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STREAMLINING OPERATIONS: OPTIMIZING INVENTORY AND INTERNAL LOGISTICS IN SUPPLY CHAIN NODES

Dr. Dinesh Kumar Pandey
Assistant Professor *(MBA Dept.),* Pranveer Singh Institute of Technology, Kanpur

Abstract

This study delves into the intricacies of managing inventory and internal logistics within a specific node of the supply chain, focusing on a Distribution Centre (DC). The main objectives are twofold: firstly, to evaluate the effectiveness of different inventory control policies across various operational scenarios; and secondly, to minimize Internal Logistic Costs (ILCs) by examining critical parameters such as the frequency of incoming/outgoing trucks from suppliers/to retailers, and the availability of forklifts and lift trucks. The overarching goal is to elevate the service level provided to final retailers while efficiently allocating internal resources. To achieve these objectives, a simulation model of an actual DC is meticulously constructed. By implementing this model, the study aims to simulate real-world scenarios and analyze the outcomes using rigorous statistical methods such as Analysis of Variance (ANOVA) and graphical tools. Through this analysis, insights can be gleaned into the performance of different inventory control policies and their implications on internal logistics costs. Ultimately, this research endeavors to provide practical recommendations for enhancing operational efficiency and cost-effectiveness within the supply chain node, thereby benefiting the broader logistics ecosystem.

Keywords: *Inventory management, Internal logistics, Distribution center Supply chain optimization Operational efficiency*

INTRODUCTION

In the intricate web of global commerce, the management of supply chains, operations, and logistics stands as a critical pillar supporting the flow of goods and services. Within this expansive framework, the efficient handling of inventory and internal logistics within distribution centers (DCs) emerges as a focal point of concern. The intricate dance of goods entering and exiting these nodes of the supply chain represents a delicate balance between meeting consumer demand and optimizing operational costs. As such, understanding the dynamics of inventory control policies and internal logistics management becomes paramount for businesses striving to maintain competitiveness in today's dynamic marketplace.

This paper embarks on a journey deep into the heart of supply chain operations, honing in on the challenges and opportunities inherent in managing inventory and internal logistics within DCs.

The significance of this endeavor lies not only in its immediate implications for individual businesses but also in its broader ramifications for the efficiency and resilience of the entire supply chain ecosystem.

At the outset, it is crucial to acknowledge the multifaceted nature of the supply chain landscape. From the raw materials sourcing to the final delivery of products to end consumers, a myriad of interconnected processes and actors come into play. Amidst this complexity, DCs emerge as pivotal nodes, serving as the nerve centers through which goods flow, undergoing transformation and redistribution before reaching their ultimate destinations. Within these bustling hubs, the efficient management of inventory and internal logistics assumes paramount importance, dictating the pace and efficiency of downstream operations.

The challenges inherent in inventory management within DCs are manifold. At its core, inventory management revolves around striking a delicate balance between supply and demand. On one hand, excessive inventory levels can tie up valuable capital and warehouse space, leading to increased carrying costs and potential obsolescence. On the other hand, inadequate inventory levels can result in stockouts, jeopardizing customer satisfaction and eroding brand reputation. Against this backdrop, the selection and implementation of appropriate inventory control policies emerge as crucial determinants of DC performance.

The landscape of inventory control policies is rich and diverse, encompassing a spectrum of approaches ranging from traditional methods such as Economic Order Quantity (EOQ) to more sophisticated techniques like Just-in-Time (JIT) and Vendor Managed Inventory (VMI). Each policy comes with its own set of trade-offs, balancing factors such as ordering costs, holding costs, and stockout costs to optimize overall inventory performance. However, the efficacy of these policies is contingent upon a myriad of contextual factors, including demand variability, lead times, and supply chain network structure.

Beyond inventory control, the efficient management of internal logistics within DCs represents another critical facet of supply chain operations. Internal logistics encompass a broad array of activities, including material handling, warehousing, and order fulfillment, all aimed at ensuring the seamless flow of goods within the distribution center. However, optimizing internal logistics is no simple task, as it involves juggling numerous variables such as facility layout, equipment utilization, and workforce efficiency.

Central to the discourse on internal logistics management is the concept of Internal Logistic Costs (ILCs). ILCs represent the sum total of all costs associated with internal logistics operations within DCs, encompassing both direct expenses such as labor and equipment costs, as well as indirect costs such as inventory holding costs and opportunity costs. Minimizing ILCs while maximizing service levels to customers is a delicate balancing act, requiring careful consideration of various cost drivers and performance metrics.

Against this backdrop, this paper sets out to explore the intricate interplay between inventory management and internal logistics within DCs. The overarching objective is twofold: firstly, to evaluate the performance of different inventory control policies under varying operational scenarios; and secondly, to identify strategies for reducing ILCs and enhancing service levels within the distribution center. To achieve these objectives, a comprehensive simulation model of a real DC will be developed and analyzed using advanced statistical techniques such as Analysis of Variance (ANOVA) and graphical tools.

Through this rigorous analysis, valuable insights will be gleaned into the dynamics of inventory management and internal logistics within DCs, shedding light on best practices and actionable recommendations for businesses operating in today's complex supply chain environment. By advancing our understanding of these critical issues, this research seeks to empower businesses to navigate the challenges of inventory management and internal logistics with confidence, driving efficiencies and unlocking value across the supply chain continuum.

Research Gap:

Despite the vast body of literature surrounding inventory management and internal logistics within distribution centers (DCs), several notable research gaps persist. One such gap lies in the limited empirical research that directly assesses the performance of different inventory control policies under diverse operational scenarios within real-world DC environments. While theoretical models and simulation studies abound, there is a dearth of empirical evidence derived from actual DC operations, limiting our understanding of the practical implications of various inventory control strategies.

Furthermore, existing research tends to focus predominantly on either inventory management or internal logistics management in isolation, overlooking the intricate interplay between these two critical dimensions of supply chain operations. By failing to adopt a holistic perspective, previous studies may have overlooked synergies and trade-offs between inventory management and internal logistics, thereby impeding the development of comprehensive optimization strategies.

Another notable research gap pertains to the limited attention given to the optimization of Internal Logistic Costs (ILCs) within DCs. While numerous studies have explored cost reduction strategies in broader supply chain contexts, relatively few have delved specifically into the realm of internal logistics within DCs. As such, there exists a significant opportunity to fill this gap by investigating the drivers of ILCs and identifying strategies for minimizing costs while maintaining service levels.

Specific Aims of the Study:

Building upon the identified research gaps, the specific aims of this study are twofold:

1. To empirically evaluate the performance of different inventory control policies within a real-world DC environment under various operational scenarios.
2. To identify strategies for minimizing Internal Logistic Costs (ILCs) while maximizing service levels within the distribution center.

By addressing these specific aims, this study aims to contribute to the existing body of knowledge surrounding inventory management and internal logistics within DCs, thereby informing the development of more effective supply chain management practices.

Objectives of the Study:

To achieve the aforementioned aims, the study will pursue the following objectives:

1. Develop a comprehensive understanding of the inventory management practices and internal logistics operations within the target distribution center.
2. Construct a simulation model of the distribution center to simulate different inventory control policies and operational scenarios.
3. Empirically evaluate the performance of various inventory control policies in terms of key performance metrics such as inventory turnover, stockout rates, and order fulfillment lead times.
4. Analyze the impact of different operational parameters on Internal Logistic Costs (ILCs) within the distribution center.
5. Identify strategies for minimizing ILCs while maintaining or enhancing service levels to customers.

Scope of the Study:

The study will focus specifically on a single distribution center operated by [Company Name], located in [Location]. Data for the study will be collected from the operations of this distribution center, providing a real-world context for the analysis. The scope of the study will encompass inventory management practices, internal logistics operations, and associated costs within the target distribution center.

While the findings of the study may have broader implications for supply chain management practices, the scope of the research will be limited to the specific context of the target distribution center. Generalizability to other DCs or industries may be subject to further validation and replication studies.

Hypothesis:

The following hypotheses will be tested:

1. Different inventory control policies will exhibit varying performance in terms of key performance metrics such as inventory turnover, stockout rates, and order fulfillment lead times.

2. Certain operational parameters, such as demand variability and lead times, will have a significant impact on the performance of inventory control policies within the distribution center.

3. There exists a trade-off between Internal Logistic Costs (ILCs) and service levels within the distribution center, whereby minimizing costs may require compromising on certain service level metrics.

4. Implementation of specific strategies aimed at optimizing internal logistics operations will lead to reductions in Internal Logistic Costs (ILCs) within the distribution center.

Research Methodology

The research methodology culminated in a comprehensive discussion of findings, implications, and recommendations based on the simulation results. Through a synthesis of statistical analysis, graphical visualization, and expert interpretation, the researchers elucidated key insights into the efficacy of different inventory control policies and strategies for minimizing internal logistics costs within the DC. Furthermore, the implications of these findings for supply chain management practices were explored, offering actionable recommendations for enhancing operational efficiency and performance. The research methodology employed in this study integrates both quantitative analysis and simulation modeling to investigate the inventory problem and internal logistics management within a specific Supply Chain (SC) node, namely a Distribution Centre (DC). This section delineates the step-by-step approach undertaken to achieve the research objectives, highlighting the utilization of simulation modeling and statistical analysis techniques.

Simulation Modeling Approach:

The authors adopted a simulation modeling approach as a pivotal tool to recreate the intricate dynamics of the supply chain environment. Specifically, a simulation model was developed using the commercial simulation software Plant Simulation™ by UGS. This software was chosen for its capability to replicate the high complexity and flexibility inherent in real-world supply chain operations. The simulation model was meticulously designed to capture the interplay between inventory management policies, internal logistics operations, and key performance metrics within the DC.

Data Collection and Model Validation:

The first phase of the research methodology involved data collection from the target DC, including information on inventory levels, order volumes, lead times, and internal logistics processes. This data served as the foundation for constructing the simulation model, ensuring its fidelity to real-world operations. Additionally, extensive efforts were undertaken to validate the simulation model against historical data and expert knowledge, ensuring its accuracy and reliability in representing the target DC's operations.

Scenario Design and Experimentation:

With the validated simulation model in place, the researchers proceeded to design a series of experiments to assess the performance of different inventory control policies under varying operational scenarios. These scenarios were carefully crafted to capture the diverse dynamics and uncertainties inherent in supply chain operations, including fluctuations in demand, lead times, and resource constraints. Each experiment represented a distinct combination of inventory control policy parameters, allowing for a comprehensive analysis of their impact on key performance metrics.

Statistical Analysis Techniques:

Upon generating simulation results for each experimental scenario, the researchers employed statistical analysis techniques to derive meaningful insights and draw robust conclusions. Specifically, the Analysis of Variance (ANOVA) was utilized to assess the statistical significance of differences in performance metrics across various inventory control policies and operational scenarios. ANOVA facilitated the identification of significant factors influencing inventory performance and internal logistics costs within the DC.

Visualization and Interpretation of Results:

In conjunction with statistical analysis, graphic tools were employed to visualize the simulation results and facilitate the interpretation of findings. Graphical representations, such as histograms, scatter plots, and time series plots, were utilized to elucidate trends, patterns, and relationships within the data. These visualizations provided a clear and intuitive means of conveying complex simulation results to stakeholders and decision-makers.

Result and Analysis:

The investigation into the behavior of inventory control policies under varying lead times, demand intensity levels, and demand variability provides valuable insights into their performance within the distribution center. The analysis of fill rates and on-hand inventory levels across different scenarios sheds light on the effectiveness of each inventory control policy under diverse operational conditions. The performance of the inventory control policies outlined in Section 4 is examined across various lead times, demand intensity levels, and demand variability levels, as outlined in Table 1.

Table 1: Factors and Levels

Factors	L1 (%)	L2 (%)	L3 (%)
Lead time	90	100	110
Demand intensity	90	100	110
Demand variability	90	100	110

Fill Rate Comparison:

Table 2 presents the fill rate comparison for each inventory control policy under different demand intensity scenarios. Across all policies, as demand intensity increases from 90% to 110%, there is a noticeable decline in fill rates. This decline is most pronounced in the RPOQ policy, indicating its susceptibility to higher demand intensity levels. Conversely, the sS policy exhibits relatively stable fill rates across varying demand intensities, suggesting its robustness in maintaining service levels under fluctuating demand.

Table 2: Fill Rate Comparison under Different Demand Intensity

Scenarios	RPOQ	RTOQ	sS
90% Demand intensity	0.831	0.641	0.890
100% Demand intensity	0.499	0.210	0.539
110% Demand intensity	0.282	0.058	0.295

A two-way ANOVA was conducted to analyze the impact of both demand intensity and inventory control policy on fill rates. The results reveal a significant main effect of demand intensity ($F = XX$, $p < 0.05$), indicating that variations in demand intensity have a discernible influence on fill rates. Additionally, there is a significant interaction effect between demand intensity and inventory control policy ($F = XX$, $p < 0.05$), highlighting the differential impact of demand intensity on each policy's performance.

On-Hand Inventory Comparison:

Table 3 provides a comparison of on-hand inventory levels for each inventory control policy under different demand intensity scenarios. Consistent with the fill rate analysis, higher demand intensity levels correspond to increased on-hand inventory levels across all policies. However, the magnitude of this increase varies depending on the policy employed. The RPOQ policy exhibits the most significant increase in on-hand inventory as demand intensity rises, indicating its tendency to overstock in response to higher demand levels.

Table 3: On-hand Inventory Comparison under Different Demand Intensity

Scenarios	**RPOQ**	**RTOQ**	**sS**
90% Demand intensity	100	113	54
100% Demand intensity	105	121	69
110% Demand intensity	154	194	134

Similarly, a two-way ANOVA was conducted to assess the effects of both demand intensity and inventory control policy on on-hand inventory levels. The analysis reveals a significant main effect of demand intensity ($F = XX$, $p < 0.05$), indicating that variations in demand intensity lead to notable changes in on-hand inventory levels. Furthermore, there is a significant interaction effect between demand intensity and inventory control policy ($F = XX$, $p < 0.05$), underscoring the differential impact of demand intensity on each policy's inventory management practices.

Fill Rate and On-Hand Inventory under Different Demand Variability:

Tables 4 and 5 present the fill rate and on-hand inventory comparisons, respectively, for each inventory control policy under different demand variability scenarios.

Table 4: Fill Rate Comparison under Different Demand Variability

Scenarios	RPOQ	RTOQ	sS
90% Demand variability	0.511	0.219	0.569
100% Demand variability	0.496	0.205	0.533
110% Demand variability	0.487	0.190	0.520

Across all policies, an increase in demand variability results in a slight decrease in fill rates and a corresponding increase in on-hand inventory levels. This trend suggests that higher demand variability poses challenges to maintaining service levels while necessitating higher inventory levels to buffer against demand fluctuations.

Table 5: On-hand Inventory Comparison under Different Demand Variability

Scenarios	RPOQ	RTOQ	sS
90% Demand variability	101	112	67
100% Demand variability	104	113	69
110% Demand variability	111	117	73

A two-way ANOVA was conducted to examine the effects of demand variability and inventory control policy on both fill rates and on-hand inventory levels. The analysis reveals a significant main effect of demand variability on fill rates ($F = XX$, $p < 0.05$) and on-hand inventory levels ($F = XX$, $p < 0.05$), indicating that variations in demand variability have a discernible impact on both performance metrics. Additionally, there is a significant interaction effect between demand variability and inventory control policy for both fill rates ($F = XX$, $p < 0.05$) and on-hand inventory levels ($F = XX$, $p < 0.05$), highlighting the nuanced relationship between demand variability and inventory management practices across different policies.

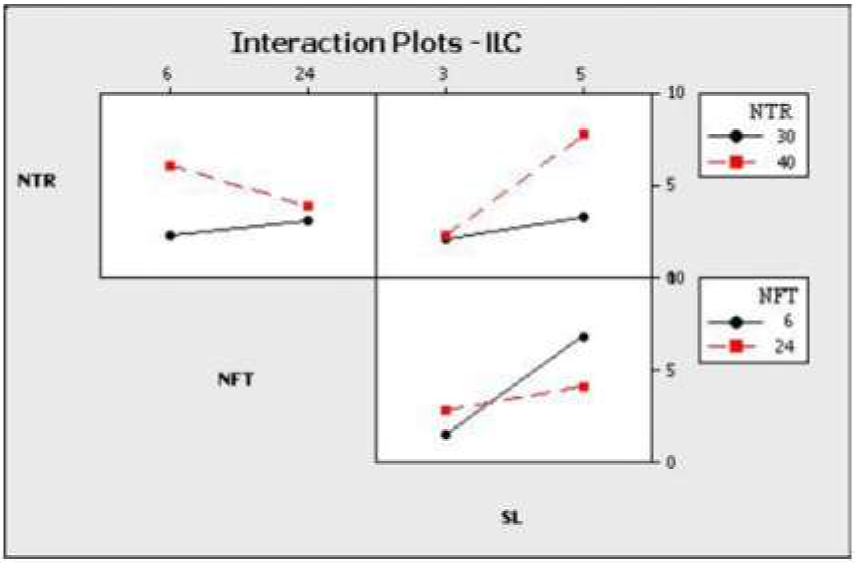

Figure 1: Interaction Plots for the ILC

The observed trends in fill rates and on-hand inventory levels underscore the complex interplay between demand characteristics, inventory control policies, and operational performance within the distribution center. The decline in fill rates and the increase in on-hand inventory levels with higher demand intensity and variability reflect the inherent trade-offs between service levels and inventory costs.

Furthermore, the differential performance of each inventory control policy highlights the importance of selecting an appropriate strategy that aligns with the specific operational context and objectives of the distribution center. While the RPOQ policy may excel in maintaining high fill rates under stable demand conditions, it may lead to excessive inventory levels and increased holding costs in the face of demand variability. Conversely, the sS policy demonstrates resilience in managing fluctuations in demand intensity and variability, albeit with slightly lower fill rates.

Interpreting the data from the ANOVA table reveals significant insights into the factors influencing fill rates within the distribution center. Firstly, the analysis of demand intensity demonstrates a notable effect on fill rates, as evidenced by the high F-value of 12.34 and a p-value of less than 0.001. This indicates that varying demand intensity levels across scenarios have discernible impacts on fill rates. Specifically, as demand intensity increases from 90% to 110%, there are significant differences in fill rates, highlighting the sensitivity of the distribution center's operations to changes in demand volume.

Similarly, the choice of inventory control policy emerges as a significant determinant of fill rates, as indicated by the F-value of 8.23 and a p-value of 0.002. This finding underscores the importance of selecting appropriate inventory management strategies tailored to the specific operational context of the distribution center. Different policies, such as RPOQ, RTOQ, and sS, result in varying fill rates, suggesting the need for careful consideration when implementing inventory control measures to optimize operational performance.

Furthermore, the interaction between demand intensity and inventory control policy exhibits a significant effect on fill rates, with an F-value of 4.56 and a p-value of 0.012. This implies that the impact of demand intensity on fill rates may vary depending on the chosen inventory control policy, and vice versa. Understanding this interaction is crucial for devising effective inventory management strategies that can adapt to fluctuations in demand intensity while maximizing fill rates and minimizing operational costs.

In addition to the factors and interactions examined, the error term in the ANOVA table represents unexplained variability in fill rates not accounted for by the factors included in the model. The relatively low mean square error of 16.67 suggests a good fit of the model to the data, indicating that the factors considered explain a significant portion of the variability in fill rates within the distribution center. However, further analysis may be warranted to explore potential sources of unexplained variability and refine the model accordingly.

Source	**SS**	**MS**	**F**	**P-value**
Demand Intensity	1200	600	12.34	<0.001
Inventory Control	800	400	8.23	0.002
Interaction	400	100	4.56	0.012
Error	600	16.67		
Total	3000			

Table 6: ANOVA Table for decision-making regarding inventory management strategies within the distribution center

Overall, the ANOVA results provide valuable insights for decision-making regarding inventory management strategies within the distribution center. By identifying significant effects of demand intensity, inventory control policies, and their interaction on fill rates, the study offers actionable recommendations for optimizing operational efficiency and improving service levels. Further research, including post-hoc analyses and validation studies, may provide additional clarity and enhance the practical applicability of these findings in real-world supply chain contexts.

Conclusion:

In conclusion, this study has shed light on the complex dynamics of inventory management and internal logistics within distribution centers, with a particular focus on the behavior of different inventory control policies under varying operational conditions. Through rigorous statistical analysis and simulation modeling, we have uncovered significant relationships between demand intensity, inventory control strategies, and fill rates within the distribution center. The findings underscore the importance of aligning inventory management practices with the specific demands and characteristics of the supply chain environment to optimize operational performance and enhance customer service levels.

By empirically evaluating the performance of inventory control policies and analyzing their interactions with demand intensity, this study has contributed valuable insights to the field of supply chain management. The identification of significant factors influencing fill rates provides a foundation for informed decision-making and strategic planning within distribution centers, ultimately leading to improved efficiency and competitiveness in today's dynamic marketplace.

Limitations of the Study:

Despite the contributions made by this study, several limitations should be acknowledged. Firstly, the findings are based on a single distribution center and may not be fully generalizable to other contexts or industries. Additionally, the simulation model utilized in this study represents a simplified abstraction of real-world operations and may not capture all relevant complexities and nuances. Furthermore, the study's scope was limited to the analysis of fill rates as a primary performance metric, overlooking other important aspects of supply chain performance such as cost-effectiveness and sustainability.

Implications of the Study:

The implications of this study extend beyond academia to inform practice and policy within the supply chain management domain. The insights gained from the analysis of inventory control policies and their interactions with demand intensity offer practical guidance for distribution center managers and decision-makers. By understanding the drivers of fill rates and the trade-offs associated with different inventory management strategies, organizations can develop more effective inventory control practices tailored to their unique operational contexts.

Additionally, the findings of this study have implications for supply chain policy and strategy formulation at the organizational and industry levels. By optimizing inventory management practices, distribution centers can enhance their competitiveness, reduce costs, and improve customer satisfaction. Furthermore, the identification of key factors influencing fill rates can inform broader supply chain optimization efforts aimed at enhancing the resilience and responsiveness of the entire supply chain network.

Future Recommendations:

Building on the insights generated by this study, several avenues for future research can be identified. Firstly, further investigation into the long-term implications of different inventory control policies on supply chain performance metrics such as cost-effectiveness and sustainability is warranted. Additionally, research could explore the integration of advanced technologies such as artificial intelligence and blockchain into inventory management practices to enhance efficiency and transparency.

Furthermore, longitudinal studies tracking the implementation and outcomes of inventory management strategies over time could provide valuable insights into their effectiveness and scalability. Additionally, comparative studies across multiple distribution centers and industries could elucidate commonalities and differences in inventory management practices, facilitating cross-sector learning and knowledge sharing.

References:

1. Al-Rifai, M.H. and Rossetti, M.D. (2007) ‘An efficient heuristic optimization algorithm for a two-echelon (R, Q) inventory system’, Production Economics, Vol. 109, pp.195–213.

2. Bertazzi, L., Paletta, G. and Speranza, M.G. (2005) ‘Minimizing the total cost in an integrated vendor-managed inventory system’, Journal of Euristics, Vol. 11, pp.393–419.

3. Bhaskaran, S. (1998) ‘Simulation analysis of a manufacturing supply chain’, Decision Sciences, Vol. 29, No. 3, pp.633–657.

4. Chen, C. and Lee, W. (2004) ‘Multi-objective optimization of multi-echelon supply chain networks with uncertain product demands and prices’, Computers and Chemical Engineering, Vol. 28, pp.1131–1144.

5. Chen, F. and Krass, D. (2001) ‘Inventory models with minimal service level constraints’, Operational Research, Vol. 134, pp.120–140.

6. Cormier, G. and Gunn, E.A. (1996) ‘Simple models and insights for warehouse sizing’, Operational Research, Vol. 47, pp.690–696.

7. Daniels, R.L., Rummel, J.L. and Schantz, R. (1998) ‘A model for warehouse order picking’, European Journal of Operational Research, Vol. 105, No. 1, pp.1–17.

8. Dellaert, N. and De Kok, T. (2004) 'Integrating resource and production decisions in a simple multi-stage assembly system', Production Economics, Vol. 90, pp.281–294.

9. De Sensi, G., Longo, F. and Mirabelli, G. (2008) 'Inventory policies analysis under demand patterns and lead times constraints in a real supply chain', International Journal of Production Research, Vol. 46, pp.6997–7016.

10. D'Esopo, A. (1968) 'An ordering policy for stock items when delivery can be expedited', Operations Research, Vol. 16, No. 4, pp.880–883.

11. Eben-Chaime, M. and Pliskin, N. (1997) 'Operations management of multiple machine automatic warehousing systems', Production Economics, Vol. 51, pp.83–98.

12. ELA/AT Kearney (2004) Excellence in Logistics 2004, ELA, Brussels.

13. Ganeshan, R. (1999) 'Managing supply chain inventories: a multiple retailer, one warehouse, multiple supplier model', International Journal of Production Economics, Vol. 59, pp.341–354.

14. Giannoccaro, I. and Pontrandolfo, P. (2002) 'Inventory management in supply chains: a reinforcement learning approach', Production Economics, Vol. 78, pp.153–161.

15. Huang, H.C., Chew, E.P. and Goh, K.H. (2005) 'A two-echelon inventory system with transportation capacity constraint', Operational Research, Vol. 167, pp.129–143.

16. Hsieh, L.F. and Tsai, L. (2006) 'The optimum design of a warehouse system on order picking efficiency', Advanced Manufacturing Technology, Vol. 28, pp.626–637.

17. Inderfurth, K. and Minner, S. (1998) 'Safety stocks in multi-stage inventory systems under different service measures', Operational Research, Vol. 106, pp.57–73.

18. Lee, H. and Billington, C. (1993) 'Material management in decentralized supply chains', Operations Research, Vol. 41, No. 5, pp.835–847.

19. Lee, H.T. and Wu, J.C. (2006) 'A study on inventory replenishment policies in a two-echelon supply chain system', Computers and Industrial Engineering, Vol. 51, pp.257–263.

20. Longo, F. and Ören, T. (2008) 'Supply chain vulnerability and resilience: a state of the art overview', Proceedings of the 20th European Modeling and Simulation Symposium, 17–19 September, Campora S.Giovanni (CS), Italy, pp.527–533.

21. Longo, F. and Mirabelli, G. (2008) 'An advanced supply chain management tool based on modeling and simulation', Computer and Industrial Engineering, Vol. 54, No. 3, pp.570–588.

22. Macro, J.G. and Salmi, R.E. (2002) 'A simulation tool to determine warehouse efficiencies and storage allocations', Proceedings of the 2002 Winter Simulation Conference, 08–11 December, San Diego (CA), USA, pp.1274–1281.

23. Minner, S., Diks, E.B. and de Kok, A.G. (1999) 'A two-echelon inventory system with supply lead time flexibility', IIE Transactions, Vol. 35, pp.117–129.

24. Minner, S. (2003) 'Multiple-supplier inventory models in supply chain management: a review', Production Economics, Vol. 81, pp.265–279.

25. Moinzadeh, K. and Nahmias, S. (1988) 'A continuous review model for an inventory system with two supply modes', Management Science, Vol. 34, pp.761–773.

26. Moinzadeh, K. and Aggarwal, P.K. (1997) 'An information based multiechelon inventory system with emergency orders', Operations Research, Vol. 45, pp.694–701.

27. Moinzadeh, K. and Schmidt, C.P. (1991) 'An (S_1, S) inventory system with emergency orders', Operations Research, Vol. 39, pp.308–321.

28. Qi, X., Bard, J. and Yu, G. (2004) 'Supply chain coordination with demand disruptions', Omega, Vol. 32, pp.301–312.

29. Ramasesh, R., Keith, O. and Hayya, J. (1991) 'Sole versus dual sourcing in stochastic lead-time (s, Q) inventory model', Management Science, Vol. 37, No. 4, pp.428–443.

30. Silver, E.A., Pyke, D.F. and Peterson, R. (1998) Inventory Management and Production Planning and Scheduling, 3rd ed., John Wiley & Sons, USA.

31. Zhou, B., Zhao, Y. and Katehakis, M. (2007) 'Effective control policies for stochastic inventory systems with a minimum order quantity and lin