PD3) in depth where several risks are housed. Most authors emphasise that it is important to understand exactly what is meant by risk before it can be managed. There are numerous definitions of risk which have changed only little over the decade focusing on the likelihood of occurrence and the degree of impact of a negative event adversely affecting any activity (1,2,3,4,5,6).

Identification of risks are considered by many authors to be the most important element of the complete (PD3) process, as once it has been identified it is possible to take action to address it (7,8,9,10,11,12,13). Thus, the success of the identification process to a very large degree is dependent on the "complete understanding of the engineering projects in a multi-partner, multi-site environment" as discussed in this paper.

The new technologies, computing and communication have become indispensable in every aspect of the design and manufacturing process, leading to structural changes in social and economical dimensions. Internet technology has led to e-Manufacturing which boosted tremendously marketing and sales operations of organisations but not operational aspects of manufacturing. Through B2C (business to customer) and B2B (business to business), customers and businesses have become interconnected carrying out fast on-line transactions. The full scale involvement of manufacturers at operational levels has not been achieved yet due to a lack of complete understanding of the project life cycle. According to Tseng et al(14) this is mainly because every aspect of engineering design and/or manufacturing capabilities have not been linked with customers and suppliers proactively throughout the (PD3) process and collaborating across boundaries. The significant impacts would be on three major areas, namely:

1. Speed of decision (the exchange of information including requirements, drawings, models, test results, etc. dramatically reduced time to market, cost of uncertainty and inventory in product design and development).
2. Expansion of scope (the web inter-connectivity integrated contributions to product design and development regardless of time, geographical distances, stakeholders, suppliers and customers anywhere around the world).
3. Degree of concurrency (people as well as machines can interact in parallel inside and outside of organisations, anywhere around the world).

Engineering projects inherits several risks due to knowledge sharing, decision sharing, process sharing and resources sharing. Thus, to transform from designing products to designing the complete (PD3) process – is rewarding but challenging as well, introducing several risks to manufacturing projects. This paper reviews the published work in supply chain management and proposes a framework which can be used as a risk identification tool as well as a route to establish inter- and intra-relationships between various risk factors in MSMP engineering projects.

2. Collaborative Engineering Approach

Nowadays, the possibility to reach anywhere and anyone immediately through internet is very economical. The instant transmission of information between every partner of a project as well as the flexibility of manufacturing systems helps manufacturers avoid several risks. Designing the complete (PD3) process approaches customers as an important stakeholder and consider suppliers as partners. This is intended to extend manufacturing capability while focusing on core competencies of each. The paradigm then is to view design as teamwork and achieve collaborative effort through effective communication among geographically distributed partners. The dilemma then is information sharing, collaborative decision-making, compatibility of processes and resource sharing, leading to enhanced effectiveness and efficiency of the product design and development on one hand, while introducing new risks on the other. For example, initial studies of merging two big truck companies in Sweden, Scania and Volvo showed that out of 150 important terms used in their product design, only five were common to both companies. Still those five didn't have exactly the same meaning (15,16).

A methodology to analyse a collaborative design process and management of product design conflicts was developed by Lu and Cai (17,18). Within the context of new e-Manufacturing, the design style must be changed from the "Design OF" in the past, through the "Design FOR" at present, to the "Design WITH" in the future (14).

The key feature of "WITH" approach is that designers continuously and collaboratively negotiate their decisions with all other stakeholders around the globe across the Internet. Collaborative negotiation requires communication, consideration and collaboration supports beyond those traditional design approaches, which relied on iterations.

Lu and Cai (17) proposed Engineering as Collaborative Negotiation (ECN) paradigm to address this problem of collaborative design in the new e-Manufacturing era. ECN is an interactive co-construction process where decision interdependencies, mutual adjustments, conflict of priorities, misunderstandings etc. are investigated. Under the ECN paradigm, the socio-technical framework (STF) was developed for collaborative design (17), which takes the view that engineering design is a "technical" activity with a "human" purpose. Modern engineering design always involves multiple stakeholders with competing life-cycle concerns, and hence, is a complex socio-technical activity. In today's collaborative design environment, the number of project participants has been increased and the nature and means of collaboration has been changed with different participant backgrounds, interests, expertise, behaviours, cultural features, etc. This complexity is greatly multiplied in the e-Manufacturing economy, because the World Wide Web facilitates coupling, promotes conflicts and communication problems among project teams with different educational, cultural and social backgrounds(14).

Particularly with e-Manufacturing, the number of participants has increased. For example, supplier collaboration early in the design reduces products lifecycle cost and extend company's ability beyond its traditional boundaries for improvements and to improve total cost of doing business together (17). Hence, to increase the chances of success for manufacturing organisations, Jin and Lu (18) emphasised the importance of collaboration between project partners during engineering design especially in these three areas: task decomposition and representation, communication infrastructure and collaboration support. Indeed, in order to face a growing demand for low cost, high quality, reliable and flexible product designs, new logistics strategies, which advocated the establishment of cooperative and strategic buyer-supplier relationships were developed thus revealing the resulting benefits of such cooperation. The term supply chain was coined and supply chain management progressively evolved from material management to include the physical distribution and transportation functions. Thus, the improvement initiatives have intended to make the entire value chain, the network of organizations that are involved, through upstream and downstream linkages, in the different processes more efficiently by exploiting the supplier strength and technology as well as developing collaboration between distribution and transportation functions (19). This collaboration will eventually lead to competitiveness of organisations, due to better knowledge utilisation and sharing with every project partner and incorporating the changing design style from the "Design OF" in the past, via the "Design FOR" at present, to the "Design WITH" in the future.

3. Supply Chain Related Risks

Although the international standards acknowledge both upside and downside aspects of risk, majority of the authors consider only the latter, thus focusing on events with adverse consequences, and in order to tackle circumstances leading to benefits refer to opportunities. Furthermore, in the literature, supply chain risk is not precisely defined and tends to be amalgamated with the risks arising from the supplier and then threatening the operations of the purchasing companies. It is perceived in the current literature as an approach to identify and assess the supply chain vulnerabilities, and define mitigation strategies accordingly (20,21), rather than a process to identify the uncertainties faced by supply chain partners and the resulting trade-offs between the potential benefits and losses, as it is considered in this research carried out by the authors of this paper.

Although the precaution is taken in the international standards not to make this confusion by defining the latter as risk treatment, the literature with regard to supply chain risk is not always as precise and generally refers to both aspect of the definition, as illustrated by the definition of supply chain risk management provided by Peck (2002).
Identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members aim to reduce supply chain vulnerability as a whole. Zsidisin et al. (2004) and Tang (2006) mentioned the the lack of research covering several aspects of supply chain vulnerability. Thereafter, more research has been published with regard to supply chain risks and more attempts have been made to provide a risk management process. Jüttner et al. (2003) proposed not only a basis with a four-step managerial process, but also recommendations for future research in order to develop this approach (24). As in majority of the research that follows, the authors do not intend to define the process itself but rather to provide recommendations for its implementation as well as the tools and methods that can be used in each step, as illustrated in the article of Deleris et al. (2004) which provided a comprehensive summary of their approach by defining not only the process but also the tools to be used with the information needed and ultimately the results of each step (25). Some researchers emphasized the importance of risk management to be a reactive approach to risk, but definitely indicate the importance of the proactive process (19,20,22,23,26,27,28,29,30,34). The key role of Collaborative engineering approach was also emphasized.

Many typologies have been proposed and discussed in the literature as summarised in Table 1. Three main classifications have been identified based on the type of risk. The first one is based on the classifications according to the type of risk (29, 30, 31, 32, 33, 35). The second classification is from the supply chain viewpoint which is summarised in Table 1 (19,25,26,27,36,37,38).

Table 1: Classifications from a supply chain viewpoint

References	Classification	Definitions
Peck (2002)	Internal to the supply chain	Arise from interaction between constituent organizations across the supply chain
	External to the supply chain	Arise from interactions between the supply chain and its environment
Christopher (2003)	Level 1 – Value stream	Workflows and information flows
	Level 2 – Asset & Infrastructure	Fixed and mobile assets needed to produce and carry the goods and information flows in level 1
	Level 3 – Organization	Contractual and trading relationships
	Level 4 - Environment	Wider macroeconomic and natural environment within which organizations do business, assets and infrastructure are positioned and value stream flows.
Deleris et al (2004)	First-level factors Supply Transportation Production Storage Demand Structural factors	Directly affect the outcome, but not within the control of the firm nor always directly related to its supply chain but affect the outcome values
	Second level factors	Affect the value of the first-level factors. For each first-level factor, the second-level factors are man, machine, infrastructure
	Risk factors Operational/technological Social Nature/hazard Economy/competition Legal/political	Internal or external uncertain events that cause or worsen supply chain disruptions through their effect on first- and second-level factors
Cavinato (2004)	Physical network	Actual movement and flows within and between firms, transportation, service mobilization, delivery movement, storage, and inventories
	Financial network	Flows of cash between organizations, incurrence of expenses, and use of investments for the entire chain/network, settlements, A/R and A/P processes and systems

References	Classification	Definitions
	Informational network	The processes and electronic systems, data movement triggers, access to key information, capture and use of data, enabling processes, market intelligence
	Relational network	The appropriate linkage between a supplier, the organization and its customers for maximum benefit; includes internal supply matter relationships throughout the organization
	Innovational network	The processes and linkages across the firm, its customers, suppliers, and resource parties for the purpose of discovering and bringing to market product, service, and process opportunities
Kleindorfer and Saad (2005)	Supply & demand coordination	
	Normal activities disruptions	
	Operational contingencies	Equipment malfunctions, unforeseen discontinuities in supply, human-centred issues from strikes to fraud
Veenstra et al. (2006)	External	Sources of risk that are outside the scope of the supply chain
	Internal	Internal to the companies in the supply chain, but not related to supply chain processes

The third classification is from an organisation's point of view. Kiser and Cantrell's framework (2006), considers internal and external risks in relation to the individual firm, thus considering the supply chain risk as external. This distinction has been made to specify who has to take actions in order to manage a particular risk (19). Jüttner et al. (2003)'s framework covers some organizational and supply chain related risks (24).

In addition to those three different types of classification, other frameworks that do not fall into one of these categories have been identified (39,40,41). In conclusion, majority of the classifications presented have, in fact, been designed with the objective of classifying risk and not the sources of risk. However, as mentioned above, risk is a multidimensional concept, and a classification that proves suitable for the causes may not be adequate for the consequences. Moreover, in some cases, the criterion according to which the differentiation has been made is not clearly stated which renders the taxonomies difficult to use by a third person. This is emphasised by the lack of clear definition of the categories and their boundaries, most of the classifications being defined through examples. Furthermore, while some classifications tend to be very specific (eg, type of risk) others are much more general (eg, internal vs. external). It is believed that in order to make a comprehensive and directive framework that will enable to identify and understand as many risks as possible a mix of broad categories and more specific one should be use, i.e. the broader categories must be sub-divided as far as possible, without losing the generality of the framework. Additionally, majority of the authors only consider downside risk and this is reflected in their typologies through the use of terms such as vulnerabilities or other negative terms.

Accordingly, this paper proposes a framework by utilising all the categories mentioned above together with the risks that the supply chain network can be exposed in MSMP engineering projects, aiming to provide the most comprehensive list of potential sources of risks.

4. Methodology

4.1 Supply Chain Framework

A framework is built based on Jüttner et al.'s framework (2003) as shown in Figure 1. However, as previously mentioned, the broad categories should be further divided, as it is believed that it can allow a focus on a particular area and therefore the identification of more uncertainties. In order to achieve this, Miller's classification (42) has also been utilised. The next three sections aim to present and define the risk areas that compose this framework as well as the subcategories.

4.1.1 Environmental factors

The environmental factors are the parameters that affect a company's and its supply chain's performance as a result of a third party's (i.e., not part of the supply chain) activities; therefore they are not in control of the supply chain or a firm and cannot be avoided, but only mitigated. Table 2 summarizes environmental factors covered in the framework.

4.1.2 Supply-chain related factors

These factors represent events arising within a particular supply chain of an industry since they may result from activities either upstream or downstream in this particular supply chain. It is summarised in Table 3 with related examples.

4.1.3 Organizational factors

The organizational factors are the conditions specific to an individual firm in the supply chain and are in control of this firm only. They are summarised in Table 4.

4.2 Propositions

Once potential risks have been identified, the relationships between them need to be established in order to appraise the probability of materialization of any scenarios to occur and the magnitude of the potential consequences for establishing a structured risk management process. Several outcomes of a MSMP engineering projects have been developed to ensure covering all potential risk factors to ensure "in the right quantity, to the right place, at the right time in a cost effective manner" (43, 44, 45). A backward approach of the potential risks causes are established, and then, from these causes more outcomes can be generated with the development of what-if scenarios. An example is given in Figure 2. The use of cause/effect relationships allowed the traceability of the risks to be captured resulting in a total of three tools to be developed. These are cause versus consequence matrix, fault tree and event tree analysis and influence diagrams.

4.2.1 Cause versus consequence matrix

The matrix developed displays the potential causes of risks on the vertical axis and the consequences on the horizontal axis. The relationship between two factors is displayed by ticking the box at the intersection points. It can also be used as a tool to map the supply chain relationships already identified and then identify the areas that need further analysis. Due to space restrictions these tables cannot be displayed in this paper. Moreover, this matrix could also be used for risk estimation by adding a third dimension in order to display the magnitude of the risk.

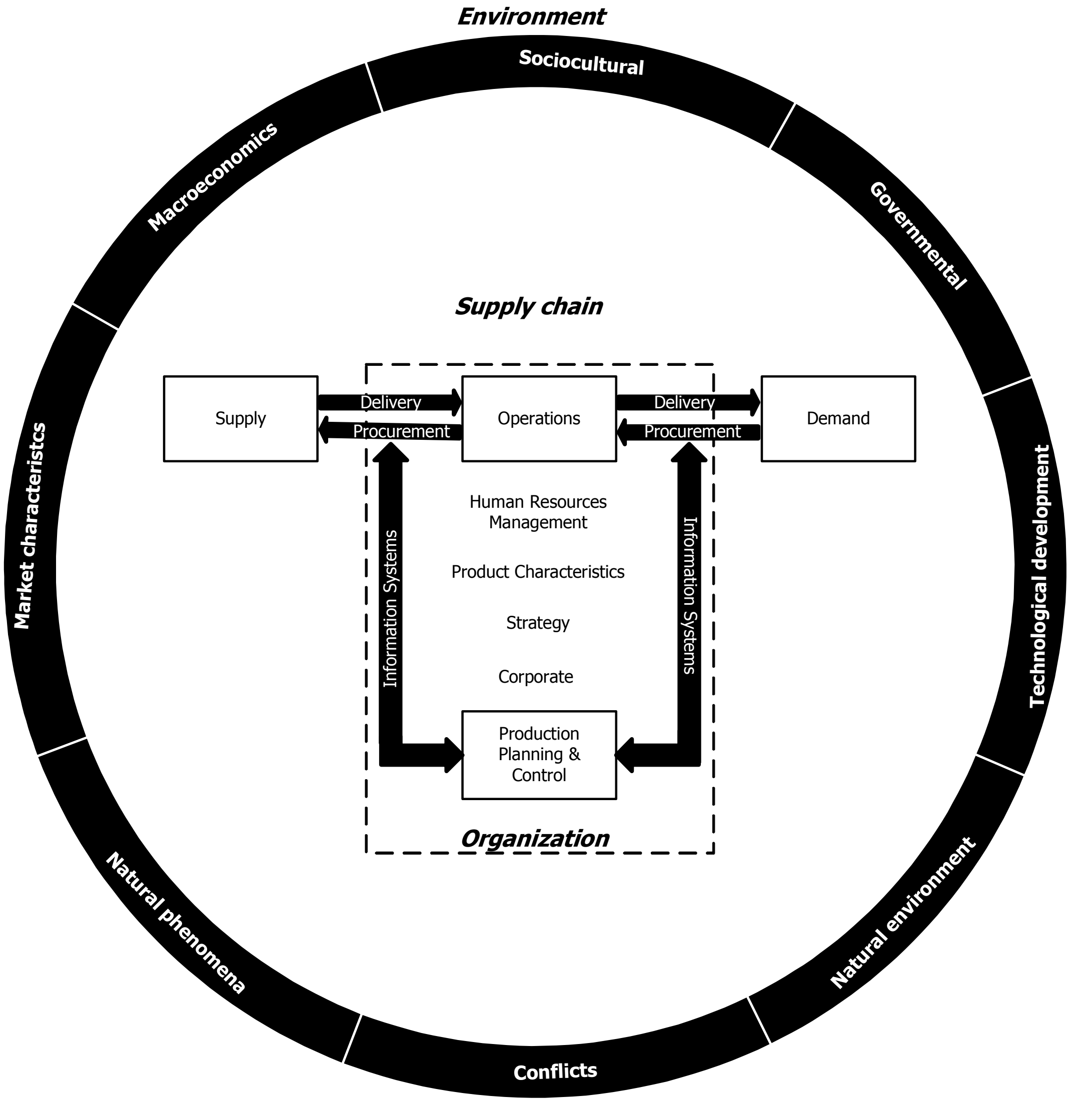

Fig 1. The structure of the proposed Framework

Table 2: Sample of environmental factors

Risk Area	Examples
CONFLICT	Coup d'état, terrorism, war
GOVERNMENTAL	Fiscal & monetary reforms, government actions/policy, government change, inadequate provision of public services, legal risk (corporate social responsibilities), political stability, poor infrastructure, pressure groups actions (non governmental groups or organizations), regulation (current & change), threat to government
MACROECONOMICS	Currency devaluation, economic activity, economic slump, economy stability, exchange rate, firms closing down, globalization, inflation, level of trade barriers, multilateral agreements, price (control and change), terms of trade, unemployment rate
MARKET CHARACTERISTICS	Complementary goods availability, level of competition, market capacity, market stability, mass customization, new entrants, new market opportunities, number of customers, number of qualified suppliers, raw materials availability, speed of change, substitute goods availability
NATURAL ENVIRONMENT	Country's natural resources, disposal/recycling, environment preservation, global warming, natural resources depletion, pollution, waste generation
NATURAL PHENOMENA	Geological phenomenon, meteorological phenomenon
SOCIO-CULTURAL	Culture, demonstrations, labour dispute, labour unrest, riots, social concerns, social stability
TECHNOLOGICAL DEVELOPMENT	IT dependence, new technologies

Table 3: Sample of supply chain factors

Risk Area	Examples
DELIVERY	Border crossing, damage in transit, delivery date, delivery failure (wrong location, time, quantity), handling, no incoming material, transportation lead time (delays), route (choice, change), transportation disruption, transportation modes (choice, change)
DEMAND	Change in customer tastes/needs, customer satisfaction, customers expand forecast, demand for performance, demand for variety, demand level, demand pattern regularity, demand predictability, demand volatility, loss of customer, service level
INFORMATION SYSTEMS	Incompatibility of information systems, information quality, information security, information sharing initiatives failure, information sharing systems implementation, information technology control failures, transaction complexity, transaction velocity
PROCUREMENT	Batch purchasing, bullwhip effect, erroneous order form, forward buying, procurement costs, product availability, purchasing cycles fluctuation
RELATIONS	Blurring boundaries, contracts, control, coordination, demand knowledge, dependence, inertia, information sharing, ownership, supply chain complexity, supply chain design, supply chain facilities, supply chain understanding, TQM program, trust, upstream company training in quality
SUPPLY	Financial stability, global sourcing, interruption of supply, obligation to other customers, quality, sole sourcing, supplier location, supplier's flexibility, supplier's operations, supply lead time

Table 4: Sample of organizational factors

Risk Area	Examples
CORPORATE	Claim to tribunal, compliance with regulatory environment, credit uncertainties, financial performance, fines, improper investments, loss of business, reputation, sales, taxes
HUMAN RESOURCES MANAGEMENT	Culture (resistance to change), employee availability, employee safety, key employee experience, managerial or employee self-interested behaviour, opportunistic behaviour, personnel reduction (lay off), reward for entrepreneurial risk taking, training programme
OPERATIONS	Accidents, adequate processes, asset impairment, automation, core competence, damage, defective product, destruction, equipment maintenance, equipment malfunctions, equipment obsolescence, flexibility, losses, production interruption, production lead time, production or technological change, productivity variation, quality consistency, rework
PRODUCT CHARACTERISTICS	Innovation, manufacturability, nature of product application, new product development, new product introduction, PLC, product variety, product/process complexity, product/process design change, time-to-market, uniqueness of product/process, unpredictable cycle times, use of common components
PRODUCTION PLANNING and CONTROL	Buffer stock, capacity constraint, forecast accuracy, forecast horizon, forecasting difficulty, distortion, inventory control accuracy, inventory level, obsolescence rate, planning methods adequacy, replenishment lead time stability, scheduling methods, information adequacy, volume/mix requirement change
STRATEGY	Centralisation of production/distribution facilities, choice of partners, concurrent engineering, cost focus, focus on efficiency, focused factory, lack of mitigation & contingency plans, lean manufacturing, logistics conceptual choices (eg, JIT), marketing strategies, objectives, outsourcing, pricing, quality focus.

4.2.2 Fault tree and event tree analysis

Event tree and fault tree analyses (ETA/FTA) were carried out to display the sequential order and combination of events, as well as conditional circumstances, that lead to a particular risk; thus enabling risk traceability. Whereas, the lack of flexibility have been the limitations for both the causes versus consequences matrix and ETA/FTA, since they offer a static representation of what is supposed to be a dynamic problem. Therefore the third tool to be tested is system dynamics modelling based on influence diagrams.

4.2.3 Influence diagrams

Detailed influence diagrams have been developed using the risk framework described in section 4.1 and different risks identified in the literature. Vensim- Dynamic modelling software was used to develop a total of 33 influence diagrams. They display the complex relationships between the three major classifications, risk areas and subcategories and related other factors. At this detailed level, as far as possible, the relationships within a subcategory have been allocated a polarity in order to explicit the relationship that link two factors. That is to say; Reinforcing behaviour (+) is the causal factor which supports its consequences, i.e. an increase in its level increases the consequence magnitude. Similarly, Balancing behaviour (-) is the causal factor which adversely affects the factor it is linked to; its increase reduces the consequence magnitude. When no polarity exists, the influence will depend on specific circumstances. For example a change in customer taste (or need) impacts on the demand level, but depending on the reason for this change, an increase or decrease in demand can result. To avoid such situation, the factors should be defined more precisely.

The numerous advantages of influence diagram representation is worth the excessive time spent by the authors to build the process and related models. Indeed, the relevance of the factors displayed and the accuracy of their definition and labelling have a major impact on the quality of the analysis, as subsequent steps, i.e. data collection and simulation. As a consequence, matrices developed to structure the relationships between different factors proved really useful not only to identify and understand how risk triggers but also to define and establish linkages. Two of the diagrams developed are shown in Figures 3 and 4.

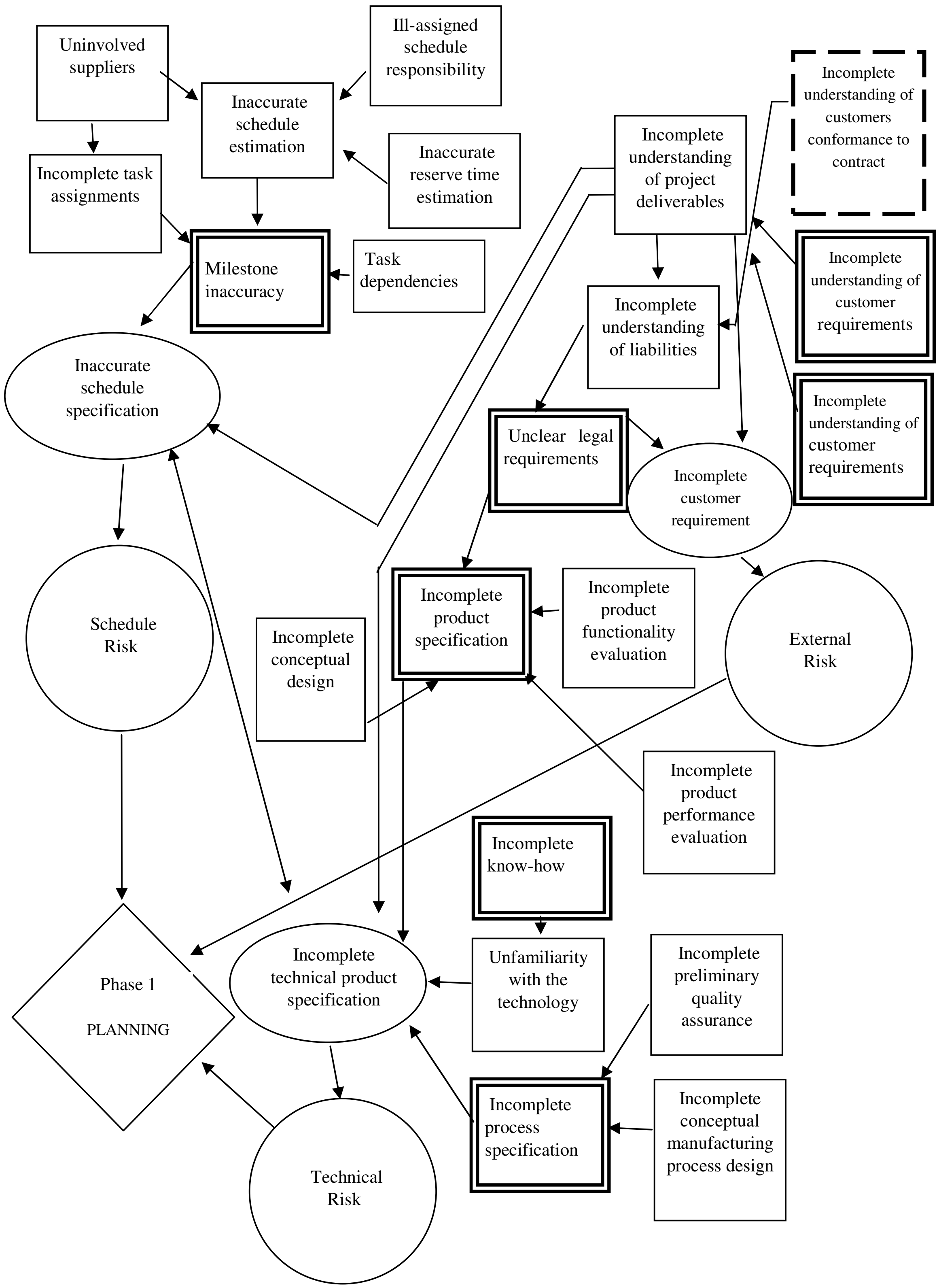

Fig 2: An example of the risk identification approach used (Savci and Kayis, 2006)

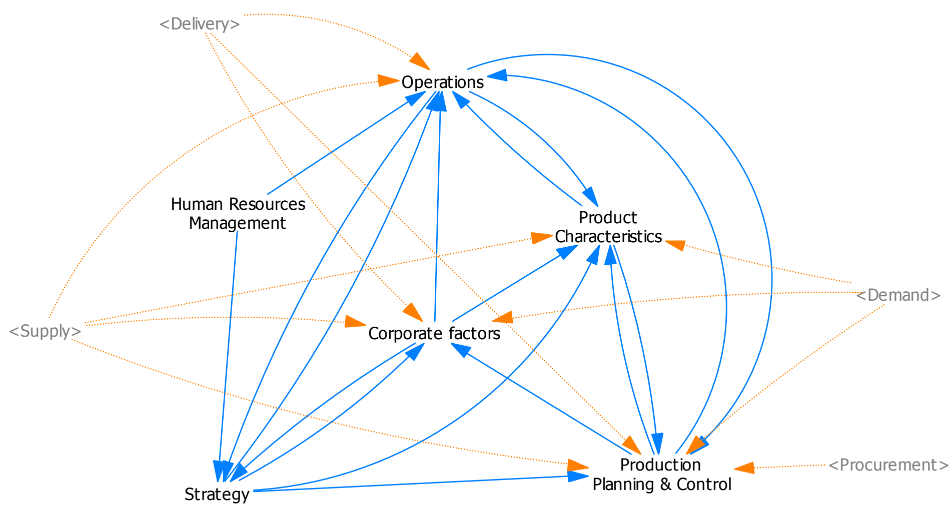

Fig 3: Impact of the supply chain on the organisation

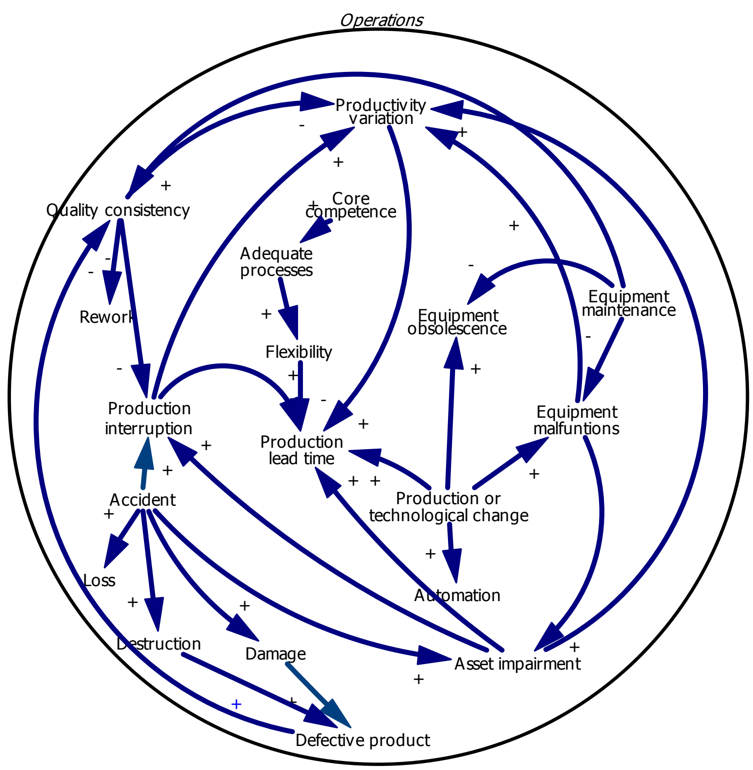

Fig 4: Sample of operational factors interactions

5. Conclusions

A framework developed is presented in this paper to categorize the sources of risks into three main areas – environment, supply chain and organization with unique risk classifications. This framework can be used as a risk identification tool as well as a route to establish inter- and intra-relationships between various risk factors. The framework and tools developed in this research is planned to be further utilised in a software called “Risk Mapping and Assessment System” (IRMAS™) which was recently developed covering most of the gaps to enhance its supply chain management features (47). Most of the existing commercially available tools for risk management are mainly designed for risk analysis and assessment. Several Commercial-Off-the-Shelf (COTS) software for risk management were evaluated by the authors and only a few of them were found to have some features to be utilised for risk identification (46). For instance, the available COTS software lacked capabilities to support project managers in a MSMP engineering environment to identify, analyse and mitigate risks during the life cycle of the project. There are no COTS software available that can capture and reuse the lessons learnt from previous projects, case studies and best practices, to utilise and share the previous as well as existing knowledge and experience within the companies with an extensive supply chain knowledge and implementation. The (IRMAS™) system will be commercially available as Intelligent Risk Exchange (IREX).

6. References

[1] Project Management Institute (US) Standards Committee. A Guide to the Project Management Body of Knowledge. Reproduced by Australian Institute of Management, 1996.

[2] Larson, N., Kusiak, A., “Managing Design Processes: A Risk Assessment Approach,” *IEEE Transactions on System, Man and Cybernetics, Part A* (26:6), 1996, pp. 749-759.

[3] Jaafary, A., “Management of Risks, Uncertainties and Opportunities on Projects: time for Fundamental Shift,” *International Journal of Project Management* (19), 2001, pp. 89-101.

[4] Conroy, G., Soltan, H., Conserv, A., “Project Specific Risk Management Concept,” *International Journal of Project Management* (16), 1998, pp. 353-366.

[5] Craig, R. D., “Calculated Risk: A Framework for Evaluating Product Development,” *IEEE Engineering Management Review* (31:1), 2000, pp. 38-443.

[6] Smith, P. G., Merritt, G. M., *Proactive Risk Management*, Productivity Press, NY, 2002.

[7] Wideman, R. M., “Risk Management,” *Project Management Journal* (17:4), 1986, pp. 20-26.

[8] Cooper, D. F., Chapman, C. B., *Risk Analysis for Large Projects: Models, Methods and Cases*, New York, Wiley, 1989.

[9] CCTA – The Government Centre for Information Systems, An Introduction to Managing Project Risk, London: HMSO, 1993.

[10] CCTA – The Government Centre for Information Systems, An Introduction to Managing Project Risk, London: HMSO, 1994.

[11]Chapman, C. B., Ward, S. C., *Project Risk Management: processes, techniques and insights*, John Wiley& Sons, Chichester, 1997.

[12] Perry, J. G., Hayes, R. W., Risk Management for Project Managers. Building Technology and Management, August/September 8-11, 1986.

[13] Hertz, D. B., Thomas, H., *Risk Analysis and its Applications*, New York: Wiley, 1983.

[14] Tseng, M. M., Kyellberg, T., Lu, S. C. Y., “Design in the New e-Manufacturing Era,” *Annals of the CIRP*, (52:2), 2003, pp. 51-60.

[15] Prasad, B. Concurrent Engineering Fundamentals: Integrated Product and .Process Organisation, Prentice Hall, PTR, USA, 1996.

[16] Haque, B., “Problems in Concurrent New Product Development: an In-depth Comparative Study of Three companies,” *Integrated Manufacturing Systems*, (14:3), 2003, pp. 191-207.

[17] Lutters, D., Mentink, R. J., Van Houten, F., Kals, J. H. H., “Workflow Management based on Information Management,” *Annals of CIRP*, (50:1), 2003, pp. 109-121.

[18] Lu, S. C. Y., Cai, J, “STARS: A Socio-Technical Framework for Integrating Design/Knowledge over the Internet,” *IEEE Computing*, (4:5), 2000, pp. 54-62.

[19] Christopher, M., “Creating Resilient Supply Chains: A Practical Guide,” Cranfield University, School of Management, 2003.

[20] Kiser, J., Cantrell, G., “6 Steps to Managing Risk,” *Supply Chain Management Review*, (10:12), 2006.

[21] Peck, H., “Supply Chain Vulnerability,” Cranfield University, School of Management, 2002.

[22] Zsidisin, G. A., Ellram, L. M., Carter, J. R., Cavinato, J. L. “An analysis of supply risk

assessment techniques," *International Journal of Physical Distribution & Logistics Management*, 2004, pp. 34- 39.

[23] Tang, C. S., "Perspectives in supply chain risk management," *International Journal of Production Economics* (103), 2006, pp. 451-488.

[24] Jüttner, U., Peck, H., Christopher, M., "Supply chain risk management: outlining an agenda for future research," *International Journal of Logistics: Research & Applications*, (6), 2003, pp. 197-210.

[25] Deleris, L., Erhun, F., Paté-Cornell, M. "Quantitative Risk Assessment of Supply Chain Performance," *Management Science and Engineering*, 2004.

[26] Hauser, L. M., "Risk-Adjusted Supply Chain Management," *Supply Chain Management Review* (7), 2003, pp. 64-66.

[27] Kleindorfer, P. R., Saad, G. H, "Managing Disruption Risks in Supply Chains," *Production and Operations Management* (14), 2005, pp. 53-58.

[28] Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V.-M., Tuominen, M., "Risk management processes in supplier networks," *International Journal of Production Economics* (90), 2004, pp. 47-58.

[29] Cucchiella, F., Gastaldi, M., "Risk management in supply chain: a real option approach," *Journal of Manufacturing Technology Management* (17), 2006, pp. 700-720.

[30] Harland, C., Brenchley, R., Walker, H., "Risk in supply networks," *Journal of Purchasing and Supply Management* (9), 2003, pp. 51-62.

[31] Zsidisin, G. A., "Managerial perceptions of supply risk," *Journal of Supply Chain Management* (39), 2003a, pp. 14-20.

[32] Zsidisin, G. A., "A grounded definition of supply risk," *Journal of Purchasing and Supply Management* (9), 2003b, pp. 217-224.

[33] Chopra, S., Sodhi, M. S., "Managing Risk to Avoid Supply-Chain Breakdown," *MIT Sloan Management Review* (46), 2004, pp, 53-55.

[34] Berry, A.J.,Collier, P.M., "Risk in supply chain: explanatory case studies in automotive industry," *International Journal of Risk Assessment and Management*,(14), 8, 2007,pp 1005-1026.

[35] Spekman, R. E., Davis, E. W., "Risky business: expanding the discussion on risk and the extended enterprise," *International Journal of Physical Distribution & Logistics Management* (34), 2004, pp. 414-420.

[36] Veenstra, A. W., Becker, J. F. F., Vrijenhoek, N. H., "Secure global supply chains - Towards a theoretical framework," *11th International Symposium on Logistics*, Beijing, 2006, pp. 323-327.

[37] Cavinato, J. L., "Supply chain logistics risks: from the back room to the board room," *International Journal of Physical Distribution & Logistics Management* (34), 2003, pp. 834-838.

[38] Emblemsvag, J., Kjolstad, L. E., "Qualitative risk analysis: some problems and remedies," *Management Decision* (44), 2006, pp. 395-408.

[39] Smallman, C., "Risk and organizational behaviour: a research model," *Disaster Prevention and Management* (5), 1999, pp. 126-133.

[40] Svensson, G., "A conceptual framework for the analysis of vulnerability in supply chains," *International Journal of Physical Distribution & Logistics Management* (30), 2007, pp. 310-315.

[41] Cousins, P. D., Lamming, R. C., Bowen, F., "The role of risk in environment-related supplier initiatives", *International Journal of Operations & Production Management* (24), 2004, pp. 554-560.

[42] Miller, K., "A Framework for Integrated Risk Management," *International. Journal of International Business Studies* (23), 1992, pp. 311-316.

[43] Kayis, B., Zhou, M., Savci, S., Khoo, Y. B., Ahmed, A., Kusumo, R., Rispler, A., "IRMAS – Development of a Risk Management tool for Collaborative Multi-site, Multi-partner New Product Development Projects," *Journal of Manufacturing Technology and Management*, (18:4) 2007, pp. 387-412.

[44] Kara, S., Kayis, B., "Competing on Capabilities - An Analysis of Supply chain Flexibility in Australian Manufacturing Industry," *International Journal. of Risk Assessment and Management* (7:1), 2007, pp. 79-99.

[45] Kayis, B. and Kara, S., "The Supplier and Customer Contribution to Manufacturing Flexibility: Australian Manufacturing Industry's Perspective," *Manufacturing Technology and Management*, (16:7), 2005, pp. 733-752.

[46] Savci, S., Kayis, B., "Knowledge Elicitation for Risk Mapping in Concurrent Engineering Projects," *International Journal of Production Research* (44:9), 2006, pp. 1739-1755.

[47] Kayis, B., Arndt, G., Zhou, M., Savci, S., Khoo, Y. B., Rispler, A., "Risk Quantification for New Product and Process Design in Concurrent Engineering Projects," *CIRP Annal*s (55:1), Kobe, Japan, 2006, pp. 147-150.