DEVELOPMENT OF FUTURISTIC SUPPLY CHAIN RISK MANAGEMENT PILOT STRATEGIES FOR ACHIEVING LOSS REDUCTION IN MANUFACTURING ORGANISATIONS

D. Elangovan*[1], Karpagam College of Engineering, Coimbatore, India
G. Sundararaj[2], PSG College of Technology, Coimbatore, India
S. R. Devadasan[3], PSG College of Technology, Coimbatore, India
P. Karuppuswamy[4], Sri Ramakrishna Engineering College, Coimbatore, India

Abstract: Manufacturing organisations are expected to produce their products with prompt delivery using better supply chain activities. Starting from the procurement of raw materials to the delivery of final products, there are inevitable losses occurring due to major time delays in supply chain activities. Hence it is essential to study, understand and track these major time delays by developing futuristic supply chain risk management strategies. This paper reports a research which was conducted to meet this requirement. During this research, major time delays were investigated by conducting a questionnaire supported interview based survey in 15 manufacturing organisations. On analysing the responses, pilot strategies for achieving loss reduction have been proposed. The paper is concluded by pointed out the necessity for developing dynamic models for achieving loss reduction and continuous improvement.

Keywords: Supply chain, supply chain management, risk, risk management, risk mitigation, major time delays, loss producing events, loss reduction, continuous improvement

INTRODUCTION

Global market influences the role of the cooperation, coordination and consistent integration of various activities along the supply chain in order to reduce the likelihood of risk events. On the other hand, manufacturing organisations are in need to implement the risk management practices to observe a key challenge that lies in the trade-off between opportunity and loss (Schwab and Schwab, 1997). Thus continuous monitoring

[1*]Department of Mechanical Engineering, Karpagam College of Engineering, Othakkal Mandapam (PO), Coimbatore – 641 032, Tamil Nadu, India, E-mail: delangovan_cbe@rediffmail.com
[2]Department of Mechanical Engineering, PSG College of Technology, Coimbatore – 641 004, Tamil Nadu, India, E-mail: gsraj_558@yahoo.com
[3]Department of Production Engineering, PSG College of Technology, Coimbatore – 641 004, Tamil Nadu, India, E-mail: devadasan_srd@yahoo.com
[4]Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Coimbatore – 641 022, Tamil Nadu, India, E-mail: pkaruppuswamy_cbe@rediffmail.com

of supply chain activities are essential to stay in the fierce competitive environment. Today manufacturing organisations are ready to focus and adopt newer techniques, principles and strategies to achieve an overall effectiveness in the entire system. The introduction of variety of products from various competitors insists manufacturing organisations to focus better alternative strategies in the internal as well external supply chains to timely meet the customer expectations and due date demand requirements.

Starting from procurement of raw materials to the delivery of final products, there are inevitable losses due to various issues in supply chain activities. Ultimately, these issues are causing time delay in entire manufacturing cycle. Supply chain planning is vital for prompt execution of various supply chain activities (Kok and Fransoo, 2003). Applications of optimisation techniques for various strategic issues are highly contributing better supply chain planning (Muriel and Simchi-Levi, 2003). Flexibility considerations in supply chain activities (Bertrand, 2003) are necessary for an effective manufacturing system. Thus the streamlined investigations in supply chain activities and its execution are necessary to satisfy the customers in time. Hence, it is essential to study, understand and track the various expected risk events due to major time delays in supply chain activities for loss reduction and continuous improvement.

LITERATURE REVIEW

The literature was surveyed from three perspectives namely supply chain management (SCM), risk management and loss reduction. The papers identified through this literature survey were reviewed systematically. The interesting results derived through this literature survey are presented in this section. Recently, it is increasingly observed that supply chains compete with other supply chains in the same organisation (Christopher, 1992). The increasing global competition, the changing customer's expectations and technological innovations challenge organisations to aim for business agility through process-focused thinking. The global performance of business processes is however constrained by unpredicted events, which cause deviations from the expected purpose. By anticipating these probable events, the process management team shall balance cost, risk and associated performance. Thus it is necessary to provide methods for risk considerations (Sienou et al., 2006) for mitigation and loss reduction. The number of potential response for particular risk events is risk avoidance, risk retention, risk transfer and risk reduction. The related data are properly recorded as risk documents for further reference and future review analysis. Hence, continuous monitoring and supply chain integration for risk mitigation, loss reduction and its future elimination are essential.

Global competition and maturing domestic markets have driven supply chain members to reassess their activities to remain competitive in the market. Recently, the issue of buyer-seller relationships in SCM is highlighted (Myers et al., 2000) to achieve enhanced supply chain executions. Thus the essence of information sharing and supply chain coordination is necessary to retain customers in the fierce competition (Chen, 2003) and timely respond to the customer's demand requirements. Effective risk control measures are executed by adopting appropriate cause consequence analysis (Lewis, 2003) to achieve risk identification, reduction and control. Mathematical approaches such as 'evolutionary computation' have shown an interesting potential in the engineering fields. The optimisation strategies that

are used in these approaches have led an increasing number of researchers to address several types of problems encountered in the area of manufacturing systems (Pierreval et al., 2003).

Fast and dramatic changes in customer expectations, competition and technology are creating an increasingly uncertain environment. To respond this, manufacturers are seeking to enhance flexibility along the supply chain activities. It is strategically important for enhancing competitive position and winning customer orders. It also has strong, positive and direct relationships with customer satisfaction (Zhang et al., 2003). A framework was proposed for prioritising lead time reduction to achieve desirable levels of market mediation performance explored (Treville et al., 2004). When an organisation faces the global market, they would have to reengineer their processes and reorient their operations by adopting strategies such as 'supply chain positioning' to achieve better performance. This refers to actions taken by organisations to respond to satisfy customer's demand requirements (Sen et al., 2004). A framework which defines ideal profiles of products and markets for manufacturing and investment decisions that relate to alternative process choices of priorities have been explored (Silveira, 2005).

Six dimensions of SCM practices (strategic supplier partnership, customer relationship, information sharing, information quality, internal lean practices and postponement) were conceptualised, developed and validated to provide a precise measurement instrument to assess the performance of the overall supply chain (Li et al., 2005). Integrating the parts of the supply network will create operationally outperforming business models that further boost the inherent dynamics of supply chain activities (Hameri and Paatela, 2005). A model 'predictive control methodology' is proposed with a stochastic optimisation approach and adopts a scenario-based multistage stochastic mixed integer linear programming model is introduced to address the problem of dynamic SCM. The study also incorporates uncertainty and process dynamics into enterprise wide models which also contemplate cross-functional decisions. It is emphasised that the significance of merging uncertainty treatment and control strategies improve the supply chain performance (Puigjaner and Lainez, 2008).

Trkman and McCormack (2009) have pointed out that uncertainties ultimately cause time delay in the manufacturing cycle. Supply risk or supply chain disruptions are caused due to time delays, which are key challenges to supply chain risk management (SCRM). Further, in recent years, the challenges are experienced while managing supply chains due to external factors as well as the turbulent environment existing within the organisation. This often dominates system dynamics and affects the dynamic operability of the organisation. A major challenge for an organisation to stay in today's highly competitive market environment is to be able of capturing and handling the dynamics of its entire supply chain (Puigjaner and Lainez, 2008). Hence it is essential to identify and address the reasons and associated root causes of disruptions occurring along supply chains. For this purpose, assessment of loss producing events (LPEs) with a view to reduce and prevent them in future using appropriate SCRM strategies is needed. Thus manufacturing organisations must pay more attention to futuristic SCRM strategies for achieving better, systematic and dynamic executions of supply chains, using risk mitigation coupled with appropriate strategies.

OBJECTIVES OF THE RESEARCH

The research briefly reported in this paper was carried out to achieve three objectives. They are listed below:

- to investigate the various forms of expected LPEs due to major time delays in supply chain activities of manufacturing organisations
- to justify the necessity and more attention needed for SCRM strategies for better, systematic and dynamic executions using risk mitigation with appropriate strategies
- to emphasise the need for more dynamic models for achieving loss reduction with a future scope of risk prevention for continuous improvement

INVESTIGATION ON VARIOUS FORMS OF LPES DUE TO TIME DELAY IN SUPPLY CHAIN ACTIVITIES OF MANUFACTURING ORGANISATIONS

Manufacturing organisations are seeking better strategies and ways to identify, evaluate, control and monitor supply chain risk, which will serve to safeguard business continuity and maximise profitability. It is becoming increasingly clear that traditional SCRM approaches must be enhanced to include ways and means by which the new uncertainties arising from these trends and developments that can be identified and addressed. But there is a gap between theory and practice of the SCRM initiatives. Hence, there is more scope of doing research improvements for reducing this gap.

The decisions at the strategic level of the supply chain influence its effective execution of various activities. There are five major activities take place within a supply chain at the strategic level namely buy, make, move, store and sell (Govil and Proth, 2002). If there is any execution deficiency in these supply chain activities, then there is inevitable time delay will be caused in the manufacturing cycle. Thus these time delays must at least be identified, listed and addressed in an appropriate manner for achieving loss reduction. To achieve these objectives, an investigation conducted in few batch production manufacturing organisations and among them 15 responses was received. The various forms of expected LPEs due to major time delays along the supply chain activities of manufacturing organisations are investigated, listed and described below:

Major time delays caused due to improper selection of materials and suppliers

During the conduct of this research, the improper selection of materials and suppliers was found to be one of the reasons for major time delays occurring along the supply chains of manufacturing organisations. The root causes for this reason are further divided into primary and secondary root causes. These details are listed in Table 1.

Major time delays caused due to improper use of machines and equipment

During the conduct of this research, the improper use of machines and equipment was found to be another important reason for the occurrence of major time delays along the supply chains of manufacturing organisations. The root causes for this reason are further divided into primary and secondary root causes. These details are enumerated in Table 2.

Major time delays caused due to improper manpower utilisation

During the conduct of this research, the improper manpower utilisation was found

Table 1 Root causes for the major time delays occurring due to improper selection of materials and suppliers

Serial Number	*Root causes for major time delays occurring due to improper selection of materials and suppliers*	
	Primary root causes	*Secondary root causes*
1.	Inadequate inventory	Failure to place orders and instructions clearly in time Permitting the use of improper materials Permitting improper suppliers to supply materials Not knowing the right kind of suppliers to order
2.	Excess inventory	Ordering more materials than necessary Not returning excess materials in stock, when there is no further need
3.	Lack of material knowledge	New employees not thoroughly instructed Employees not instructed on new works Blueprints or sketches torn or illegible
4.	Inadequate and slack supervision	Spoilage of materials Failure to explain money value of materials to employees
5.	Lack of attention and follow-up	Not paying much attention to employees' eyesight and health Lack of discipline among employees, thereby encouraging carelessness
6.	Lack of materials utility and traceability of defective materials	Allowing employees to use supplied materials unsuited for the work whether too good or not good enough Inability to trace the defective work of an employee who did it, so that it can be corrected
7.	Lack of control in man-material handling	Taking employees' ability for granted about material handling Not making sure that employees (especially new employees) are qualified for the work that they are to do
8.	Loss of materials	Failure to see that materials are inspected, piled and stored properly Lack of system to control the supplied materials to prevent loss and theft
9.	Loss due to material condition and wastages	Failure to investigate all bare wires, leaky valves, pipes, fittings on sun stream, water, gas, electric and compressed air lines etc. Permitting the waste or abuse of such supplies as brooms, stationery, oils, gloves, shovels, rubber hoses etc.
10.	Lack of material processing and associated wastages	Scrapping materials that could be salvaged Allowing employees to use oil, compressed air, small tools, chemicals etc. for their personal use

to be another reason for causing major time delays along the supply chains of manufacturing organisations. The root causes for this reason are further divided into primary and secondary root causes. These details are enumerated in Table 3.

Major time delays caused due to inefficient work organisation

During the conduct of this research, inefficient work organisation was found to be another reason for the occurrence

Table 2 Root causes for the major time delays occurring due to improper use of machines and equipment

Serial Number	*Root causes for major time delay occurring due to improper use of machines and equipment*	
	Primary root causes	*Secondary root causes*
1.	Improper planning and scheduling	Failure to plan full work properly so as to use all available machinery
		Lack of time related considerations and planning
2.	Loss due to machine selection and completion of jobs	Foreman's lack of knowledge on possible use and capacity of various machines
		Lack of knowledge on jobs to be completed using available machines and equipment
3.	Lack of maintenance activities	Failure to inspect machines to keep them in good working condition and to prevent breakdowns
		Failure to make regular examination of wire ropes, belts, chain drives, gear drives, conveyors, lubrication systems, valves etc.
		Lack of cooperation with maintenance department
4.	Loss due to machine utilization	Using unnecessarily large and powerful machines for small works
		Employing small machines to carry out heavy works
5.	Lack of knowledge of latest machines and equipment	Failure of the foremen to keep information about the latest types of machinery and equipment
		Failure to keep the list of suppliers' of machinery and equipment
6.	Loss due to idleness of machines	Not protecting idle machinery from weather, dust, dirt, rust, fumes etc.
		Allowing machinery to stay dirty because of lack of periodical cleaning and follow-up actions
7.	Loss due to improper inspection on machines	Failure to inspect for proper lubrication of all moving parts
		Failure to make timely repairs
8.	Lack of instructions on machine operation	Lack of instruction to employees on the proper operation of machines
		Lack of proper discipline of employees resulting in the abuse of machines or equipment
		Allowing employees to make sloppy repairs
9.	Loss due to machinery and equipment condition	System to follow-up machine's current performance
		Failure to pay attention to employees' opinions on the value and condition of machinery and equipment
10.	Loss due to machinery replacement and scrap	Repairing machinery that should be scrapped; it may be costlier than buying new machinery
		Scrapping machinery that should be repaired

of major time delays along supply chains of manufacturing organisations. The root causes of this reason are further divided into primary and secondary root causes. These details are enumerated in Table 4.

Major time delays caused due to wrong work concept and ideas

During the conduct of this research, the wrong work concept ideas and ideas were

Table 3 Root causes for the major time delays occurring due to improper manpower utilisation

Serial Number	*Root causes of major time delays caused due to improper manpower utilisation*	
	Primary root causes	*Secondary root causes*
1.	Failure to control turnover of capable employees	Not considering the direct and indirect costs of employee turnover Not keeping promises which could be fulfilled Making promises which cannot be fulfilled with regard to wages, promotion etc. Discharging employees without sufficient reason and improper use of the discharge slip as a penalty. Keeping an employee on a job for which he has a violent dislike Failure to investigate employee turnover
2.	Loss due improper man power management	Too much bossing without considering the other persons' views Too strict or too lax enforcement of discipline Treating one employee better or worse than others: leading to favoritism Taking sides in employees' groups Criticizing one employee before another Failure to interpret correctly the management's real aim and policies to employees Failure of the foremen to fix wages and working conditions fairly
3.	Failure to get full production from new employees	Not receiving new employees in a kindly and helpful manner Incomplete job instructions to new employees Failure to impress new employees about the necessity of a full day work and what it consists of Failure to select new employees having proper education and qualifications Impatience with new employees who learn slowly Failure to encourage other employees to show friendly and helpful attitude towards new employees Failure to contact new employees as often as may be necessary Not informing new employees about the plant's conditions, regulations, safety precautions, pay days, levarotary, drinking water, lockers, washrooms etc.
4.	Lack of information and knowledge of manpower	Lack of system to inform the new employees about unpleasant or dangerous parts of their work Lack of knowledge on work and inadequate training Failure to train an unskilled employee
5.	Failure to extract work from employees	Failure to commend employees for doing good work Failure to explain as much about the work as possible in order to make it interesting Lack of interest in employees' progress and personal affairs Failure on the formen's part to admit a mistake to the employee Lack of attention to an employee's ability and temperament while assigning work to him Failure to study employees as individuals in order to get their best efforts Rating employees on the basis of regional, religious and social considerations Keeping an employee in a job for which he is physically or mentally unsuited Permitting an employee to remain at work when he is sick Not giving an employee all the help that is needed Failure to promote employees, when it is possible and advisable Lack of due consideration of problems affecting wages and working conditions

Table 4 Root causes for the major time delays occurring due to inefficient work organisation

Serial Number	*Root causes of major time delays occurring due to inefficient work organisation*	
	Primary root causes	*Secondary root causes*
1.	Lack of planning	Keeping employees waiting between successive jobs Keeping employees waiting for the arrival of materials
2.	Lack of knowledge	Lack of knowledge regarding work content Lack of knowledge regarding full day work
3.	Lack of foreman's orders and instructions	Failure to serve work orders to employees Lack of clarity in giving instructing the employees
4.	Lack of traceability	Failure to insist on keeping tools, materials and portable equipment in proper places Failure to identify and group common tools, materials and portable equipment
5.	Overtime work	Avoidable additional time consumption Avoidable additional resources, and their associated cost
6.	Inappropriate utility	Not using proper machine tools and tools suited to particular jobs Not using proper measuring instruments
7.	Lack of work execution	Under-utilization of work force Lack of follow-up actions
8.	Deficiency of work force	Lack of adequate man power for carrying out the work Improper communication with employment and training department
9.	Poor work force utility	Keeping too many persons at work Unnecessary discussions during working hours
10.	Lack of record keeping	Failure of recording the activities for carrying out further follow-up actions Time delay in sending requisitions for further execution
11.	Lack of stability	Inconsistent remuneration paid to employees Failure to question and correct employees who leave the organisation
12.	Lack of time management	Lack of awareness of due date requirements of customers Allowing employees to get the habit of talking and wasting time
13.	Slack supervision	Failure to monitor and instruct in time
14.	Time delay in decision making	Lack of clarity about constraints Non-availability of adequate advisors
15.	Absenteeism	Foreman's absenteeism Employee's absenteeism
16.	Time delay in report generation	Time delay due to compilation and consolidation of report Time delay in passing report at various levels
17.	Lack of maintenance activities	Lack of corrective maintenance activities Lack of preventive maintenance initiatives
18.	Time delay in work extraction	Lack of necessary intermediate check-up and follow-up actions Unnecessary visiting and conversation on the job

Table 4 Root causes for the major time delays occurring due to inefficient work organisation (... continued)

Serial Number	*Root causes of major time delays occurring due to inefficient work organisation*	
	Primary root causes	*Secondary root causes*
19.	Lack of work management	Failure on foreman's part to organise his own time and work Failure on employees' part to organise their own time and work
20.	Lack of education and training	Inadequate communication skills Lack of interest and involvement in learning

Table 5 Root causes for the major time delays occurring due to wrong work concept and ideas

Serial Number	*Root causes of major time delays occurring due to wrong work concept and ideas*	
	Primary root causes	*Secondary root causes*
1.	Lack of interactions about work ideas	Failure to encourage when employees offer valuable suggestions Failure to listen and make comment, when employees offer suggestions Failure to receive suggestions from experts
2.	Lack of problem solving skills	System to investigate the lack of problem and its associated constraints Not asking employees' advice on problems
3.	Lack of learning	Failure to read and study the work methods Failure to read and study the business methods
4.	Lack of contacts and conversations	Failure to get from new employees' helpful ideas, which they may bring from previous employment Not consulting enough with other departments
5.	Lack of involvement in work ideas	Failure to consider or refer to the proper person having valuable suggestions Failure to take proper interest in conducting meetings

found to be another reason for the occurrence of major time delays along the supply chains of manufacturing organisations. The root causes for this reason are further divided into primary and secondary root causes. These details are enumerated in Table 5.

Major time delays caused due to accidents

During the conduct of this research, accidents were found to be another reason for the occurrence of major time delays along the supply chains of manufacturing organisations. The root causes for this reason are further divided into primary and secondary root causes. These details are enumerated in Table 6.

DEVELOPMENT OF PILOT STRATEGIES, RESULTS AND DISCUSIONS

The reasons of occurrence of LPEs and their various root causes mentioned in the previous section were further analysed to trigger the futuristic SCRM strategies. The associated root causes were analysed by studying cost sheet, discussion with employees, discussion with experts and past analysis with collected

Table 6 Root causes for the major time delays occurring due to accidents

Serial Number	*Root causes of major time delays occurring due to accidents*	
	Primary root causes	*Secondary root causes*
1.	Lack of accident preventive measures	Failure to recognize accident prevention during production Failure to provide all the employees with thorough instructions on safety Failure to install mechanical safeguards Failure to display danger signs at proper places and to see that they are legible Failure to stimulate and maintain interest of employees in accident prevention
2.	Loss due to improper handling of safety tools	Keeping guards out of the reach of employees during work Poor house-keeping Allowing employees to work without necessary protective devices such as goggles, welding helmets, safety shoes, safety belts etc.
3.	Loss due to improper understanding of safety measures	Failure to understand indirect accident costs thoroughly Lack of understanding of what constitutes accident hazard Not setting a good example in the matter of safety practices Failure of the foremen to recognise his responsibility for preventing accidents in his department
4.	Lack of awareness and involvement in safety measures	Lack of regular and conscious safety inspection Lack of cooperation with state and insurance inspectors
5.	Lack of accident database for carrying out future safety measures	Failure to keep records of accidents to analyze them and to use the information gained Failure to enforce consistently all safety rules and regulations

data. Based on the results of these analyses and discussion, the personnel interviewed were advised to execute preliminary actions using risk control measures on trial basis. These SCRM pilot strategies are enumerated in Table 7.

The above results and discussions are just sample action taken. These personnel of the organsiations had taken preliminary steps to implement these proposed actions. These steps were used for achieving better, systematic and dynamic execution of supply chain activities using the SCRM initiatives. Recently, utilising external resources has been increased and these have become a new source of business success to ensure quality up-gradation. At the same time, this has given rise to various new risks and, therefore, the need for collaborative risk management has also increased (Hallikas et al., 2005). The interest of futuristic investigations in SCRM remains underdeveloped. In this context, the necessity of a dynamic model for achieving loss reduction with a future scope of risk prevention was realised to facilitate continuous improvement.

Table 7 Preliminary actions proposed using risk control measures

Preliminary actions taken	*Risk control measures*
Reduction of unnecessary movement	Pursuance of method study and further follow-up actions
Reduction in over-production	Accurate estimates of customers' requirements and follow-up actions
Reduction in inventory	Accurate estimates of customer due date requirements and follow-up actions
Reduction in defects of materials	Scrutiny of materials and follow-up activities
Reduction in waiting time and idle time	Proactive maintenance and follow-up activities
Reduction of under-production	Accurate estimates of customer demand / due date requirements and follow-up actions
Minor layout modification	Effort to minimize the processing time and movement of both employees and materials
Reduction in processing waste	Accurate estimates of material requirements and follow-up actions
Reduction in transportation time	Accurate estimates of internal processing follow-up

CONCLUSION

Of late competitive, technological and social circumstances have magnified the challenges to overcome the supply chain operations related time delays. These challenges normally tackled by employing additional resources and facilities to meet customer's demand and due date requirements. The reasons for the occurrence of these time delays are not normally investigated in detail. The research reported in this paper investigated these aspects. At the end of this research, corrective measures were suggested for achieving loss reduction. A major finding of this research is that, it is essential to explore more futuristic supply chain risk management strategies for better, systematic and dynamic executions using risk mitigation with appropriate real time initiatives. This paper also suggests the need for more dynamic models with a future scope of risk prevention for continuous improvement. The implications of above aspects are influencing customer acceptability, retaining customers, reduced cycle time, improved delivery performance, rapid response to customer needs, product customisation and hence overall time cum cost reduction.

BIOGRAPHY

D. Elangovan is currently working as a Professor in the Department of Mechanical Engineering at Karpagam College of Engineering, Coimbatore, Tamil Nadu, India. He obtained his Bachelor's Degree in Mechanical Engineering and holds a Master's Degree in Production Engineering. He has 14 years of teaching experience. He has published five papers in various International Journals. His current research interest is *'Application of Risk Management Approach in Supply Chain Issues'*.

Dr. G. Sundararaj is working as an Assistant Professor in the Department of Mechanical Engineering at PSG College of Technology, Coimbatore, Tamil Nadu, India. He completed his Bachelor's Degree in Mechanical Engineering, Master's Degree in Industrial Engineering and obtained a Doctorate Degree in *Industrial*

Engineering – Risk Management. He worked in a public sector steel plant for about 12 years. He has been teaching and involved in research and development for about 16 years in the area of '*Manufacturing, Laser Technology, Quality Management and Safety Management*'.

Dr. S. R. Devadasan is a Professor in the Department of Production Engineering at PSG College of Technology, Coimbatore, Tamil Nadu, India. He obtained his Bachelor's Degree in Mechanical Engineering and Master's Degree in Industrial Engineering. His Doctorate work is on *Strategic Quality Management*. He has published thirty six papers in various International Journals. He is on the editorial board of *European Journal of Innovation Management*, UK. His area of interest includes '*Strategic Quality Management*' and '*Risk Management*'.

P. Karuppuswamy is currently working as a Professor in the Department of Mechanical Engineering at Sri Ramakrishna Engineering College, Coimbatore, Tamil Nadu, India. He obtained his Bachelor's Degree in Mechanical Engineering and holds a Master's Degree in Production Engineering. His Doctorate work is on *Application of Risk Management Approach in Equipment Maintenance Activities*. He has worked in various capacities in industries for about 10 years, and he has also 13 years of teaching experience. He has published five papers in various International Journals.

REFERENCES

Bertrand, J.W.M. (2003) 'Supply Chain Design: Flexibility Considerations', *Handbooks in Operations Research and Management Science*, Vol. 11, pp.133–198.

Chen, F. (2003) 'Information sharing and supply chain coordination', *Handbooks in Operations Research and Management Science*, Vol. 11, pp.341–421.

Christopher, M. (1992) 'Logistics and supply chain management: Strategies for reducing costs and improving services', Pitman Publishing: London.

Govil, M. and Proth, J-M. (2002) 'Supply chain at the strategic level: Strategic and Tactical Perspectives', Academic Press, USA.

Hallikas, J., Puumalainen, K., Vesterinen, T. and Virolainen, V-M. (2005) 'Risk-based classification of supplier relationships', *Journal of Purchasing and Supply Management*, Vol. 11, No. 2-3, pp.72–82.

Hameri, A-P. and Paatela, A. (2005) ' Supply network dynamics as a source of new business', *International Journal of Production Economics*, Vol. 98, No. 1, pp.41–55.

Kok, T.G.de and Fransoo, J.C. (2003) 'Planning supply chain operations: Definition and comparison of planning concepts', *Handbooks in Operations Research and Management Science*, Vol. 11, pp.597–675.

Lewis, M.A. (2003) 'Cause, consequence and control: Towards a theoretical and practical model of operational risk', *Journal of Operations Management*, Vol. 21, No. 2, pp.205–224.

Li, S., Rao, S.S., Ragu-Nathan, T.S. and Ragu-Nathan, B. (2005) 'Development and validation of a measurement instrument for studying supply chain management practices' *Journal of Operations Management*, Vol. 23, No. 6, pp.618–641.

Muriel, A. and Simchi-Levi, D. (2003) 'Supply chain design and planning – Application of optimization techniques for strategic and tactical models', *Handbooks in Operations Research and Management Science*, Vol. 11, pp.15–93.

Myers, M.B., Daugherty, P. J. and Autry, C.W. (2000) 'The effectiveness of automatic inventory replenishment in supply chain operations: antecedents and outcomes', *Journal of Retailing*, Vol. 76, No. 4, pp.455–481.

Pierreval, H., Caux, C., Paris, J.L. and Viguier, F. (2003) 'Evolutionary approaches to the design and organization of manufacturing

systems', *Computers and Industrial Engineering*, Vol. 44, No. 3, pp.339–364.

Puigjaner, L. and Lainez, J.M. (2008) 'Capturing dynamics in integrated supply chain management' *Computers and Chemical Engineering*, Vol. 32, No. 11, pp. 2582–2605.

Schwab, B. and Schwab, H. (1997) 'Better risk management: A key to improved performance', *Journal of General Management*, Vol. 22, No. 4, pp.65–75.

Sen, W., Pokharel, S. and YuLei, W. (2004) 'Supply chain positioning strategy integration, evaluation, simulation, and optimization', *Computers and Industrial Engineering*, Vol. 46, No. 4, pp.781–792.

Sienou, A., Karduck, A. and Pingaud, H. (2006) 'Towards a framework for integrating risk and business process management', The 12th IFAC Symposium on Information Control Problems in Manufacturing (INCOM 06), Vol.1, pp.615–620, Saint-Etienne, France.

Silveira, G.J.C.da. (2005) 'Market priorities, manufacturing configuration, and business performance: an empirical analysis of the order-winners framework', *Journal of Operations Management*, Vol. 23, No. 6, pp.662–675.

Treville, S.de., Shapiro, R.D. and Hameri, A-P. (2004) 'From supply chain to demand chain: the role of lead time reduction in improving demand chain performance', *Journal of Operations Management*, Vol. 21, No. 6, pp.613–627.

Trkman, P. and McCormack, K. (2009) 'Supply chain risk in turbulent environments - A conceptual model for managing supply chain network risk', *International Journal of Production Economics*, Vol. 119 , No. 2, pp.247–258.

Zhang, Q., Vonderembse, M.A. and Lim, J-S. (2003) 'Manufacturing flexibility: Defining and analyzing relationships among competence, capability, and customer satisfaction', *Journal of Operations Management*, Vol. 21, No. 2, pp.173–191.