A Novel Model for Simultaneously Minimising Costs and Risks in Just-in-Time Systems Using Multi-Backup Suppliers: Part 1- Modelling

Faraj El Dabee, Romeo Marian, Yousef Amer

***Abstract*—**Just-In-Time (JIT) is a lean manufacturing tool, which provides the benefits of efficiency, and of minimizing unnecessary costs for many organisations. However, the risks arising from these benefits have been disregarded. These risks impact on system processes disrupting the whole supply chain. This paper proposes an inventory model that can simultaneously reduce costs and risks in JIT systems. This model is developed to ascertain an optimal ordering strategy for procuring raw materials by using regular multi-external and local backup suppliers to reduce the total cost of the products, and at the same time to reduce the risks arising from this cost reduction within production systems. Some results that will be illustrated in the second part of this paper are presented.

***Keywords*—**Lean manufacturing, Just-in-Time (JIT), production system, cost-risk reduction, inventory model, eternal supplier, local backup supplier.

I. Introduction

In today's competitive global marketplace, organisations have being challenged to adopt more effective and efficient business approaches that will ultimately lead them to improve their performance measures. These strategies can be achieved by the continuous improvement and optimisation of organisations' processes, cost reduction of their products, and the increasing of their outputs' capacity with satisfactory quality and rates [1]. Lean manufacturing is a philosophy, which has been developed for a long time. The basis of which is simple concepts through which it has gained wide popularity [2].

The main task of the lean manufacturing system is to find the major sources of waste which would then be eliminated by the application of a large number of tools such as JIT and production smoothing [3]. JIT is considered as one of the significant lean manufacturing tools. It can be used within organisations leading to improvement on a continuous basis including the material flow and information, management of human resources, improved throughputs, costs reduction, and elimination of wastes and non-value added activities [4].

Most international organisations have implemented JIT in their processes to reduce their costs and to improve their efficiencies. Nevertheless, they ignored the risks arising from these goals. These risks will impact on their processes disrupting the whole supply chain.

The main objective of this paper is to develop an inventory model for simultaneously reducing costs and their effects in JIT systems. The goal is to determine an optimal ordering strategy for obtaining raw materials within the production systems using both external and local backup suppliers in case of the occurrence of likely disruption such as natural and man-made disasters, and economic crises to achieve high product quality and total financial and operational actions within the supply chain.

The paper is organised as follows: Section II reviews the literature on JIT, and cost and risk modelling. Section III presents the proposed model formulation to reduce costs and their risks in JIT systems and some results that will be illustrated in detail in the second part of this paper. Finally, Section IV summarises and concludes this paper.

II. Literature Review

Just-in-Time (JIT) is a Lean manufacturing tool that can be utilised to improve organisations' efficiency. It is a manufacturing pull system, which can be used for planning and controlling operations, in order to produce, and supply the required products at the correct place, when they are required, and at the right ordered amounts [5], [6]. The main principles of JIT include: high quality, small lot sizes, and regular deliveries in short lead times, close contact with suppliers [7]. The appropriate use of JIT in manufacturing can reduce waste and increase productivity, efficiency, profit, and customer satisfaction [8], [9]. According to Tourki [9], some critical principles such as people involvement, training and education, supplier relations, waste elimination, Kanban or pull system, uninterrupted work flow, and total quality control are used for successful implementation of JIT system. In addition, JIT is highly beneficial for a large number of companies, as the literature indicates that the efficiencies gained from the consideration of the JIT principle in production processes is in terms of accelerated productivity. Inventory levels of

Faraj El Dabee is a PhD student at the School of Advanced Manufacturing and Mechanical Engineering, Division of Information Technology, Engineering and the Environment, University of South Australia, Mawson Lakes, 5095 Australia (phone: +61883023112; e-mail: eldfy001@mymail.unisa.edu.au).

Dr. Romeo Marian is a Senior Lecturer and Program Director at the School of Advanced Manufacturing and Mechanical Engineering, Division of Information Technology, Engineering and the Environment, University of South Australia, Mawson Lakes, 5095 Australia (phone: +61883025275; e-mail: romeo.marian@unisa.edu.au).

Dr. Yousef Amer is a Program Director and Academic Integrity Officer at the School of Advanced Manufacturing and Mechanical Engineering, Division of Information Technology, Engineering and the Environment, University of South Australia, Mawson Lakes, 5095 Australia (phone: +61883023006; e-mail: Yousef.Amer@unisa.edu.au).

manufacturing dropped from 50 days to 40 days during 1999 and 2000 in United States. This implies the importance of JIT implementation in the production processes of companies in achieving operational efficiency [10]. Furthermore, it is a critical tool that can also be utilized for the purpose of managing the external activities associates with an organisation including that of purchasing, as well as distribution. Three elements included in case of JIT are: JIT production, JIT distribution and JIT purchasing [3].

Recently, researchers have searched for an economic quantity model of a production system following JIT approach for ordering raw materials and the shipping process. Different kinds of models can be utilised for the purpose of ensuring reduction in the level of cost and risk in case of JIT systems. For instance, one such model type that can be utilised for achieving cost efficiency is the lot size reduction model. This model emphasizes that by ensuring reduction in the lot size, it can become possible to achieve a reduction with respect to the level of the cost required in performing the delivery of finished products to final consumers [11]. A higher lot size unnecessarily increases cost and some components of risk, while reducing others. As a result, the lot size risk reduction model can be utilised in order to ensure an optimum lot size and thereby, efficient management of risk from the lot size can ultimately become possible to achieve cost efficiencies. An operation model can also be used for the purpose of JIT scheduling which explains each and every process included in the JIT system. Thus, by way of having identification of the stages of JIT system, necessary actions can be taken for the purpose of achieving cost efficiency in the operation [12]. Fahimnia et al. [13] developed a mixed integer formulation for optimising a two-echelon supply network. They concluded that by implementing the developed model in a case study, it is clear that considering all production costs prove the effectiveness of this model in the real applications.

Sarker and Khan [14] developed a general cost model for the two-stage batch environment considering both supplier raw materials to meet the production necessities and buyer finished products. This model can be utilised to ascertain the product batch-sizes and raw materials order-sizes to reduce the total cost that meet the same batches of products, at fixed intervals, to the buyers. Yang and Pan [11] investigate a JIT purchasing model where a single vendor supplies a single purchaser with a product. Their work presents an integrated inventory model, which minimizes the sum of the ordering cost, holding cost, quality improvement and crashing cost by optimizing the order quantity, lead time, process quality and the number of deliveries to provide a lower total cost, higher quality, smaller lot size and shorter lead time. Therefore, JIT skills applications such as small lot size, lead time reduction and quality improvement have a significant role in achieving JIT purchasing. In their article, Additionally, Julka et al. [15] propose a unified, flexible, and scalable framework for modelling, monitoring and management of refinery supply chains. This framework has two basic elements: object modelling of supply chain flows and agent modelling of supply chain entities. Three classes of agents, emulation, query, and project agents are used for methodologies required for decision-support systems. A stochastic model, which includes two stages, was developed by Carneiro et al. [16] to optimise investment portfolios within an oil supply chain in Brazil. Three sources of uncertainty are considered by adopting the conditional value-at-risk (CVaR) as a risk measure within six oil refineries, in order to minimise the expected net present value (ENPV) in the supply chain. It is essential to define the optimum production lot size and the ordering quantities of associated raw materials together. These could be done treating the production and purchasing as components of a single system, minimizing the total cost of the system [14].

As systems become increasingly integrated, any disturbance cannot be arrested in the functional area of origin and propagated through the production and distribution system. The reduction of waste (muda), as inventory or extra production capacity, exposes adjacent activities and may affect the whole supply chain. In his article, Tomlin [17] investigates some features of the organisation, its supplier(s), and its products such as supplier reliability, and supplier failure correlation and their impacts on the organization’s preference. Also, he mentions that common dual sourcing can protect organisation from any disruption impacts due to receiving its delivery from both in case of one supplier has disruption. Simchi-Levi et al. [18] point out the risks associated with a JIT system in case of unforeseen disasters occurrence such as what actually happened to some auto manufacturers following Sept. 11, 2001. They emphasise that sharing risks during the whole supply chain parties has a significant impact on them.

Dimakos and Aas [19] present a new method to model the required total economic capital, in order to keep a financial organization against possible losses. The system was implemented in the Norwegian financial group DnB’s system for risk management. It is concluded that the total economic capital was reduced by 20% of the actual rate for a one year. Also, Jose [20] clarifies how risk management sources in a project´s innovation can be better managed through a modelling process. Although the innovation management relevance is uncertain, several methods of risk management have been proposed. This article focuses on the formation and management of uncertainties in a context and the deployment of risk management techniques. By using a general model of innovation to manage the parameters of risk creation, the risk management process is applied in a specific case. In addition, Gaivoronski et al. [21] present an approach for considering a cost–risk balanced process to manage the scarce water resources in conditions of uncertainty. A new technique relating to a re-optimization phase was modelled that allows users to organise emergency strategies by adopting the barycentric value as a new target, which resulted in drastic risk reduction of resources delivery. El Dabee et al. [22] developed a mathematical model to reduce the total cost of the products, and at the same time to reduce the risks arising from this cost reduction within production systems using external suppliers for supplying raw materials to the production systems. They concluded that comparing the use of a JIT system with the use of a specific amount of inventory during a limited period of time had a significant impact on the production system.

It is clear that risks have an adverse impact in organisations' performance, which leads them to increase their total costs and at the same time reduce their efficiency. Therefore, risks should be assessed by identifying, evaluating, and measuring them, in order to reduce their undesired effects within these organisations.

III. Model Development

According to the literature review related to JIT, all developed models were used to reduce either cost or risk independently. In this paper, a general cost model is developed for simultaneously reducing the costs and their risks effect in JIT systems. All notations and assumptions, decision variables, parameters, and mathematical formulations will be described as follows:

A. Assumptions

The model formulation is based on the following assumptions:

- The ordering cost of raw materials is a fixed rate for each order regardless of the order size;
- The utilities cost of the final product is a percentage of total cost of the product that can be changed by the inventory batch size;
- The final product price is a fixed rate regardless of the inventory batch size;
- The raw materials are supplied by the regular external supplier if there is no disruption occurs;
- The raw materials can be purchased from the local backup supplier when one or more of the regular external suppliers are disrupted;
- The raw materials cost from the local backup supplier S_{LB} can be considered as a percentage of their cost when they are purchased from the regular external suppliers depending on its reliability (R_S);
- The worker cost required for producing the final product per time unit is a fixed rate per time unit;
- The risk cost arising from the likelihood of risk occurrence is a percentage rate depending on its impact on the production system;
- The duties cost is incurred if raw materials can be supplied by an external supplier; and
- The transfer price required to procure raw material from the regular external supplier can be considered as a percentage of its total cost CM.

B. Notations

The following the notations are used in the proposed model:

C_T: Total cost required to produce one product in monetary unit (MU);

C_M: Raw material cost required for producing one product (MU);

C_O: Ordering cost of raw materials (MU);

C_H: Holding cost of raw materials within the production system warehouses (MU);

C_{UM}: Unit cost of the raw material at the beginning of that cycle (MU);

C_R: Risk cost arising from disruption occurrence (MU);

C_{Li}: Labor cost rate per labor time in operation i (MU/hr);

C_{tr}: Transportation cost for delivering raw materials to the production system (MU);

C_P: The purchasing cost of the raw materials that are required to produce the product (MU);

C_U: Utilities cost of the final product (MU);

C_D: Duties cost arising from procuring raw material from an external supplier (MU);

C_{UH}: The cost that is carried per unit during each cycle (MU);

TP_i: Transfer price required for procuring raw material i from an external supplier i (MU);

D_i: Duty rate (%) per price of raw material i supplied by an external supplier (MU);

tp: The percentage rate of raw material cost (MU);

$T_{S,\ n,\ m}$: Tensor for transportation cost per critical measurement (MU);

S: Origin of ordered raw materials;

V: Destination of required raw materials;

m_i: Transportation mode for transporting raw material i to its customer;

t_m: Critical transportation measurement of raw materials shipped using transportation mode m;

S_{Ei}: Raw material external supplier i;

S_{LBi}: Raw material local backup supplier i;

IF: Indicator function for duty with a value 1 or 0. 1 if the supplier and the production facility are in the same country and 0 otherwise;

M_i: raw material types required in producing one unit of product i;

LH: Likelihood of occurrence for risk in the supply chain;

I: Impact of risk occurrence in the supply chain; and

$\%TRS$: Total risk score percentage value.

C. Parameters

d_P: Customer demand for the final product in a period (unit);

N_O: Number of operations required for producing one product (unit);

N_W: Number of workers required to produce one product (unit);

N_h: Number of working hours for producing the final product (unit);

N_P: Number of parts required to produce one product (unit);

N_S: Number of external suppliers required to supply raw materials to the production system (unit);

C_W: Worker cost required for producing the final product per time unit (MU);

R_S: The reliability of supplier reflects the availability for supplying raw materials at the planned time (0- 1);

h_i: Operation time required to produce a product i (hr); and

P_i: Final price per unit of final product *i* sold to the customer (MU).

D. Decision Variables

Q_M: The quantity of raw materials ordered in each patch (unit); and

LT: Lead-time in time unit taken between placing and receiving the placed order (day).

E. Model Formulation

A general cost model is developed considering supplier of raw material point of view. This model is utilised to ascertain an optimal ordering strategy for obtaining raw materials batch size using both external and local backup suppliers to minimize the total cost of the final products and its risk effect in JIT systems. It is built to determine the total cost of producing the final product within production systems. The total cost of this product can be found by:

$$C_T = C_M + C_W + C_U + C_R \tag{1}$$

Also, C_M can be calculated by two ways depending on a raw materials supplier either an external or a local supplier. For the regular external supplier, C_M includes the sum of costs C_O, C_H, C_P, C_{tr}, C_D and *TP*. Therefore, it can be estimated by:

$$C_M = C_O + C_H + C_P + C_{tr} + C_D + TP \tag{2}$$

where, C_O as the cost of ordering and receiving an amount of raw materials each order that can be calculated as:

$$C_O = \sum_{i=1}^{N_P} C_{O_i} \tag{3}$$

Also, the rate of C_H equals:

$$C_H = \sum_{i=1}^{N_P} C_{UH_i} \tag{4}$$

C_P is the unit cost of the raw material at the beginning of that cycle C_{UR} that equals:

$$C_p = \sum_{i=1}^{N_P} C_{UM_i} \tag{5}$$

C_{tr} as a component of C_M can be calculated as:

$$C_{tr} = t_m \times \sum_{i=1}^{N_S} T_{S_i,V,m} \tag{6}$$

C_D is the duties that arise from supplying raw materials by a regular external supplier to the production system. It can be calculated as:

$$C_D = \sum_{i=1}^{N_P} \sum_{i=1}^{N_S} C_{M_i} (1 - IF_j) \times D_j \tag{7}$$

TP as a transfer price for procuring raw material from a regular external supplier S_{Ei} can be calculated as:

$$TP = \sum_{i=1}^{N_P} \sum_{i=1}^{N_S} (1 + tp_j) \times C_{M_i} \tag{8}$$

Therefore, C_M can be calculated as follows:

$$\begin{aligned} C_M = & \sum_{i=1}^{N_p} C_{O_i} + \sum_{i=1}^{N_P} C_{UH_i} + \sum_{i=1}^{N_P} C_{UM_i} + t_m \times \sum_{j=1}^{N_S} T_{S_j,V,ml} \\ & + \sum_{i=1}^{N_P} \sum_{j=1}^{N_S} C_{M_i} (1 - IF_j) \times D_j + \sum_{j=1}^{N_S} \sum_{i=1}^{N_P} (1 + t_{P_j}) \times C_{M_i} \end{aligned} \tag{9}$$

However, for the local backup supplier, C_M just includes the sum of costs C_O, C_H, C_P, and C_{tr}. In this case, C_M can be calculated as:

$$C_M = \sum_{i=1}^{N_p} C_{O_i} + \sum_{i=1}^{N_P} C_{UH_i} + \sum_{i=1}^{N_P} C_{UM_i} + t_m \times \sum_{j=1}^{N_S} T_{S_j,V,ml} \tag{10}$$

Also, the worker cost C_W can be found as:

$$C_W = \sum_{i=1}^{N_O} C_{W_i} = \sum_{i=1}^{N_O} C_{L_i} \times h_i \tag{11}$$

In addition, C_U is the utilities cost that can be considered as a raw material cost percentage of the final product. It equals:

$$C_U = \sum_{i=1}^{N_P} \% C_{M_i} \tag{12}$$

Furthermore, C_R as a risk cost can be calculated by the following equation:

$$C_R = \sum_{i=1}^{N_P} \% TRS_i \times C_{M_i} = \sum_{i=1}^{N_P} (LH \times I / Max(LH \times I)) \times C_{M_i} \tag{13}$$

Finally, C_T can be calculated in case of using the regular external supplier for procuring raw materials as follows:

$$\begin{aligned} C_T = & \sum_{i=1}^{N_p} C_{O_i} + \sum_{i=1}^{N_P} C_{UH_i} + \sum_{i=1}^{N_P} C_{UM_i} + t_m \times \sum_{j=1}^{N_S} T_{S_j,V,ml} \\ & + \sum_{i=1}^{N_P} \sum_{j=1}^{N_S} C_{M_i} (1 - IF_j) \times D_j + \sum_{j=1}^{N_S} \sum_{i=1}^{N_P} (1 + t_{P_j}) \times C_{M_i} \\ & + \sum_{i=1}^{N_O} C_{L_i} \times h_i + \sum_{i=1}^{N_P} \% C_{M_i} + \sum_{i=1}^{N_P} (LH \times I / Max(LH \times I)) \times C_{M_i} \end{aligned} \tag{14}$$

Also, when raw materials are supplied by the local backup supplier, C_T can be found as:

$$C_T = \sum_{i=1}^{N_p} C_{O_i} + \sum_{i=1}^{N_P} C_{UH_i} + \sum_{i=1}^{N_P} C_{UM_i} + t_m \times \sum_{j=1}^{N_S} T_{S_j,V,m} + \sum_{i=1}^{N_O} C_{L_i} \times h_i + \sum_{i=1}^{N_P} \% C_{M_i} + \sum_{i=1}^{N_P} (LH \times I / Max(LH \times I)) \times C_{M_i} \quad (15)$$

According to [22], the proposed model will be tested with a simple assembly process for a brushless DC electric motor (BLDC). It will be used to ascertain the decision variables effect on other studied parameters within the production system. The findings of this paper will be organised in three cases as follows:

1. Case I:

The impact of lead time on cost types of final product will be investigated for a scenario of having disruption from an external supplier. This prompts sufficient stock keeping from the external supplier to prevent any likelihood of stock running out.

The findings illustrates in Table I show that if the supplier 1 has disruption for any reason, keeping different amount of raw materials supplied by the regular external supplier in warehouses (1- 6 weeks) have direct impact on the total cost arising from the risk cost associated with the supplier. Relatively, keeping raw materials in the warehouses have high impact on the earned profit.

TABLE I
EFFECTS OF LEAD TIME ON COST TYPES ARISING FROM SUPPLIER 1

Cost type	MU/ unit						
	0 week	1week	2weeks	3weeks	4weeks	5weeks	6weeks
Ordering cost	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Holding cost	0	2.1	4.2	6.3	8.4	10.5	12.6
Purchasing cost	36	34.9	34.9	34.4	34.4	33.8	33.8
Transportation cost	12	12	12	12	12	12	12
Duties	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Transfer price	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Utilities cost	5.2	5.8	6.1	6.2	6.5	6.6	6.9
Worker cost	7	7	7	7	7	7	7
Risk cost	10.3	10.4	10.8	11.1	11.5	11.7	12.1
Total cost	74.5	75.7	78.4	80.5	83.1	85.1	87.7
Net profit	0.5	-0.7	-3.4	-5.5	-8.1	-10.1	-12.7
Sales price	75	75	75	75	75	75	75

2. Case II:

Keeping the same base case as the first, the impact of lead time on cost types of final product will be investigated where stock is procured from local backup supplier. This case assumes that the external supplier is not able to meet supplier demand due to the disruption.

By using local backup supplier for supplying the required raw material in the event of any disruption occurring from the three external suppliers, stoppage of production that is caused by the lack of raw materials can be easily avoided. However, this will increase the purchasing and risk cost that depends on the reliability of these suppliers. Table II shows the effects of lead time on the total cost arising from the disruption caused by supplier 2. This prompts the use of local backup supplier to supply the required amounts of raw materials in different periods of lead time.

TABLE II
EFFECTS OF LEAD TIME ON COST TYPES ARISING FROM SUPPLIER 2 DISRUPTION USING LOCAL BACKUP SUPPLIER

Cost type	MU/ unit						
	0 week	1week	2weeks	3weeks	4weeks	5weeks	6weeks
Ordering cost	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Holding cost	0	2.1	4.2	6.3	8.4	10.5	12.6
Purchasing cost	42.7	38.4	38.4	36.3	36.3	34.2	34.2
Transportation cost	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Utilities cost	5.1	4.9	5.1	5.1	5.3	5.3	5.5
Worker cost	7	7	7	7	7	7	7
Risk cost	6.3	6.1	6.3	6.3	6.5	6.5	6.8
Total cost	69.5	66.9	69.4	69.4	72	72	74.5
Net profit	5.5	8.1	5.6	5.6	3	3	0.5
Sales price	75	75	75	75	75	75	75

3. Case III:

In this case, the two cases are compared to find the optimum quantity of required raw materials that give an appropriate profit during the disruption period.

Table III illustrates the comparison between the total costs of producing final product if disruptions occur from supplier 1. This compares the case of solely relying on an external supplier or using local backup supplier. It can be observed that if supplier 1 has disruption, the cost arising from keeping inventory during this time using local supplier is less than the cost using the same supplier. Therefore, it can be observed that working with a 3 weeks inventory from a local backup supplier during the disrupted time gives a reasonable profit for the production system.

TABLEIII
COMPARISON BETWEEN TOTAL COST ARISING FROM SUPPLIER 3 USING THE DISRUPTED SUPPLIER AND LOCAL BACKUP SUPPLIER

Cost type	MU/ unit						
	0 week	1week	2weeks	3weeks	4weeks	5weeks	6weeks
Total cost using external supplier	79.6	80.8	83.7	85.7	88.6	90.6	93.5
Total cost using local supplier	69.8	67.2	69.8	69.8	72.3	72.3	74.9

IV. CONCLUSION

This paper introduced the development of a mathematical model for simultaneously reducing the cost and risk in JIT systems. It was developed to determine an optimal policy for procuring raw materials within the production systems by using regular multi-external and a local backup suppliers in case of the occurrence of likely disruption such as natural and man-made disasters, and economic crises. Some of the results that will be illustrated in the second part of this paper were presented. Thereby JIT principles can be effectively applied for satisfying customer requirements at a minimum inventory cost with a minimum level of risk.

REFERENCES

[1] R. A.Hokoma, M. KKhan and K. Hussain,"Investigation into the Implementation Stages of Manufacturing and Quality Techniques and Philosophies within the Libyan Cement Industry,"*Journal of Manufacturing Technology Management,* vol. 19, no. 7, pp. 893-907,2008.

[2] A.Badurdeen, "What is Lean Manufacturing?," 2006,[Online], Available:http://www.learnleanblog.com/2006/12/what-is-lean-manufacturing.html [Accessed 07.11.2011].

[3] F.Abdullah, "Lean Manufacturing Tools and Techniques in the Process Industry with a Focus on Steel," PhD thesis, University of Pittsburgh, 2003.

[4] Y.Monden, "Japanese Cost Management," World Scientific, 2000.

[5] T. C. E. Chengand S.Podolsky, "Just-in-time manufacturing: an introduction," New York, Chapman & Hall, 1996.

[6] R. A.Hokoma, M. K.Khan and K.Hussain, "The Present Status of Quality and Manufacturing Management Techniques and Philosophies within the Libyan Iron and Steel Industry,"*TQM Journal*, vol. 22, no. 2, pp. 209-221, 2010.

[7] Z. X. Chen andB. R. Sarker, "Multi-vendor integrated procurement-production system under shared transportation and just-in-time delivery system,"*The Journal of the Operational Research Society,* vol. 61, pp. 1654-1666, 2010.

[8] Y.Li, K. F.Man, K. S.Tang, S. Kwong and W. H.Ip, "Genetic algorithm to production planning and scheduling problems for manufacturing systems," Production Planning & Control, vol. 11, no. 5, pp. 443-458 , 2000.

[9] T.Tourki, "Implementation of Lean within the Cement Industry," PhD thesis, De Montfort University, 2010.

[10] L.Eldenburg, "Cost Management: Measuring Monitoring and Motivating Performance," John Wiley & Sons, 2007.

[11] J. S. Yang and J. C. H.Pan, "Just-in-Time Purchasing: an Integrated Inventory Model Involving Deterministic Variable Lead Time and Quality Improvement Investment," *International Journal of Production Research*, vol. 42, no. 5, pp. 853-863, 2004.

[12] A.Chae and H.Fromm, *Supply Chain Management on Demand*. Springer, 2005.

[13] B.Fahimnia, L.Luongand R.Marian, "An integrated model for the optimisation of a two-echelon supply network," *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 31, pp. 477-484, 2008.

[14] R. A.Sarker and L. R.Khan, "An Optimal Batch Size for a Production System Operating under Periodic Delivery Policy,"*Computers & Industrial Engineering*, vol. 37, pp. 711-730, 1999.

[15] N.Julka, R.Srinivasan and I.Karimi, "Agent-Based Supply Chain Management—1: Framework," *Computers and Chemical Engineering*, vol. 26, pp. 1755-1769, 2002.

[16] M. C.Carneiro, G. P.Ribas and S.Hamacher, "Risk Management in the Oil Supply Chain: A CVaR Approach," *Industrial & Engineering Chemistry Research*, vol. 49, no. 7, pp. 3286-3294, 2010.

[17] B. Tomlin, "Disruption-Management Strategies for Short Life-Cycle Products," Naval Research Logistics, vol. 56, pp. 318-347, 2009.

[18] D.Simchi-Levi, L. Snyder and M. Watson, "Strategies for Uncertain Times. Supply chain Management Review," 2002, [Online]. Available: http://www.lehigh.edu/~lvs2/Papers/SCMR.pdf [Accessed 06 November 2012].

[19] X. K. Dimakos and K.Aas, "Integrated Risk Modelling," *Statistical Modelling*, vol. 4, pp. 265-277, 2004.

[20] G. V.-H.Jose, "Modelling Risk and Innovation Management," *Advances in Competitiveness Research*, vol. 19, no. 3&4, pp. 45-57, 2011.

[21] A. A.Gaivoronski, G. M.Sechi and P.Zuddas, "Balancing Cost-Risk in Management Optimization of Water Resource Systems under Uncertainty," *Physics and Chemistry of the Earth*, vol. 42-44, pp. 98-107, 2012.

[22] F. El Dabee, R. Marian and Y. Amer,"An Optimisation Model for a Simultaneous Cost-Risk Reduction in Just-in-Time Systems," in the 11th Global Congress on Manufacturing and Management, *GCMM2012*, Auckland, New Zealand,2012, pp. 190-201.