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Towards a Framework for Aligning RFID Applications With Supply Chain Strategies

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TOWARDS A FRAMEWORK FOR ALIGNING RFID APPLICATIONS WITH SUPPLY CHAIN STRATEGIES

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Abstract

Supply chain management has two streams of strategies, namely lean and agile. However, current RFID applications tend to overlook supply chain strategies and are designed for obvious RFID applications, like simply replacing barcodes. However, the full potential of RFID might not be achieved when RFID applications are not aligned with the supply chain strategies. Therefore, this study analyzes the current literature to investigate whether RFID applications are indeed misaligned with their strategies. Results shows that RFID is still at its infancy and most RFID applications focus on cost reduction, a lean practice, and less attention has been paid on how RFID can satisfy customer demands, an agile practice. It is therefore suggested that management should ensure that RFID applications are aligned with their supply chain strategy, in order to gain the most benefits out of RFID.

Introduction

RFID holds the promise to revolutionize supply chain management, by providing visibility to all supply chain partners. Wal-Mart and other major retailers started the RFID inertia by mandating their top suppliers to tag cases and pallets with RFID tags in 2005. However, RFID is still far from reaching its critical mass. As a matter of fact, RFID adoption has been stagnating after the RFID mandates from the major retailers [1]. The RFID adoption has been relatively slow partly due to the fact that we are not fully aware of the benefits it can bring [2] and due to the fact that RFID has not brought the envisaged benefits yet.

One of the explanations of the unclear benefits might be explained by that all supply chains are treated as equal when designing RFID applications. However, literature has actually already defined two different types of supply chain strategies, namely lean and agile. Where lean focuses on eliminating waste and where agile focuses on satisfying customer demands. Nevertheless, supply chain strategies are often ignored when designing IT and information sharing applications. It is therefore very plausible that current RFID applications are not aligned with their supply chain strategies. Authors like [3] support this view, as they imply that many RFID applications merely replicate Wal-Mart's example. Thus Wal-Mart's RFID application was initially designed for a typically lean supply chain, but replicated to both lean and agile oriented supply chains. This obviously limits the true potential of RFID applications and we therefore need to realign RFID applications with the supply chain strategy.

The major purpose of this study is twofold. First, this study provides a landscape of the current RFID applications, by reviewing the existing literature. Secondly, this study verifies whether the existing RFID applications are aligned with the supply chain strategy.

Literature review

Supply chain strategies

One of the first recognized supply chain strategies is mass production, as introduced by Henry Ford in the early 20th century [4]. Mass production created standard processes to effectively and efficiently manufacture products in house. In the 1970s Toyota developed the Toyota Production System, based on the Just in Time (JIT) principle and what later has become lean production [5]. The main philosophy of lean is to eliminate waste, e.g. redundant cost and labor. Soon the lean philosophy was not only applied by manufacturers, but was applied across supply chains, due to globalization and rapid technological innovations [6]. Agile supply chains can be traced back to the 1990s and its main philosophy is to be flexible in order to meet the fluctuating customer demands [7]. Fischer [8] was one of the first to suggest that lean and agile are supply chain strategies and he was one of the first to explain which specific supply chain strategy to use in different market environments. The market place in combination with the product type should determine the appropriate supply chain strategy, as shown in Table 1.

Table 1. Supply Chain Strategies

	Functional product	**Innovative product**
Predictable market place	Lean	Mismatch
Volatile market place	Mismatch	Agile

Lean and agile supply chain strategies have been widely used to explain many SCM phenomena. Moreover, many academics developed variants of the lean and agile supply chain strategies. Leagile strategy was proposed by [9], where lean is used in the upstream supply chain and where agile is used in the downstream supply chain. Moreover, the supply chain strategies were extended by taking the supplier uncertainty into account [10]. Albeit supply chain strategies have evolved, they are still based on the elemental lean and agile philosophy. Therefore, this study considers only lean and agile as supply chain strategies in order to keep the study parsimonious.

IT and information sharing are often considered as enabling factors in supply chain management [11] and both have been widely discussed in the supply chain management context. Lean has two paradigms regarding IT and information sharing, where one side supports that IT and information sharing can improve the lean principle [12]. While others question whether IT and information sharing is useful and suggest that they actually create more overhead and maintenance,and thus waste [13]. On the other hand, IT and information sharing seems to be the foundation of agility, as it enables better coordination between supply chain partners in order to meet the customer demand [14]. Thus the literature advocates that IT and information sharing is more effective for agile supply chains than lean supply chains. However, as aforementioned many RFID applications are replicates of Wal-Mart's RFID application, which was designed for a lean supply chain. As a result many RFID applications are not aligned with the (agile) supply chain strategy and possibly limit the potential RFID benefits.

RFID diffusion

RFID is a prominent technology that has been much discussed recently and the discussion is expected to further extend [15]. The technology is often discussed as it can integrate the material flow with the information flow, providing a real-time track and trace of products [16]. It is even proclaimed to be as revolutionary as the Internet [17]. RFID is far from reaching a critical mass, despite the envisaged benefits. Literature suggests that lack of standards, privacy and security issues, high RFID tag cost, and unclear benefits are the main barriers RFID adoption [18] [19] [20]. The lack of standards is currently being addressed by EPCglobal [21] and the high tag cost should drive down with the rapid technological improvements. Privacy and security issues of RFID are a major concern and have been extensively covered by many studies [22]. However, the benefits of RFID remain elusive and are typically reported by only a few case studies [23], leaving managers to make decisions while they are still uncertain about the true RFID benefits like ROI and inventory turnover [20].

Methodology

This study provides a landscape of the current RFID applications by reviewing the literature. Academic journals were examined, as we believe that they usually provide the most in-depth and objective reviews of RFID applications. Only studies that covered actual RFID applications or studies that proposed applications with a real case to test the proposed application were considered, mere conceptual work is omitted as they are not designed or tested against a specific supply chain strategy. Moreover, theses, dissertations, textbooks, conference papers, and unpublished papers were excluded, in order to keep the papers consistent and of high quality. The following five electronic databases were consulted for this study: ABI/INFORM, Academic Search Premier, Emerald Fulltext, Science Direct, and IEEE Xplore. The search was based on the keywords "RFID" and "radio frequency identification". The full text of each article was reviewed to only include those that were considered as RFID applications, as aforementioned. We found a total of 1542 articles with the matching keywords and out of those articles only 21 satisfied our RFID application criteria.

The 21 studies were classified into lean or agile supply chains, in order to provide a supply chain strategy view of the RFID applications. The supply chain classification was done according to the classification as proposed by [8]. First of all, the articles are reviewed for whether the demand is either stable (lean) or uncertain (agile). Secondly, the product type is analyzed for whether they are functional or innovative. Studies where the supply chain strategies could not be determined were excluded. Moreover, the RFID applications were analyzed for the supply chain practices as illustrated in Table 2. Lean practices and agile practicesThis allows us to verify whether RFID applications were implemented in alignment with the respective supply chain strategy. Notice that the "soft practices", which are tailored to sociological aspects, were excluded, as these are unlikely to be directly influenced by RFID. The reader is referred to [12] [24] [25] for more readings about the supply chain practices found in Table 2.

Table 2. Lean practices and agile practices

Lean	Agile
Pull approach (Kanban)	Close supplier relationship
Inventory reduction	Enterprise integration
Quick setups / orders	Concurrent business activities
Quality at source (Jidoka)	Customer requirement satisfaction
Supplier networks	Rapid development cycles
Continuous improvement (Kaizen)	Customer driven innovation
	Use flexible production technology

An overview of the RFID applications studies can be found in Table 3. The overview shows that almost all RFID application studies were published after 2006, which can be explained since Wal-Mart started the RFID inertia in 2005. Even though the goal is to discuss RFID applications on a supply chain level, the overview illustrates that most of the RFID applications are designed and implemented on an organizational level and only a few studies share information between supply chain partners let alone share information across the entire supply chain. However, the true benefit of RFID lies in information sharing across the entire supply chain as aforementioned. For instance, when inventory levels are shared the Bullwhip effect can be lessened [26] and the production planning can be improved [27].

The overview also illustrates that many of the RFID applications are for inventory tracking purposes, where it can generally depict a more up to date and accurate picture of the inventory. Only a few of the studies like [28] demonstrated that RFID can be used for redesigning the supply chain and creating new business opportunities, rather than only replacing barcode or automating certain manual processes.

Furthermore, the overview illustrates that the supply chain strategy and the supply chain practices of the RFID applications are not always aligned. A summary of the alignment between supply chain strategies and supply chain practices is illustrated in

Table 4. The overview shows that 8 out of the 21 RFID applications are lean supply chains and 13 are agile supply chains. The overview also shows that 7 out of the 8 lean supply chains implemented RFID applications aligned with their strategy and only 3 out of the 13 agile supply chains implemented RFID applications aligned with their strategy.

Thus 11 out of the 21 RFID applications are tailored to supply chain practices that are not aligned with their supply chain strategy. The misalignment can be attributed to that most of the RFID applications, 14 out of 21, are tailored to lean practices. Thus the RFID applications are mostly tailored to lean practices disregarding the supply chain strategy, while the literature suggested that IT and information sharing is more effective for agile supply chains. This finding indicates that RFID is not optimally used to support their supply chain strategy.

Discussion

The literature shows that there are two streams of supply chain strategies, namely lean and agile. However, the literature review showed that RFID applications are often not tailored to the practices that aid the supply chain strategies. Studies like [49] demonstrated that the correct supply chain practices can improve the supply chain strategy and hence the performance. Moreover, as aforementioned the literature suggests that IT and information sharing should aid the agile supply chains more than the lean supply chains. The RFID application review on the other hand illustrates that most supply chain strategies focus on lean practices disregarding the supply chain strategies. The literature also showed that current RFID applications address most lean practices, but left various agile practices unexplored. A possible explanation of this phenomena is that lean practices often focus on waste reduction, and thus cost, which is relatively easy to quantify and where agile practices focus on customer demand satisfaction, which is more difficult to quantify. Moreover, most of the RFID applications are focused on internal operations and automating processes, which is more along the line of lean thinking. This also indicates that we are only at the start of the RFID diffusion, as the true potential of RFID lies in redesigning supply chains and developing new business opportunities [50].

This study suggests academics and practitioners to take the supply chain strategy into account when designing and discussing IT and information sharing applications. The literature shows that supply chain strategies are well known and they usually discuss operational issues. However, IT and information sharing can support those operational issues and attention should be paid when designing them. Moreover, the study also suggest to further investigate in the supply chain practices that RFID has left unexplored, e.g. supplier network, concurrent business activities, customer driven innovation, and use flexible

production technology. Note that most of the unexplored supply chain practices are agile, which according to the literature can greatly facilitate the supply chain performance.

Table 3. RFID applications overview

Article	Strategy	Practices	Summary
[17]	Lean	Kaizen	Monitors the repairable airplane items in an aviation engineering company.
[29]	Lean	Inventory reduction Kaizen	Investigates at how RFID data can be used to better track inventory.
[30]	Agile	Enterprise int. Inventory reduction	Visualizes processes by capturing 3PLs' RFID data and shares them over the Internet.
[31]	Lean	Jidoka	Ensures that bottles go through all the dispense processes.
[32]	Agile	Kaizen	Monitors the calibrated tools location and that they do not unauthorized leave the plant.
[33]	Agile	Kaizen Quick set up/order	Uses RFID over existing GSM network to automate receiving incoming goods.
[34]	Agile	Jidoka	Ensures that the correct parts are assembled on the right chassis.
[35]	Lean	Quick set up/orders	Tracks and traces trucks that go in and out of the Shanghai Port.
[36]	Lean	Kaizen	Monitors the use of pallets throughout the supply chain.
[37]	Lean	Inventory red.	Manage retail inventory of chilled groceries and ensures that products are sold before the due date.
[38]	Agile	Kanban Close sup. rel.	Proposes a multi agent auto replenishment system based on RFID.
[39]	Agile	Close sup. rel. Customer req. sat.	Provides an inventory visibility of the OEM suppliers to the dealers via Internet.
[40]	Agile	Kanban	Track and traces the pre-cast components in a storage yard.
[41]	Agile	Inventory red. Rapid dev. Cycles	Track and traces the inventory of "RFID unfriendly" pipe spools.
[42]	Agile	-	Monitors the inventory in a warehouse.
[28]	Lean	Customer req. sat.	Tracks and traces the physical locations of containers in a container depot and keeps track of the container conditions.
[43]	Agile	Kaizen	Investigates how real time tracking of inventory can improve the operations of the manufacturer.
[44]	Agile	Enterprise int.	Allows RFID tags to capture the production information of semi conductors and provides the information to the retailers.
[45]	Lean	Inventory reduction	Investigates whether RFID is cost effective when it is used for product shrinkage.
[46]	Agile	Inventory reduction	Utilizes RFID to identify the misplacement of goods in a retail shop.
[47]	Agile	-	Investigates how RFID can benefit a car manufacturer in the shipping yard of a car manufacturer.

Table 4. Supply chain strategies aligned with practices

Strategy	Practices aligned	Practices misaligned
Lean	7	1
Agile	4	9
Total	11	10

In practice supply chain management might not have such a clear distinction between lean and agile supply chain strategies. For instance, an organization can follow both lean and agile supply chain strategies. According to the literature agile supply chains try to satisfy the changing customer demand, but not at an unlimited price. Therefore, agile supply chains will also often focus on waste reduction, once the customer demand is satisfied or when the product is matured [51]. Albeit there might not be such a clear distinction between the two supply chain strategies, this study can provide management with a guidance of how to implement RFID. After all, management should be aware whether the priority should be set to waste reduction or customer demand satisfaction.

This study only looked at academic publications, which limited the RFID applications to 21. Therefore business journals should be analyzed in the future to confirm the findings. Moreover, this study will continue and will develop a framework that can explain how different types of RFID applications can impact lean and agile supply chains strategies. First, the RFID applications are categorized according to different types of RFID applications. Subsequently, the

different types of applications are analyzed to verify how they impact different strategies. Furthermore, we will investigate whether it is possible to describe which type RFID application is more beneficial for certain supply chain strategies and/or supply chain practices.

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References

[1] Wu, N.C., Nystrom, M.A., Lin, T.R., and Yu, H.C., Challenges to global RFID adoption, *Technovation*, 26(12), 2006, pp. 1317-1323.

[2] Asif, Z. and Mandviwalla, M., Integrating the Supply Chain with RFID: a Technical and Business Analysis, *Communications of the Association for Information Systems*, 15(24), 2005, pp. 393-451.

[3] Krotov, V. and Junglas, L., RFID as a Disruptive Innovation, *Journal of Theoretical and Applied Electronic Commerce Research*, 3(2), 2008, pp. 44-59.

[4] Womack, J.P., Jones, D.T., and Roos, D., The Machine That Changed the World: the Story of Lean Production, 1991, HarperBusiness.

[5] Taiich, O., Toyota Production System: Beyond Large-Scale Production, 1988, Productivity Press.

[6] Doolen, T.L. and Hacker, M.E., A Review of Lean Assessment in Organizations: an Exploratory Study of Lean Practices by Electronics Manufacturers, *Journal of Manufacturing Systems*, 24(1), 2005, pp. 55-67.

[7] McCullen, P. and Towill, D., Achieving Lean Supply Chain through Agile Manufacturing, *Integrated Manufacturing Systems*, 12(7), 2001, pp. 524-533.

[8] Fischer, M., What is the Right Supply Chain for your Product, *Harvard Business Review*, March April, 1997, pp. 105-116.

[9] Mason-Jones, R., Naylor, B., and Towill, D.R., Engineering the Leagile Supply Chain, *International Journal of Agile Management Systems*, 2(1), 2000, pp. 54-61.

[10] Lee, H.L., Aligning Supply Chain Strategies with Product Uncertainties, *California Management Review*, 44(3), 2002, pp. 105-119.

[11] Johnson, M.E. and Whang, S., E-business and Supply Chain Management: an Overview and Framework, *Production and Operations Management*, 11(4), 2002, pp. 413-423.

[12] Bruun, P. and Mefford, R.N., Lean Production and the Internet, *International Journal of Production Economics*, 89(3), 2004, pp. 247-260.

[13] Piszczalski, M., Lean vs. Information Systems, *Automotive Manufacturing & Production*, 112(8), 2000, pp. 26-28.

[14] White, A., Daniel, E.M., and Mohdzain, M., The Role of Emergent Information Technologies and Systems in Enabling Supply Chain Agility, *International Journal of Information Management*, 25(5), 2005, pp. 396-410.

[15] Ngai, E.W.T., Moon, K.K., Riggins, F.J., and Yi, C.Y., RFID Research: an Academic Literature Review, *International Journal of Production Economics*, 112(2), 2008, pp. 510-520.

[16] Angell, I. and Kietzmann, J., RFID and the End of Cash?, *Communications of the ACM*, 49(12), 2006, pp. 90-96.

[17] Ngai, E.W.T, Cheng, T.C.E, Lai, K.H, and Chai, P.Y.F., Development of an RFID-based Traceability System: Experiences and Lessons Learned from an Aircraft Engineering Company, *Production and Operations Systems*, 16(5), 2007, pp. 554-569.

[18] Shih, D.H., Chiu, Y.W., Chang, S.I., and Yen, D.C., An Empirical Study of Factors Affecting RFID's Adoption in Taiwan, *Journal of Global Information Management*, 16(2), 2008, pp. 58-80.

[19] Whitaker, J., Mithas, S., and Krishnan, M.S., A Field Study of RFID Deployment and Return Expectation, *Production and Operations Management*, 16(5), pp. 599-513.

[20] Attaran, M., RFID: an Enabler of Supply Chain Operations, *Supply Chain Management*, 12(4), 2007, pp. 249-257.

[21] Armenio, F., Barthel H., Burstein, L., Dietrich, P., Duker, J., Garrett, J., Hogan, B., Ryaboy, O., Sarma, S., Schmidt, J., Suen, K.K., Traub, K., and Williams, J. The EPCglobal Architecture Framework, EPCglobal Final Version 1.2, 10 September 2007.

[22] Garfinkel, S.L., Juels, A., and Pappu, R. RFID Privacy: An Overview of Problems and Proposed Solutions, *IEEE Security and Privacy*, 3(3), 2005, pp. 43-43.

[23] Loebecke, C., Piloting RFID Along the Supply Chain: a Case Analysis, *Electronic Markets*, 17(1), 2007, pp. 29-38.

[24] Yusuf, Y.Y., Sarhadi, M., and Gunasekaran, A., Agile Manufacturing: the Drivers, the Concept and Attributes, *International Journal of Production Economics*, 62 (1-2), pp. 33-43.

[25] Fisher, M. and Raman, A., Reducing the Cost of Demand Uncertainty Through Accurate Response to Early Sales, *Operations Research*, 44(1), 1996, pp. 87-99.

[26] Cheng, F., Drezner, Z., Ryan, J.K., and Simchi-Levi, D., Quantifying the Bullwhip

Effect in a Simple Supply Chain: the Impact of Forecasting, Lead Times, and Information, *Management Science*, 46(3), 2000, pp. 436-443.

[27] Sodhi, M.M.S., Managing Demand Risk in Tactical Supply Chain Planning for a Global Consumer Electronics Company, *Production and Operations Management*, 14(1), 2005, pp. 1059-1478.

[28] Ngai, E.W.T, Cheung, T.C.E., Au, S., and Lai, K., Mobile Commerrce Integrated with RFID Technology in a Container Depot, *Decision Support Systems*, 43(1), 2007, pp. 62-76.

[29] Delen, D., Hardgrave, B.C., and Sharda, R., RFID for Better Supply Management through Enhanced Information Visibility, *Production and Operations Management*,16(5), 2007, pp. 613-624.

[30] Harry, K.H., Chow, K.L., Choy, W.B., Lee, F., and Chan, T.S., Integration of Web-based and RFID Technology in Visualizing Logistics Operations – a Case Study, *Supply Chain Management*, 12(3), 2007, pp. 221-234.

[31] Bloss, R., Maybe the World's Largest Automated Assembly line?, *Assembly Automation*, 27(1), 2007, pp. 20-24.

[32] Jones, E.C., Riley, M.W., Franca, R., and Reigle, S., Case Study: the Engineering Economics of RFID in Specialized Manufacturing, *The Engineering Economist*, 52(3), 2007, pp. 285-303.

[33] Holmqvist, M. and Stefansson, G., Smart Goods and Mobile RFID: a Case with Innovation from Volvo, *Journal of Business Logistics*, 27(2), 2006, pp. 251-273.

[34] Gaukler, G.M. and Hausman, W.H., RFID in a Mixed-model Automotive Assembly Operations: Process and Quality Cost Savings, *IIE Transactions*, 40(11), 2008, pp. 1083-1096.

[35] Wang, W., Yuan, Y., Wang, X., and Norm, A, RFID Implementation Issues in China: Shanghai Port Case Study, *Journal of Internet Commerce*, 5(4), 2006, pp. 89-103.

[36] Mo, J.P.T., Gajzer, S., Fane, M., Wind, G., Snioch, T., Larnach, K., Seitam, D., Saito, H., Brown, S., Wilson, F., and Lerias, G., Process Integration for Paperless Delivery Using EPC Compliance Technology, *Journal of Manufacturing Technology Management*, 20(6), 2009, pp. 866-886.

[37] Kärkkäinen, M., Increasing Efficiency in the Supply Chain for Short Shelf Life Goods Using RFID Tagging, *International Journal of Retail & Distribution Management*, 31(10), 2003, pp. 529-536.

[38] Wang, S.J, Liu, S.F., and Wang, W.L., The Simulated Impact of RFID-Enabled Supply Chain on Pull-based Inventory Replenishment in TFT-LCD Industry, *International Journal of Production Economics*, 112(2), 2008, pp. 570-586.

[39] Mourtzis, D., Papakostas, N., Makris, S., Xanthakis, V., and Chrysolouris, G., Supply Chain Modeling and Control for Producing Highly Customized Products, *CIRP Annals – Manufacturing Technology*, 57(1), 2008, pp. 570-586.

[40] Ergen, E., Akinci, B, and Sacks, R., Tracking and Locating Components in a Storage Yard utilizing Radio Frequency Identification Technology and GPS, *Automation in Construction*, 16(3), 2007, pp. 354-367.

[41] Song, J., Haas, C.T., Caldas, C., Ergen, E., and Akinci, B., Automating the Task of Tracking the Delivery and Receipt of Fabricated Pipe Spools in Industrial Projects, *Automation in Construction*, 15(2), 2006, pp. 166-177.

[42] Poon, T.C., Choy, K.L., and Lau, H.C.W, A RFID Case-based Logistics Resource Management System for Managing Order-picking Operations in Warehouses, *Expert Systems with Applications*, 36(4), 2009, pp. 8277-8301.

[43] Thiesse, F. and Fleisch, E., On the Value of Location Information to Lot Scheduling in Complex Manufacturing Processes, *International Journal of Production Economics*, 112(2), 2008, pp. 532-547.

[44] Qiu, R.G., RFID Enabled Automation in Support of Factory Integration, *Robotics and Computer Integrated Manufacturing*, 23(6), 2007, pp. 677-683.

[45] De Kok, A.G., van Donselaar, K.H., and van Woensel, T., A Break-even Analysis of RFID Technology for Inventory Sensitive to Shrinkage, *International Journal of Production Economics*, 112(2), 2008, pp. 521-531.

[46] Rekik, Y., Sahin, E., and Dallery, Y, Analysis of the Impact of the RFID Technology on Reducing Product Misplacement Errors at Retail Stores, *International Journal of Production Economics*, 112(1), 2008, pp. 264-278.

[47] Kim, J., Tang, K., Kumara, S., Yee, S.T., and Tew, J., Value Analysis of Location-enabled Radio Frequency Identification Information on Delivery Chain Performance, *International Journal of Production Economics*, 112(1), 2008, pp. 403-415.

[48] Fisher, M. and Raman, A., Reducing the Cost of Demand Uncertainty Through Accurate Response to Early Sales, *Operations Research*, 44(1), 1996, pp. 87-99.

[49] Van Hoek, R.I., Harrison, A., and Christopher, M., Measuring Agile capabilities in supply

chain, *International Journal of Operations and Production Management*, 21(1/2), 2001, pp. 126-147.

[50] Hsi, S. and Fait, H., RFID Enhances Visitors' Museum Experience at the Exploratorium, *Communications of ACM*, 48(9), 2005, pp. 60-65.

[51] Vonderembse, M.A., Uppal, M., Huang, S.H., and Dismukes, J.P., Designing Supply Chains: Towards Theory Development, *International Journal of Production Economics*, 100(2), 2006, pp. 223-238.