Towards supply chain collaboration: an operations audit of VMI initiatives in the electronics industry

Jennifer Blackhurst

North Carolina State University, College of Management
Department of Business Management
Campus Box 7229, Raleigh, NC 27695–7229, USA
Fax: (919) 515–6943 E-mail: jennifer_blackhurst@ncsu.edu

Christopher W. Craighead

Auburn University, Department of Management
Lowder Building, Suite 401, Auburn University, AL 36849, USA
Fax: 334–844–5159 E-mail: craigcw@auburn.edu

Robert B. Handfield*

Bank of America University
North Carolina State University, College of Management
Campus Box 7229, Raleigh, NC 27695–7229, USA
Fax: (919) 515–6943 E-mail: Robert_Handfield@ncsu.edu
*Corresponding author

Abstract: Recently, there has been an increased focus on supply chain collaboration efforts such as Vendor-Managed Inventory (VMI). Often, supply chain partners have experienced gaps between desired and actual performance in working towards a successful collaborative relationship. In this research, we analysed two VMI initiatives that have not yet produced the level of performance desired by the supply chain partners involved. In each case, an operations audit was performed to determine where characteristic and performance gaps existed. The output of this research effort is inherent in the operations audit process employed, the VMI initiative gaps discovered during the process as well as the steps that could be undertaken to minimise or eliminate these gaps. The paper culminates in a framework that describes the operations audit in terms of an iterative, collaboration evaluation process. The framework and process can serve as valuable mechanisms for understanding the evolution towards collaborative supply chain relationships.

Keywords: supply chain management; supply chain collaboration; vendor-managed inventory; forecasting; case research; empirical research; information sharing.

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Biographical notes: Jennifer Blackhurst is Assistant Professor of Supply Chain and Operations Management in the Business Management Department, College of Management, North Carolina State University. She received her doctorate in Industrial Engineering from the University of Iowa in 2002. Her research interests include distributed systems/supply chain modelling and design; supply chain disruption modelling and management; and collaborative product development. Her publications have appeared or been accepted in such journal as *Journal of Operations Management, International Journal of Production Research,* and *ASME Transactions: Journal of Computing and Information Science in Engineering.* She is a member of POMS, INFORMS and DSI.

Christopher W. Craighead is Associate Professor of Operations Management in the Department of Management at Auburn University. He received his PhD in Operations Management from Clemson University. His current research interests are in the areas of supply chain management and service recovery – much of his work transcends the boundaries between the fields of operations management and information systems within these areas. Professor Craighead has articles published, or to appear, in *Journal of Operations Management*, *Production and Operations Management, European Journal of Operational Research, International Journal of Production Research, Supply Chain Management Review, Production and Inventory Management Journal, Communications of the ACM, DATA BASE for Advances in Information Systems, Decision Sciences Journal of Innovative Education* and other journals.

Robert Handfield is the Bank of America University Distinguished Professor of Supply Chain Management in the Business Management Department, College of Management, North Carolina State University. His research focuses on benchmarking best practices in supply chain business processes. He has published in journals such as the *Sloan Management Review, California Management Review, Journal of Operations Management, Decision Science, Journal of Supply Chain Management, Journal of Business Logistics*, and *IEEE Transactions in Engineering Management*. He also serves as Editor-in-Chief of the *Journal of Operations Management*, *SCM Columnist for APICS: The Performance Advantage*, and serves on the Editorial Board of the *Supply Chain Management Review*, *Decision Sciences* and *Journal of Supply Chain Management*.

1 Introduction: supply chain collaboration

Successful supply chain management incorporates extensive coordination among multiple functions and independent companies working together to deliver a product or service to end consumers (Lee and Whang, 1998; Lee and Billington, 1993). In traditional supply chain systems, different functions such as marketing, distribution, planning, manufacturing, and purchasing organisations within the supply chain often operate independently. Furthermore, individual organisations have their own objectives that can often conflict with those of other organisations. Yet, given the interdependent nature of supply chains and the fact that value is cumulative with respect to the final customer (Craighead and Shaw, 2003), many companies have undertaken initiatives to collaborate the efforts and activities of the supply chain members. Indeed, the potential benefits from supply chain coordination are leading more and more companies to involve suppliers on teams in a variety of different areas. Teams that include suppliers as participants report important outcomes and great supplier contributions across many performance areas, including reducing costs, improving quality, improving material delivery, and reducing cycle time (Monczka and Trent, 1993).

While collaboration can result in significant mutual benefits, collaborative efforts often produce less than desired outcomes – this is when collaboration usually breaks down and it becomes more of an adversarial relationship. It is in this situation (*i.e.*, when things are not going well) that the true test of the relationship exists – the willingness and abilities of the two companies to work through the hard times is collaboration at its best. Despite this truth, we as researchers tend to focus on the characteristics and performance of success stories. This focus of the research is indeed important as it provides valuable insights into best practices and lays the groundwork for theory development. However, success stories are, in essence, the end result rather than the process of getting there. In other words, most supply chain partners that enjoy successful collaborative relationships have (and will) experienced gaps between desired and actual performance. Therefore, researchers should consider these gaps in their efforts as potential insights may be gained relative the process towards supply chain collaboration. It is in this domain in which we focused our research efforts. Specifically, we analysed two vendor-managed inventory initiatives that are not producing the level of performance desired by the supply chain partners involved. In each case, an operations audit was performed to determine where characteristic and performance gaps existed and consequently what responses could be undertaken to minimise or eliminate these gaps.

The remainder of the paper is organised into five sections. Section 2 contains a brief overview of vendor-managed inventory. Section 3 describes the operations audit process (*i.e.*, methodology). Section 4 describes the gaps between the desired and realised characteristics and performance of the VMI initiatives. Section 5 discusses the research and Section 6 contains a brief conclusion.

2 Vendor-Managed Inventory (VMI)

Kuk (2004) states that Vendor-Managed Inventory (VMI) is a supply initiative where the supplier assumes responsibility of tracking and replenishing a customer's inventory. Similarly, while investigating the effect of VMI on brand competition, Mishra and Raghunathan (2004) describe a VMI relationship as one where the vendor or supplier is responsible for the management of stock at the retailer. The retailer provides the supplier with access to real-time inventory levels, and replenishment policies are decided by the supplier. In a recent study focusing on the development of a framework to relate information integration and firm profitability, Kulp *et al.* (2004) state that "the ability to manage and track the flow of relevant information across supply chain member has been greatly enhanced by recent technological innovations". They further state that partnerships and information integration can lead to strategic supply chain competencies.

The concept of VMI comes in different forms. Disney and Towill (2003) provide a list of common names of VMI initiatives including quick response (Lee *et al.*, 2000), Synchronised Consumer Response (SCR), Continuous Replenishment (CR), Efficient Consumer Response (ECR) (Cachon and Fisher, 1997), Rapid Replenishment (RR), Collaborative Planning Forecasting and Replenishment (CPFR) (Holmström *et al.*, 2000) and centralised inventory management (Lee *et al.*, 1997a). Collaboration in the form of VMI holds great promise for participating supply chain partners.

For example, Dong and Xu (2002) discuss evidence that VMI is shown to be beneficial to both the buying and the supplying company within the supply chain but state that the supplier may have a longer period of adjustment before reaping the benefits of VMI. These benefits can, in theory, lead to a win-win situation that can result in increased customer service, reduced lead times, and cost reductions due to increasing inventory turns and decreasing levels of safety stock (Kuk, 2004). Mishra and Raghunathan (2004) state that VMI is emerging as a significant factor as companies focus on collaboration and information sharing in the management of supply chains. In fact, manufacturers such as Campbell Soup and Proctor and Gamble and retailers such as Wal-Mart have utilised VMI relationships (Mishra and Raghunathan, 2004).

To realise the theoretical benefits of VMI, supply chain partners must overcome the barriers present in traditional supply chains. The single greatest barrier faced by supply chains attempting to manage the discontinuity between supply and demand is often inaccurate forecasting. In fact, the need to match supply and demand more closely is often the catalyst for engaging in supply chain partnerships (Angulo *et al.*, 2004). As a result of lack of visibility of real demand information, many companies are seeking ways to improve supply chain performance by sharing demand and inventory information with suppliers and customers. Therefore, information sharing is key to the successful implementation of VMI systems (Handfield and Nichols, Jr., 2002; Dong and Xu, 2002). Dong and Xu state that as parties share information in a VMI environment, less information distortion should be expected as discussed in Lee *et al.* (1997a) and Chen *et al.* (2000). The importance of information flow and forecast accuracy is inherently critical to VMI initiatives. For example, Disney and Towill (2003) apply a supply chain perspective in looking at VMI and its effect on demand fluctuations. Indeed, the complexity associated with supply chains, combined with a lack of coordination, can lead to potential problems. One example of this is the phenomenon known as the bullwhip effect or demand amplification. The bullwhip effect was first recognised by Forrester (1961) and is described as small changes in demand becoming amplified as that demand is passed along a supply chain. Accurate and timely information flow cited as one method essential to avoiding the bullwhip effect (Forrester, 1961; Lee *et al.*, 1997a–b).

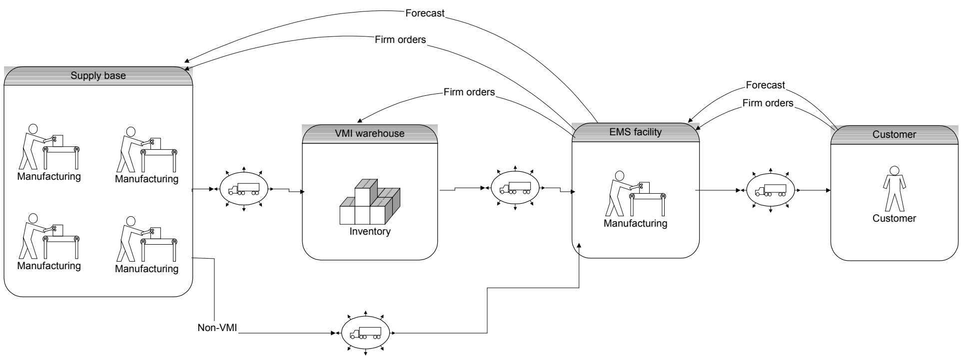
Our research analyses two VMI initiatives with the intent of finding gaps between this theoretical win-win situation and the realised performance of the initiatives. We seek insights into the cause of these gaps and the accompanying responses that could minimise or eliminate these gaps.

3 Methodology: operations audit process

3.1 VMI implementations analysed

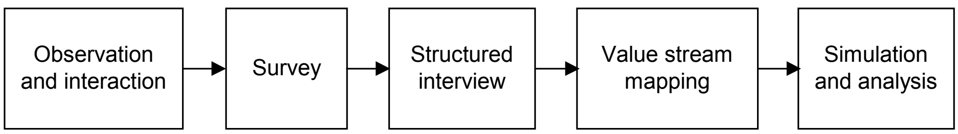
This paper presents summary results of two industry projects in the Electronic Manufacturing Services (EMS) sector. These projects, both following the same methodology, investigate improving inbound supply chain coordination for enhanced VMI performance. Case 1 (Company A) focuses on improving VMI material replenishment at an EMS facility. Case 2 (Company B) focuses on reducing inventory in the VMI process at an EMS facility. In both cases, the material replenishment process is driven by customer forecasts. Figure 1 illustrates a high-level view of the VMI process of both cases. Figure 1 illustrates the flow of information and material between the supplier and the manufacturer. In both cases information flow triggers material flow and is as follows: the end customer (shown on the far right) sends both a forecast as well as firm orders to the manufacturer. Note that for each link having forecasts and firm orders, there is a time lag between the forecast and the firm order. Next, the manufacturer sends a forecast and, later, a firm order to the supplier. The supplier must use the forecast to plan for shipments of inventory to the VMI warehouse in order to meet the needs of the manufacturer. In turn, the manufacturer pulls material from the VMI warehouse for use in production and ships final products to the customer.

Figure 1 VMI process view



As indicated earlier, the intent of both projects was to improve the coordination between partners in existing VMI implementations. The methodology, henceforth referred to as an operations audit, was a thorough, detailed analysis of the VMI implementations. An overview of the operations audit process is shown in Figure 2. First, we observed the process and interacted with the process owners. Next, each process owner completed our survey which was followed up with a structured interview. Next, we collected additional data needed and performed a value stream mapping which provided data for the simulation and process analysis. Each of the steps in the audit is briefly discussed in the following sections.

Figure 2 Operations audit process



3.2 Observation and interaction

The goal of the observation and interaction stage was to gain a general understanding of the baseline processes, representative decisions, and products. In addition to a general understanding, this step involved the selection of representative parts, thus, allowing for the gathering of step-by-step data in subsequent phases of the operations audit. These parts, provided by facility management, represent typical processes and decisions. Insights gained from analysis of these representative supply chains can be adopted across multiple-part families.

3.3 Surveys

Questionnaires were developed based on the understanding of the baseline process outlined through interactions with the process owners. The questionnaires were part-specific and function-specific. The respondents were process owners for each step or function in the supply chain. The information was collected only from the actual process performers and not from their supervisors who may not know the day-to-day problems involved. The process owners for the material replenishment process were asked to confine their responses only to the parts taken for analysis. Apart from the questions relating to the performance characteristics of the processes there were also questions on the problems encountered by the process owners in performing their task and possible improvement areas. The questionnaire was structured to be the input for mapping the process.

3.4 Structured interviews

Follow-up personal and telephone interviews were conducted with the questionnaire respondents. This proved to be a valuable input for developing insight into the problem and for developing the recommendations. The surveys provided breadth to the analysis whereas the interviews contributed to the depth.

3.5 Value stream mapping

Value Stream Mapping (VSM) was used to study the end-to-end process and identify any process problems and nonvalue-adding activity involved. Value stream mapping was developed to help identify waste in a system (Hines *et al.*, 1998). Benefits of mapping include:

- visualises the entire system
- helps the user to see the waste in the system and the sources of waste
- provides a common method and language across multiple processes
- makes decision criteria apparent
- shows linkages between information flows and material flows (Wood, 2004).

The key rule of the mapping exercise we employed was to walk the process and follow the material or information from the time it enters until the time it exits the system. Parts were traced from the customer order to when they ceased being component inventory and became WIP (that is, ownership change from materials procurement to manufacturing). This involved the advanced planning, forecasting, procurement, material receipt, and distribution phases. Key information in the map includes task triggers, process owners, performance times, flow times, and frequencies. The value stream map was used to determine the performance capabilities of the processes, process difficulties, problem areas, and nonvalue-added activities involved. The map is also used to provide quantitative input needed for building the simulation model and analysis.

3.6 Data analysis and simulation

The input for the data analysis was collected through the previous steps and historic information. Data collected include, but not limited to, the following:

- forecasts received from the customer
- forecasts sent to the suppliers
- material receipt to the VMI hub and plant (date and quantity)
- inventory levels in the VMI hub and plant
- shipment details to the customer and standard transportation lot sizes.

In cases where the effect of a parameter could not be directly computed using a spreadsheet, simulation models were utilised. The simulation models, developed in ARENA, helped in data analysis, and 'what-if' scenario generations.

The analysis is carried out using a simulation model built using the software package Arena 5.0 and its process analyser tool. The simulation model is used to evaluate the process metrics such as inventory carried in the supply chain, service level, and expediting requirements. As illustrated in Figure 1, the simulation consisted of both physical material flow and the flow of information. Additionally, the models also incorporated the forecast information, production scheduling parameters, shipment quantities, pull signals, shipment decisions, expediting requirements, and lost sales.

The model input data included rolling forecast information, form order placements, cost of inventory, inventory holding costs, and expediting costs. Outputs measured included inventory at all points in the supply chain, service level provided, expediting and cost of missed shipments. Total supply chain cost was then calculated.

The simulation was run for a period of 2000 days or 400 weeks with the first 100 days as the initialisation period, the statistics from which were not used in the results (Law and Kelton, 1991). Fifty replications were employed and a paired *t* test was performed to ascertain the statistical validity of the results. The validation techniques prescribed by Kleijnen (1995) were employed. In particular, the simulated results were compared to historical data. For example, simulated inventory levels at various positions in the chain and service levels were compared to historical values – the validation procedures appeared to indicate that the simulation indeed accurately represented the real system (Kleijnen, 1995).

4 Results: VMI expectations versus actual

Upon completion of the operations audit process on each of the cases, we compared our expectations relative to a VMI initiative to the actual characteristics and performance of the situation with the intent of finding gaps. It should be noted that we derived our expectations from the supply chain literature (*e.g.*, Simchi-Levi *et al.*, 2003; Chopra and Meindl, 2004; Wisner *et al.*, 2005) and VMI research (*e.g.*, Stratman, 1997; Daugherty *et al.*, 1999; Angulo *et al.*, 2004; Yang *et al.*, 2003). We then categorised the gaps into three general areas:

1 performance

2 planning and processes

3 enablers of collaboration.

Table 1 gives an overview of these areas and examples of the gaps discovered. Each of the areas is discussed in the sections that follow.

Table 1 Overview of gaps

	Expected characteristics of collaboration	*Example of actual characteristics of collaboration*	*Comments*
Performance	Low levels of material shortages	A significant amount of material shortages was present.	This was a function of the planned levels and the ability to meet the levels.
	Infrequent expediting	A significant amount of expediting was present.	Expediting was a primary driver for increases in total costs.
	Low levels of inventory	Levels were lower at the upstream locations, yet higher at the downstream locations.	Levels of inventory were not low; they were simply shifted backwards in the chain.
Collaborative planning and processes	Appropriate inventory levels	VMI levels were often not high enough to meet demand.	This resulted in shortages even if the agreed upon levels were maintained.
	Accurate forecasts	Percent variation between forecasts and actual orders were high.	Forecast inaccuracies hindered the effectiveness and efficiency of the VMI system.
	VMI levels of inventory would be well maintained and accurate	VMI levels were often not maintained.	This led to a significant amount of shortages.
	Appropriate and accurate inventory levels and triggers for movement/ replenishment	The material movement triggers was based on the inaccurate forecasts.	This led to parts shortages and production delays.
Enablers of collaboration	Accurate information sharing	Downstream partner was sharing forecasts. However, the forecasts were inaccurate, and critical information was given too late to act upon.	This resulted in a lack of demand visibility for the upstream suppliers.
	Sharing risk	Inventory is pushed upstream to minimise the risk of stock-outs at downstream points.	The excessive inventory hindered the suppliers from meeting the actual needs of the VMI system.
	Trust between partners	Upstream suppliers were not allowed to deviate from the forecasted amounts.	The upstream partners were not allowed to use their own judgement.

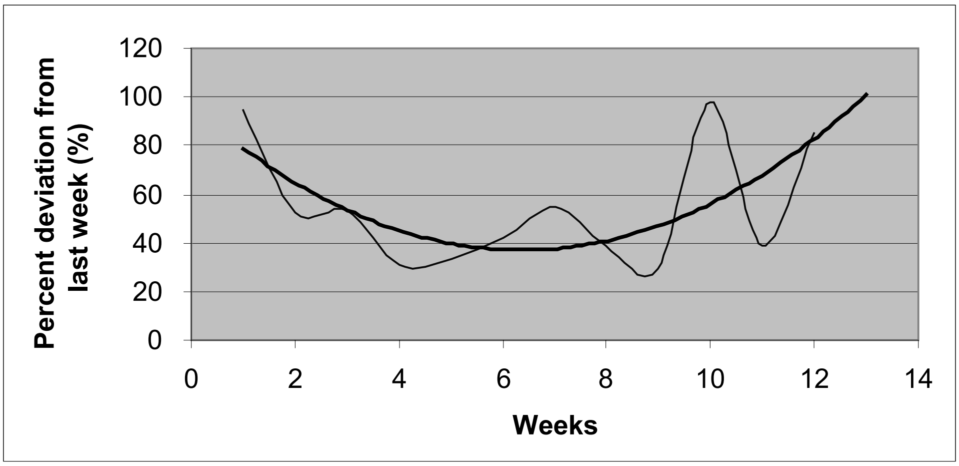
4.1 VMI performance

The expected performance of the VMI system includes characteristics such as infrequent material shortages, low levels of expediting activities, and low levels of inventory (*e.g.*, Wisner *et al.*, 2005). Indeed, the results of the two case studies were surprising in that they both showed similar results, and both were in conflict with the expected benefits of a VMI system. With regards to material shortages, significant levels of material shortages were present. In following a representative part through one supply chain, it was found that up to 35% of the time there was a potential for a material shortage based on levels of inventory below the agreed upon level. In both cases, VMI warehouse inventory did not match the VMI mandated inventory. For Company A, this was the case 18% of the time and for Company B, this was the case 43% of the time. These inventory discrepancies, in turn, lead to frequent expediting. For Company A, material was expedited 33% of the time. Similarly, for Company B, expediting occurred 44% of the time.

4.2 VMI planning and processes

Ideally, a VMI system is built upon collaborative processes and planning. Collaboration and communication allow for appropriate inventory levels based on the supply chain system requirements. A key requirement regarding inventory is to maintain strict and precise levels of inventory. Accurate and timely forecasts are essential in this environment due to their relationship to inventory maintenance and production support. Inventory, for both companies, was a problem. In investigating industry standards, average inventory turns in 2002 was ten, Company A was struggling at five turns per year, even after implementing the VMI process. Inaccurate forecasts, in both cases, drive poor VMI performance. For Company A, the reliability of the forecast 12 weeks out was the same as one week out. Figure 3 illustrates the percent deviation between the forecast quantity and the release order quantity. Note that the actual deviations are overlaid with a trend line.

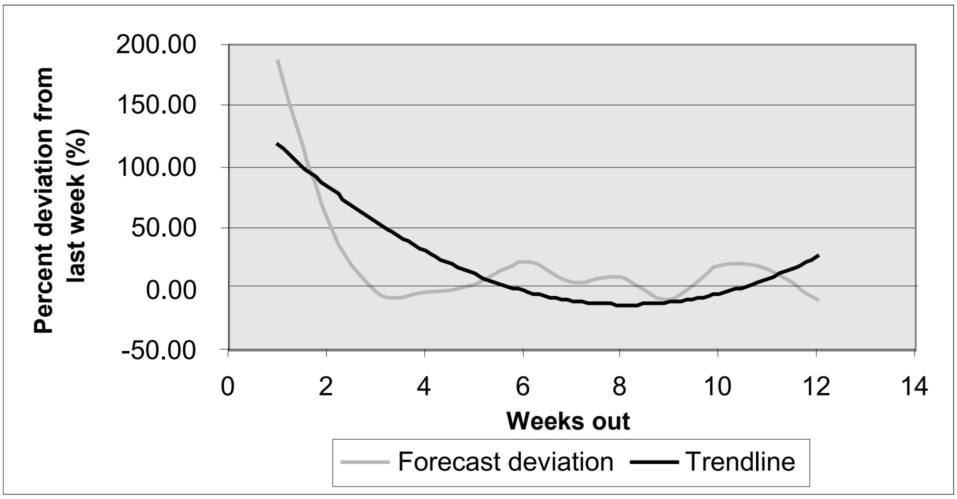
Figure 3 Company A percent deviation between forecast and release quantities



Note: Actual deviations are overlaid with a trend line.

As can be seen from the trend line in Figure 3, while forecast variance decreases as we move nearer to the production period, it starts deteriorating again in the shorter forecasting window of less than six weeks. Between week 0 and week 1 the forecast variation is as high as 80%. This is only as good as the forecast obtained ten weeks out. For company B, similar findings were noted: the week of production and two weeks out, there was a 185% in the forecast. Figure 4 illustrates the observed deviation. Indeed, the closer to production, the higher the level of forecast variation. Again, note that the actual deviations are overlaid with a trend line.

Figure 4 Company B percent deviation between forecast and release quantities



Note: Actual deviations are overlaid with a trend line.

Management of the inventory in the system was poorly managed. In both cases, material receipt was not accurately controlled. In Company A, it was found that the VMI inventory was not tracked accurately. In the case of Company B, material was often ‘lost’ in the supply chain. This led to planners calling location after location asking physical counts to be done in the hope that the material was there but not visible. Additionally, there was a mismatch of receipt to issue with an average of ten days between receipt and issue. Another note of interest is the use of pull signals in the VMI system. It was observed in Company B that the pull signals were based on the inaccurate forecasts rather than on actual demand. Company A suffered from lack of a standardised process in advance planning and scheduling. It was noted that two planners might sit next to each other but perform their job and create processes and techniques differently based on personal biases and experiences. In Company B, it was noted that the MRP-generated forecast is virtually ignored, and the production schedule is based on an entirely different set of individual and undocumented requirements. These requirements stemmed from the company’s struggles to meet customer expectations. These issues created an environment that did not foster collaborative processes and planning.

4.3 Enablers of collaboration

The enablers of collaboration in a VMI environment are critical to its success. They may be thought of as the foundation upon which the collaborative system is built. These enablers include accurate and timely information sharing, willingness to share risk, and trust between supply chain partners (*e.g.*, Simchi-Levi *et al.*, 2003). We see in our case examples the lack of these enablers, and consequently, a poorly performing system. Accurate and timely information or information visibility was lacking. We have already discussed the forecast inaccuracy. Receiving information in a timely manner was also an issue. An excellent example was a manager from Company B recalling a recent spike in demand which he learned about not from a forecast but from reading a sale ad in a paper! Trust and risk sharing are also key issues. In the case of Company B, the customer dictated that they must manage to the forecast even when evidence was available that this served to decrease the performance of the system due to inaccuracies in the forecast. Use of simulation illustrated that if the customer would agree to smooth their forecast, it would reduce the expediting percentage to 7% and the total cost incurred in the supply chain by 23%. In the case of Company B, the customer was so powerful that it could demand that the risk be assumed by the suppliers.

5 Discussion

The operations audit of the two VMI initiatives sought and discovered several gaps between expected and actual performance of the systems. The gaps were categorised and discussed in three general areas: performance; planning and processes; and enablers of collaboration. Obviously these three areas are not independent and if system improvement is sought should not be treated as such.

In essence, the Enablers may be thought of as evidence of the strength of the collaborative relationship. While the companies have sought a collaborative relationship in the form of a VMI initiative, there appears to be some evidence of lack of trust, sharing of risks, and accurate information sharing. This, of course, has hindered the VMI initiative from realising its potential as these are critical to success of supply chain partnerships (*e.g.*, Handfield and Nichols, Jr., 1999; Simchi-Levi *et al.*, 2003). Although both parties are perhaps guilty of not fully committing to the relationship, the downstream partner's actions/inactions appear to indicate a greater lack of commitment.

The downstream partner is indeed sharing information with the VMI suppliers. However, the information timeliness is often lacking, which has been found to be a critical aspect of the shared information from the supplier perspective (Whipple *et al.*, 2002). Further, the downstream partner is not allowing the partners to manipulate the information or use their own judgment relative to this information. For example, upstream partners are required to plan production based on the shared forecast without the slightest deviation from the forecasted value. Yet, it was discovered during the analysis stage of the audit that if the upstream partner could employ a simple smoothing process to the forecasted values and plan production based on the smoothed values, that expediting could be drastically reduced (from approximately 44% to 7%) and total costs could be reduced for both supply chain partners by as much as 23%.

The negative impacts of the gaps discovered in the Enabler level of the VMI initiatives are exacerbated as the planning and processes are built upon this weak foundation. The processes are often off target and inefficient as much of the efforts are channeled towards unneeded inventory (due to inflated orders) while needed inventory is not maintained at the VMI site. The major stumbling block at this point is lack of visibility of demand which in turn results in sub-optimal levels of planned inventory at the VMI site. This is consistent with the evidence that information distortion (Lee *et al.*, 1997a–b) is perhaps one of the biggest challenges facing supply chains (Smaros *et al.*, 2003).

The gaps and interactions among the Enabler and Planning and Process levels are culminating in fairly significant gaps in performance. The total costs, level of material shortages, overall levels of inventory, and the degree of expediting are not what would be expected from a collaborative inventory replenishment system such as VMI (Stratman, 1997; Daugherty *et al.*, 1999; Simchi-Levi *et al.*, 2003; Chopra and Meindl, 2004; Angulo *et al.*, 2004; Yang *et al.*, 2003; Wisner *et al.*, 2005). While these results are disappointing, when viewed in light of the 'bigger picture' of alliance development and performance improvement (*e.g.*, Krause *et al.*, 1998; Krause, 1999; Prahinski and Benton, 2004) perhaps these are part of the natural evolution of an alliance initiative.

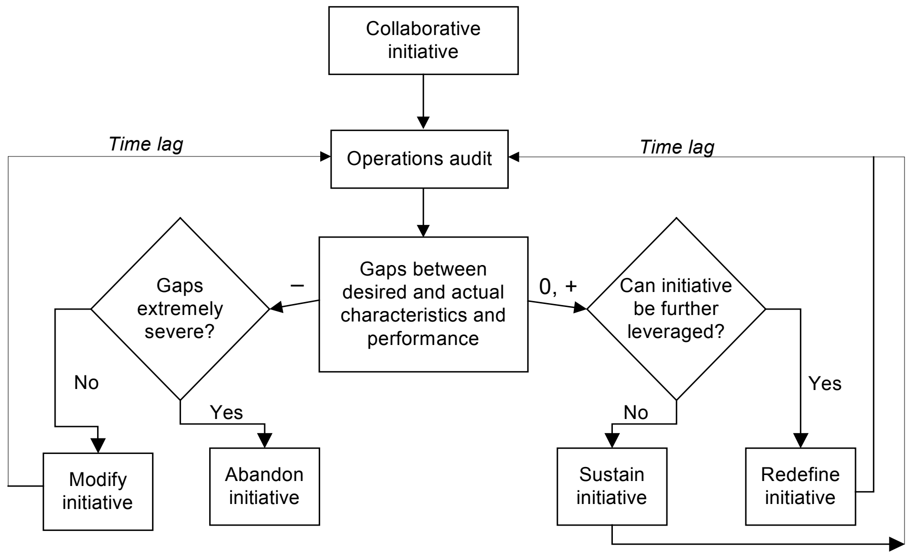
Handfield and Nichols, Jr. (1999) describe four incremental levels of alliance development. While the companies in this study have reached the final level of alliance development, alliance implementation/continuity, they are perhaps at a turning point in these endeavours. The companies in the VMI initiatives are experiencing a negative evaluation of strategic and operational dimensions (*i.e.*, performance is less than desirable) and therefore will need to modify the collaborative efforts (Handfield and Nichols, Jr., 1999). As a result of this operations audit, the companies were indeed in the initial stages of this collaboration modification.

As discussed earlier, collaboration success stories may be thought of as the desired outcome of supply chain initiatives – this paper focuses on the process of reaching that outcome. The potential success of these (and all other) collaboration initiatives will be ultimately decided by the participating companies' ability to discover gaps in desired and actual performance and modify the systems to minimise these gaps. The paper presents what should be *one iteration* of an ongoing process (see Figure 5).

As shown in Figure 5, the intent of operations audit process was to discover gaps between desired and actual performance. In both cases, the gaps were negative (*i.e.*, the collaborative efforts were not realising the desired performance. Although negative, gaps were not severe enough for the companies to abandon the collaborative initiative. Again, as a result of this audit the companies were in the initial stages of initiative modification. If the negative gaps would have been more severe, perhaps the initiative would have been abandoned.

The gaps in the two cases were negative and required modification of the initiative efforts. On the other hand, if an initiative is delivering the desired performance (indicated with a 0 in Figure 5, *i.e.*, no gap) or is exceeding the desired performance (indicated with a + sign in Figure 5), this may result in either sustaining the initiative (as is) or redefining the scope and goals of the initiative to further leverage benefits.

Figure 5 Collaboration initiative gaps model



Source: Adopted from Schmitz *et al.* (1995) and Handfield and Nichols, Jr. (1999)

6 Conclusion and future work

In this paper, we have reported two VMI initiatives that have not yet produced the level of performance desired by the supply chain partners involved. In each case, an operations audit was performed to determine where characteristic and performance gaps existed. The output of this research effort is inherent in the operations audit process employed, the VMI initiative gaps discovered during the process as well as steps that could be undertaken to minimise or eliminate these gaps. The paper culminated in a framework that describes the operations audit in terms of an iterative, collaboration evaluation process. The framework and process are intended to serve as a valuable mechanism for understanding the evolution towards collaborative supply chain relationships, yet will require additional research efforts to refine the operations audit process and framework. Furthermore, studies that analysed collaborative initiatives such as VMI via longitudinal studies would be particularly useful as successful collaborations such as Proctor and Gamble and Wal-Mart have evolved over time.

This research has reported on gaps between the expected and the actual results and characteristics of the VMI initiatives. This finding, too, would benefit from future research efforts. Perhaps future studies could build on the research efforts that have focused on gaps between expectations/perceptions (Parasuraman *et al.*, 1985) with a focus on analysing the gaps over time. Therefore, by building on this research as well as on other efforts, perhaps future research could shed some much needed light on the *process* of realising a successful collaborative effort.

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