A Case Study of Using Inventory Turnover as a Key Measure for Restructuring Supply Chain and Logistics Management

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ABSTRACT

This study aims to examine how a sample company uses inventory turnover as a measure for restructuring its supply chain and logistics management. The company is an OEM within an automotive supply chain in which a large number of parts to be coordinated and delivered at the right place and at the right time. The company implements Just-in-Time manufacturing processes and uses inventory turnover as a key measure to evaluate an efficiency of its supply chain management. Results demonstrate the causes of deficiency of the company and provide an exemplary case of how inventory turnover can be used to restructure supply chain and logistics management. This study also provides a guideline for management to identify certain areas for operation improvement.

Keywords: JIT Manufacturing, Inventory Turnover, Supply Chain Management, Logistics Management

บทความวิจัย

กรณีศึกษาการใช้อัตราหมุนเวียนสินค้าคงคลังเป็นเครื่องมือในการปรับเปลี่ยนการจัดการโซ่อุปทานและโลจิสติกส์

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บทคัดย่อ

งานวิจัยมีวัตถุประสงค์เพื่อศึกษาว่า บริษัทตัวอย่างใช้อัตราการหมุนเวียนของสินค้าคงคลังเป็นเครื่องมือในการปรับเปลี่ยนการจัดการโซ่อุปทานและโลจิสติกส์อย่างไร บริษัทที่ศึกษาเป็นผู้ผลิตชิ้นส่วนยานยนต์ในโซ่อุปทานของอุตสาหกรรมยานยนต์ ซึ่งมีชิ้นส่วนจำนวนมากที่ต้องอาศัยการประสานงานและให้มีการจัดส่งในสถานที่และเวลาที่เหมาะสม บริษัทตัวอย่างได้นำกระบวนการผลิตแบบทันเวลามาใช้ และใช้อัตราการหมุนเวียนของสินค้าคงคลังเป็นเครื่องมือหลักในการประเมินประสิทธิภาพของการจัดการโซ่อุปทาน ผลการศึกษาได้นำเสนอถึงสาเหตุของการขาดประสิทธิภาพของบริษัทและแสดงถึงกรณีศึกษาในนำอัตราการหมุนเวียนสินค้าคงคลังสามารถนำมาใช้ในการปรับเปลี่ยนการจัดการโซ่อุปทานและโลจิสติกส์ นอกจากนี้การศึกษายังเสนอแนวทางให้กับผู้บริหารในการระบุจุดต่าง ๆ ในการดำเนินงานที่ควรปรับปรุง

คำสำคัญ: ระบบการผลิตแบบทันเวลา อัตราการหมุนเวียนของสินค้าคงคลัง การจัดการโซ่อุปทาน การจัดการโลจิสติกส์

1. Introduction

Globalization and technology advancement have intensified global competition. Customer taste can be rapidly transferred from one place to another. As such, customer needs can change swiftly and vary greatly. To operate profitably with sustainable competitive advantage, companies need to be able to satisfy myriads of customer needs in a timely manner at a lower cost. Companies have to search for ways to improve the efficiency of how they do business. This has seen logistics and supply chain management attracts wider attention as ways to identify a better possible way of doing business at a lower cost.

In many businesses, customers now can customize the products they purchase. This requires flexible manufacturing processes. In addition, when there are a large number of parts required for producing a product, some companies may choose to concentrate on their core competencies and outsourced manufacturing of the remainders. Some companies have relocated their manufacturing facilities closer to the markets or where they can access to lower labour costs. All these trends are especially prominent in the automotive industry (see, Perez & Sanchez, 2001, Takeno (2001, cited in Kaneko & Nojiri, 2008), which is one of the main industries of Thailand that generates significant contribution to the economy and also its upstream industries (TAIMI, 2012). According to Perez and Sanchez (2001), there are over 15,000 parts needed to produce an "average" automobile. Therefore, the automotive supply chain is quite complex. Just-In-Time (JIT), which was first introduced as Toyota Production System, has been widely adopted and become a major driver for Japanese productivity improvements, particularly in automotive industry (Rao & Scheraga, 1988; Schonberger, 1982). Although JIT focuses on manufacturing processes, it requires suppliers to be capable of responding quickly to changes in production requirements (Boyd, et al., 2002). Hence, to produce one car, there are a large number of parts to be coordinated and delivered at the right place and at the right time. As such, without efficient supply chain and logistics management within the supply chain, inventory and other wastes can be large.

In the past three decades, most of JIT research has been focused mainly on JIT implementation in companies in developed countries such as the U.S. (Biggart & Gargeya, 2002; Cook & Rogowski, 1996; Hobbs, 1994; Inman & Mehra, 1990; Inman & Mehra, 1993; Im & Lee, 1989; Kootanaee, et al., 2013; Payne, 1993; Temponi & Pandya, 1995; Sriparavastu & Gupta, 1997; White 1993), Canada (Brox & Fader, 2002; Callen, et al., 2000; Deshpande & Golhar, 1995), and Australia (Buxey & Petzall, 1991; Clarke & Mia, 1993; McMichael, et al., 2000; Sohal, et al., 1993). However, this study focuses on improvements after the implementation.

Rather than focusing on Just-In-Time manufacturing processes of a single company, this study aims to provide an overview of three main logistics operations for delivering parts just when they are needed at an automobile original equipment manufacturer (OEM) in Thailand: inbound operations between the parent company

and the assembly plant, manufacturing processes, and outbound operations between the assembly plant and customer companies. This is to allow identification of the operation processes that causes the inventory turnover fluctuation over time and being lower than target set by the parent company.

The sample company has changed its manufacturing processes from "push" to "pull" system for 5 years, put technology in place, and been trying to get most, if not all, of its activities to be in a JIT fashion to reduce inventory. However, the company has not been able to meet inventory turnover targets for some production lines (i.e., products), which cause the company to have high inventory carrying costs, warehouse rental costs, and warehouse management costs. This study, therefore, aims to identify the causes of inventory turnover being lower than the target. This will help identify the operation processes within the supply chain that needs to be improved in order to improve its inventory turnover.

The results of this study will provide several contributions as follows. Firstly, it provides an exemplary case of how inventory turnover can be used to restructure supply chain and logistics management. In the accounting literature, inventory turnover measures how many times a company can sell its average inventory amount during the year. To improve inventory turnover, the company itself has to either sell larger amount of its inventory for each baht of inventory it held or control its inventory by not buying or manufacturing too much. There is little discussion on how to improve inventory turnover by restructuring its supply chain and logistics management. Secondly, the results of this study also inform logistics and supply chain management literature as to how to use accounting measures as a tool to spot certain areas for operation improvement. Lastly, it will provide some suggestions on what can be done to improve supply chain and logistics management for the supply chain of an OEM in the automobile industry.

The remainder of this study will briefly review Just-In-Time philosophy and discuss its implications on three main logistics operations for delivering parts. Next, research methodology will be provided. This is followed by the results of the study. Discussions and future research opportunities are finally presented.

2. JIT Philosophy and Its Implications on Three Main Logistics Operations for Delivering Parts

This section briefly reviews JIT philosophy and discusses its implications on three main logistics operations for delivering parts.

JIT Philosophy

Just-In-Time (JIT) is a Japanese management philosophy that was first introduced by Shigeo Shingo and Taichi Ohno in the mid–1970s (Biggart & Gargeya, 2002). Since the early 1980s, JIT has been widely adopted with an aim to reshape their manufacturing in response to ever greater competitive environment (Bragg, et al., 2005; Dugdale, 1990; Kros, et al., 2006). However, its definitions are vague and confused (Demeter &

Natsusz, 2011). This can be attributed to a variety of reasons (Demeter & Natsusz, 2011). For instance, TPS itself has progressed through its tremendous development over the last 40 years (Spear, 2004; Voss, 2007; Womack, et al., 1990). Prior research has reported evidence on various "lean" companies, which variedly employ lean philosophy (Demeter & Natsusz, 2011). This has seen some prior research attempt to clarify it by establish elements and sub-elements of JIT philosophy. However, most papers and text books generally describes JIT as the manufacturing philosophy that demands goods to be produced when needed (Mehra & Inman, 1992; Matson & Matson, 2007; Procter, 1995; Wang, et al., 2004).

The major goal of JIT is to reduce waste. In the rise of technology advancement and manufacturing automation, the JIT philosophy allows companies to enhance flexibility and responsiveness of their manufacturing processes to simultaneously meet customer demand in a timely manner with high quality products at the lowest possible total costs (Dugdale, 1990; Horngren, et al., 2009). Some of the benefits obtained in success cases are lower inventory-carrying costs, increased space and cost savings, and lower risk of obsolescence, higher quality, and shortened lead time (Boyd, et al., 2002; see also, Crawford & Cox, 1991; Cook & Rogowski, 1996; Hobbs, 1997; White & Ruch, 1990).

Companies implementing JIT seek to minimize inventory by reducing set up times, coordinating JIT deliveries from suppliers, balancing productive capacities, and maintaining a continuing commitment to achieving the highest level of quality (Biggart & Gargeya, 2002). As such, implementing JIT production system has implications on related operation processes either inside or outside the company. These implications are discussed below.

JIT Purchasing

JIT production system requires raw materials to be delivered to production site when needed to minimize inventory to the lowest possible level (Bandyopadhyay, 2016). This reduces capital tie up costs, storage facilities and handling activities, but it increases transportation costs and requires effective supply chain management and reliable suppliers (Haan & Yamamoto, 1999). Suppliers are selected based primarily on such criteria as high quality, low costs and on item delivery (Kaneko & Nojiri, 2008). Suppliers have to work closely with buyer on purchase planning and in some instance involve in technical cooperation in product design stage to ensure material availability and improved forecast (Frankel, 2006; Haan & Yamamoto, 1999; Linge, 1991; Williams et al., 1992, cited in Keneko & Nojiri, 2008). They are, more or less, treated as internal work centers in a JIT production system (Kaneko & Nojiri, 2008) to meet production plans and delivery schedules which are broken down to a shorter period of time basis (e.g., weekly or daily basis) (Schroeder, 1993). Keneko & Nojiri (2008) indicated that these factors encourage the build-up of suppliers in the area around the manufacturer. Suppliers in the same geographical area as the manufacturer may be preferred to increase reliability of supply

(Frankel, 2006; Mould & King, 1995; Svensson, 2001).

However, with the advancement in technology and globalization, this has seen automotive manufacturers relocate overseas and the cross-border procurement and distribution of parts. Where financial resources allow, buyers and suppliers are connected within an electronic information network (Kaneko & Nojiri, 2008). Takeno (2001, cited in Kaneko & Nojiri, 2008) has suggested that the future locations of automotive part suppliers can be at different parts of the world to take advantage of lower production and transportation costs and advanced technology.

The implications of such a close communication and supplier reliability on supply chain efficiency determine levels of relationships of trust. In addition, long-term relationship between customers and suppliers are generally preferred. Companies have employed different approaches in managing relationship with their suppliers. Rudzki (2004) indicated that Bayer Corp. classified supplier relationship into four categories ranging from: (1) transactional relationship with suppliers for non-critical and low value items; (2) basic partnership with suppliers for non-critical but high value; (3) strategic partnership with suppliers for important and high value items; and (4) acquisition/equity stake with suppliers for critical and very high value items. In other industries where customers demand higher order fill rates, suppliers are taking on responsibility for faster, more frequent and consistent delivery and inventory quality (Pfohl, et al. 1999; Aeppel, 2002; Frankel, 2006)

JIT Production

Inventories could be maintained as buffers in case there are some deviations from what is expected (e.g., greater or lower than expected customer demand, production plan changes, late delivery, unexpected reworks, and machine breakdowns) (Haan & Yamamoto, 1999). JIT aims to reduce inventories which are viewed as wastes that hide the underlying production problems by synchronizing manufacturing activities (Hilton, 2008). When these production problems are resolved, inventory can be kept to a minimum (Hilton, 2008; Horngren et al., 2009; Mowen & Hansen, 2007; Reeve & Warren, 2008).

In JIT production system, production line is organized as a sequence of manufacturing cells or workstations that group together all the different types of equipment used to make a given product. Manufacturing at any particular workstation is conducted as soon as the workstation's output is need by the next station. The flow of work in process between workstations in a production line is coordinated by the kanban system (Haan & Yamamoto, 1999). Defects or machine breakdowns at one workstation inevitably affect other workstations in the production processes. Workers in the JIT production system are trained to be multi-skilled and capable to perform any operation and solve problems within the workstation (Kaneko & Nojiri, 2008). This also allows the type and volume of manufactured products to be regulated to meet fluctuations in demand and re-allocation of workers required for a job (Kaneko & Nojiri, 2008). Setup time is reduced to enable manufacturing in

smaller batches, which reduces inventory level and enhances the company's responsiveness to uncertainty in demand.

JIT distribution

There are several demand-driven techniques that can be used to administer distribution of finished goods to customers (Bowersox & Closs, 2006). These techniques rest on real time transfer of information between parties in the supply chain in such way that finished goods are more or less continually replenished once they are sold (Lowson, 1995). Information technology enables sharing point of sales information among relevant parties within the supply chain to eliminate variability in demand and shorten lead time (Bowersox & Closs, 2006). Examples of these techniques are Efficient Consumer Response (ECR), Quick Response (QR), Vendor Managed Inventory (VMI) Co-Managed Inventory, Collaborative Planning, Forecasting and Replenishment (CPFR), which appear to be one form of another (Intentia International AB., 2001, Whiteoak, 2004, p. 142). One initiative seems to be a stepping stone towards a newer collaboration initiative (Intentia International AB., 2001, Whiteoak, 2004, p. 142).

3. Research Methodology

Research Site

Since this study aims to provide evidence on how inventory turnover can be used to improve logistics and supply chain management, this study collected data from an OEM company in Thailand that assembles automobiles for the top tier automotive manufacturers worldwide (e.g., BMW, Mercedes Benz). The sample company has sales revenue of approximately 2.4 billion Baht with 220 employees (including subcontractors). Raw materials required for the production are procured internationally from designated suppliers. The sample company has implemented JIT for 5 years and is required to meet the target inventory turnover set by its parent company in Germany. The sample company manufactures automobile parts for four brands. There are four production lines in this company. Each production line is to produce various models for one particular brand. The variety of the products produced, which require a large number of different raw materials and different production process and is to be distributed to customers worldwide, result in complications in supply chain and logistics management.

The company has implemented Just-in-Time production system for all production lines. The first production line is for parts of Sport Utility Vehicle (SUV) or Multi-Purpose Vehicle (MPV). Raw materials are procured from local suppliers. Suppliers and customers are connected with the company through electronic data interchange (EDI), which allows the company to manage its inventories effectively and be able to meet the target inventory turnover of inventories for this production line. The second production line is for assembling parts of small vehicles.The customer that this production line serves is responsible for managing all inventories for this production line. There is no inventory that is managed by the

company. Therefore, there is no target inventory turnover for this production line. The last two production lines are for manufacturing parts of high performance vehicle (i.e., BMW and Mercedes Benz). The company has not been able to meet the target inventory turnover measures for these two production lines. This study, therefore, focuses on examining the inbound logistics, manufacturing, and outbound logistics operations relating to these two production lines that account for the majority of its revenues.

Data Collection

The data were collected via semi-structured interviews with people who are responsible for inbound logistics, production, outbound logistics, and accountants in the company. Direct observations were made in those processes. Relevant documents were also examined. The questions covered in the interviews included those that are necessary to gain an understanding of activities and procedures within the three operation processes. Supporting detailed data for the inventory turnover calculations were also collected. The interviews were tape-recorded and transcribed.

4. Results of the Study

This section gives a brief description of how each of the three processes is operated. Then, inventory turnover of the two products studied will be presented. Supporting detailed data will also be analyzed to identify the cause of inventory turnover being lower than the target.

Inbound Logistics

Procurement

In consistent with the ABC analysis, its inventories are classified into three groups: 'A' items which include 10% of the total quantity that accounts for 80% of the total value of all inventories; 'B' items which include 20% of the total quantity that accounts for 15% of the total value of all inventories; and 'C' items which include 70% of total quantity that accounts for 5% of the total value of all inventories. All the items in the three categories are classified further into 4 sub-categories: 'x' – very fast moving items; 'y' – fast moving items; 'z1' – slow moving items; and 'z2' – very slow moving items. X and y sub-categories of 'A' items and 'B' items are monitored continuously and actively optimized by material planners, while z1 and z2 sub-categories of 'A' items are monitored less continuously and less actively. The remainders (i.e., z1 and z2 of 'B' items and all 'C' items) are managed by automatic scheduling with higher safety stocks. Figure 1 showed different inventory management for each sub-categories of the three items.

The majority of high value raw materials required for production are imported from its parent company in Germany, which consolidates and buys all the raw materials requirement of all customers around the world. These raw materials are supplied to all manufacturing plants around the world in accordance with their production and purchase orders, but minimum order size also applies. All other high value raw materials are bought from related companies in the U.S.

<table>
<tr><th>Movement / Value</th><th>X</th><th>Y</th><th>Z1</th><th>Z2</th></tr>
<tr><td>A (80%)</td><td colspan="2" rowspan="2">High potential for inventory optimization: Continuous and active optimization by planner.</td><td colspan="2">Medium potential for inventory optimization.</td></tr>
<tr><td>B (15%)</td><td colspan="2" rowspan="2">Low potential for inventory optimization. Automated scheduling with higher safety stocks, where possible</td></tr>
<tr><td>C (5%)</td><td colspan="2"></td></tr>
</table>

Figure 1 Inventory management for each sub-categories of the three items

These high value raw materials for brand "A" are bought from company "SA", while those for brand "B" are bought from company "SB". All the raw materials from company "SB" are assembled and supplied as each completed set of front and back absorber for each car. Before production of any new model begins, demand forecasts for that particular model for the whole expected product life from both brand A and brand B customers will email in Excel files to sales department. The customers will have at least one meeting around at the middle of the year to review and revise the demand forecasts for the remaining periods of the product life. The customers will confirm these demand forecasts and issued production orders 4 months prior to production date. Then, demand forecasts of the raw materials required are transmitted to the parent company and suppliers through EDI. Purchase orders of raw materials are confirmed 2 months later. If production of the production orders that have been confirmed does not commence at least 45 days after original production plan, all raw materials either in transit or in stock shall be counted as "pushed out raw material inventory". The transportation of raw materials imported from Germany and the U.S. is managed by a freight forwarder hired under global contracts with the parent in Germany.

The remaining raw materials, which are small slow moving parts with low value, is bought from local suppliers located 15 kilometers away from the company. Demand forecasts are transmitted to the suppliers through EDI 2 months prior to the actual production. Purchase orders are confirmed 1 month later. The company hired a logistics service provider on a yearly contract to pick up the raw materials from the suppliers once a week.

Raw Material Receiving and storing

Once raw materials arrive at receiving dock, they will be sampled and inspected by the quality control department. Then, the raw materials that meet the quality standard will be classified into two groups: larger raw materials and small raw materials, which are stored separately in two different zones. Those that do not meet the quality standard will be stored in a zone that

specifically assigned for defect raw materials, waiting for rework or claims to suppliers or the freight forwarder. The receiving department staff keys in delivery note number. The SAP system, then, retrieve the information relating to the types and quantity of raw materials delivered inputted by suppliers and automatically recorded into the company's system. A bar code, which indicates description of the raw material, quantity, and storing zone, will be printed out and stuck to each box of the raw materials received. Once they are moved to the storing zone, the person who moves the raw materials will scan the bar code and record the exact location within the storing zone.

Raw Material Requisitions

Raw material requisition staffs prepare raw material requisition orders and pick raw materials for production 3 days before the actual production. Some small raw materials are issued and assembled into a completed set of small parts for each car in the kitting process. The requisition processes for small raw materials involve picking the whole boxes of required raw materials from its shelf to the kitting area, without recording into the SAP system. The raw materials in each box are picked in the quantity required for the total number of products to be produced. After the picking of that particular raw material is done, the total number of raw materials picked is recorded into the SAP system to record material requisitions and change location in the SAP system to kitting area. A bar code will then be printed and stuck to the boxes to indicate that the raw materials are in the kitting area. Raw materials that remain in the boxes will be put back onto its shelf. This process results in the discrepancies between actual location and location shown in the SAP system. That is, raw materials that are moved from the shelf to the kitting process are still shown in the SAP system as on the shelf. Similarly, raw materials that have been assembled into a completed set of small parts waiting in the kitting area for production are still shown in the SAP system as in production line.

There is no kitting process for larger raw materials. A whole box of larger raw materials will be picked and put in the kitting area. But only the quantity that will be used in the actual production is recorded as issued quantity in the SAP system, not the quantity of raw materials in the whole boxes. Once the production is done, the remaining larger raw materials that are not used in the production will be put back to its storing location. There is no kitting process for some models of brand B as its raw materials assembled and supplied as a completed set of raw materials for front and back shock absorber for each unit of product produced.

Cycle Counting

Cycle counting is conducted every Friday for brand A. Discrepancies are found in every cycle counting. There is no cycle counting for brand B. However, there are stock takings for inventories of both brands. It is done at the end of the year for brand A and at the middle and end of the year for brand B. The weekly cycle counting does not

provide a higher accuracy of inventories recorded in the system, but it identifies shortage items early. This allows the company to order or claim the items without using a higher cost transportation mode and save some penalty fees relating to import and value added taxes. The discrepancies found in cycle counting and stock takings for both brands are similar. That is, most of the discrepancy items are small and low value items that are not imported as a completed set. They are usually in stock in the quantity that is less than the quantity shown in the system.

Manufacturing Processes

The company uses JIT production system in all production lines. Production line for brand "A" is more flexible than that for brand "B". That is, the production line for brand "A" can be modified by changing some tools and equipment to produce different models within 15 minutes. On the contrary, a different set of tools, equipment, and stations need to be set up before a different model can be produced. This could take 7–15 days, depending on the complexity involved in the set up.When there are defects or spoilage in the production processes, the person who found them will notify production engineer to rectify the problems. Spoilage will be removed and stored in different zone waiting for approval for destroying.

Work-in-process is recorded in the manufacturing control system, which currently is not integrated with the SAP system. The manufacturing control system prints two separate bar codes: (1) manufacturing bar code used for tracking manufacturing processes the work-in process goes through; and (2) traceability bar code for customers. As work-in-process goes through each manufacturing process, manufacturing staff in that particular process would scan the manufacturing bar code and also record the manufacturing in that process in the check sheet. Once the manufacturing reaches the last process, the check sheet will be sent to production supervisor of each production line to transfer work-in-process to finished goods. Therefore, before all the manufacturing processes finished, the costs of work-in-process are not shown in the SAP system.

Outbound Logistics

Supply chain department prepare delivery schedules in accordance with production plans. The company allows customers to make amendment to the delivery schedules providing that they notify the company 3 working days in advance. However, some customers often notify amendment to the delivery schedules less than 24 hours. Most of the amendments are to postpone some of the planned deliveries to later date. One day before the delivery date, delivery notes and tax invoices are issued by the distribution department and accounting department, respectively. If customers amend the delivery schedule, the company has to reissue the delivery notes and tax invoices. The distribution department has to prepare products for delivery according to the new delivery schedule and be ready by each picking up time of the day. The pickings up schedule

for each brand are organized as follows. Brand A customer organizes milk run transportation to pick up the product from the pick-up point which locates 15 kilometers away from the company twice a day – at 9 a.m. and 15.00 p.m. Brand B customer hired trucks on a yearly contract to pick up product once a day at 10 a.m. from the pick-up point which locates 100 kilometers away from the company.

Inventory Turnover Ratio

Accounting department calculates inventory turnover ratios at the end of each month for evaluating the efficiency of supply chain management by supply chain department. The formula used is slightly modified as per requirement of group policy and differs from what normally appears in accounting text book as follows:

$$\text{Inventory Turnover Ratio (ITR)} = \frac{\text{Average Monthly Sales} \times 12}{\text{Average Ending Inventory}} \text{ Times}$$

Where: sales are cost of goods sold plus a markup.

$$\text{Average Monthly sales} = \sum_{n=1}^{12} \frac{(\text{Sales}_n)}{n}$$

$$\text{Average Inventory} = \sum_{n=1}^{12} \frac{(\text{End of month inventory}_n)}{n}$$

Although it does not represent the actual inventory turnover, it does present the trend as good as that by the formula in accounting text book. This study analyses the inventory turnover ratios in the year 2014, 2015, and 2016.

From Table 1, raw materials account for the majority of total inventories at the average of 94.79% of the total inventory, which comprise 70.77% for on schedule production and the remaining 24.02% for postponed productions. Finished goods and obsolete inventory account for only 2.89% and 3.32% of the total inventory, respectively. The inventory turnover ratios in 2014 of production line for brand A increase steadily throughout the year 2014, although they are still below than the target of 4.5 times.

From Table 2, raw materials also account for the majority of total inventories at the average of 94.87% of the total inventory, which comprises 51.26% for on schedule production and the remaining 43.61% for postponed production. Finished goods account for at the average of 5.13% of the total inventory. There is no obsolete inventory. The inventory turnover ratios in 2014 of production line for brand B start off closer to the target of 6.8 times in the first three months and decline when postponed production begun for most of the remaining months in the year.

Table 1 2014 Inventory Turnover of Production Line for Brand A

2014/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	303,254.26	–	6,303.35	3,776.03	313,333.64	96.78%	0.00%	2.01%	1.21%	74,750.85	2.90	2.90
February	147,074.38	90,526.60	11,454.19	3,776.03	252,831.19	58.17%	35.81%	4.53%	1.49%	86,595.57	3.47	4.14
March	147,197.09	64,161.80	8,278.77	4,586.20	224,223.86	65.65%	28.62%	3.69%	2.05%	81,687.80	3.75	4.68
April	135,680.54	70,056.60	5,362.62	4,586.20	215,685.96	62.91%	32.48%	2.49%	2.13%	65,067.12	3.74	4.84
May	141,251.20	64,067.74	3,773.01	4,586.20	213,678.15	66.10%	29.98%	1.77%	2.15%	39,321.91	3.48	4.58
June	102,512.43	62,242.71	6,240.03	4,586.20	175,581.37	58.38%	35.45%	3.55%	2.61%	54,116.84	3.52	4.73
July	119,395.99	50,021.48	2,884.03	4,586.20	176,887.70	67.50%	28.28%	1.63%	2.59%	66,721.19	3.64	4.93
August	106,679.73	32,227.49	3,527.58	4,586.20	147,021.00	72.56%	21.92%	2.40%	3.12%	59,930.63	3.76	5.07
September	111,793.02	22,205.16	6,483.55	3,493.99	143,975.73	77.65%	15.42%	4.50%	2.43%	72,439.97	3.95	5.26
October	123,018.74	32,340.93	2,824.95	3,493.99	161,678.62	76.09%	20.00%	1.75%	2.16%	48,303.77	3.93	5.21
November	122,918.64	30,955.64	6,342.20	3,493.99	163,710.47	75.08%	18.91%	3.87%	2.13%	92,731.25	4.15	5.48
December	152,608.15	44,975.02	5,360.69	7,977.36	210,921.22	72.35%	21.32%	2.54%	3.78%	68,453.05	4.14	5.45
Average	**142.782.01**	**46,981.76**	**5,736.25**	**4,460.72**	**199,960.74**	**70.77%**	**24.02%**	**2.89%**	**2.32%**	**67,510.00**	**3.70**	**4.77**

Table 2 2014 Inventory Turnover of Production Line for Brand B

2014/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	60,071.33	–	7,298.53	–	67,369.86	89.17%	0.00%	10.83%	0.00%	36,839.69	6.56	6.56
February	61,658.51	–	2,424.29	–	64,082.80	96.22%	0.00%	3.78%	0.00%	30,607.78	6.16	6.16
March	39,681.42	–	4,554.30	–	44,235.71	89.70%	0.00%	10.30%	0.00%	32,426.60	6.82	6.82
April	81,473.13	–	–	–	81,473.13	100.00%	0.00%	0.00%	0.00%	23,852.12	5.77	5.77
May	17,208.01	48,484.85	3,342.92	–	69,035.78	24.93%	70.23%	4.84%	0.00%	23,509.47	5.42	6.36
June	49,736.06	46,492.32	5,890.09	–	102,118.47	48.70%	45.53%	5.77%	0.00%	32,281.10	5.03	6.46
July	15,987.11	80,416.00	4,398.98	–	100,802.09	15.86%	79.78%	4.36%	0.00%	47,158.40	5.14	7.69
August	4,481.98	91,896.00	3,254.10	–	99,632.08	4.50%	92.24%	3.27%	0.00%	47,075.95	5.22	9.09
September	25,363.03	66,378.00	6,872.31	–	98,613.34	25.72%	67.31%	6.97%	0.00%	56,462.21	5.45	10.07
October	31,283.58	47,220.00	3,834.70	–	82,338.29	37.99%	57.35%	4.66%	0.00%	53,832.19	5.69	10.75
November	29,949.42	38,616.00	5,028.22	–	73,593.63	40.70%	52.47%	6.83%	0.00%	53,858.47	5.95	11.33
December	21,750.87	30,564.00	–	–	52,314.87	41.58%	58.42%	0.00%	0.00%	44,532.45	6.19	11.92
Average	**36,553.70**	**37,505.60**	**3,908.20**	**–**	**77,967.51**	**51.26%**	**43.61%**	**5.13%**	**0.00%**	**40,203.04**	**5.78**	**8.25**

From Table 3, raw materials account for the majority of total inventories at the average of 90.95% of the total inventory, which comprise 76.85% for on schedule production and the remaining 14.10% for postponed productions. Finished goods and obsolete inventory comprise 3.39% and 5.67% of the total inventory, respectively. The inventory turnover ratios in 2015 for production line of brand A continue to increase consistently throughout the year and sometimes are even better than the target of 4.5 times.

From Table 4, raw materials account for the majority of total inventories at the average of 95.85% of the total inventory, which comprise 35.23% for on schedule production and the remaining 60.62% for postponed productions. Finished goods account for at the average of 4.15% of the total inventory. There is no obsolete inventory. The inventory turnover ratios in 2015 for production line of brand B are much lower than those in the year 2014 and the target of 6.8 times, but gradually increase throughout the year.

From Table 5, raw materials account for the majority of total inventories at the average of 86.41% of the total inventory, which comprise 77.80% for on schedule production and the remaining 8.61% for postponed productions. Finished goods and obsolete inventory comprise 3.34% and 10.25% of the total inventory, respectively. The inventory turnover ratios in 2016 for production line of brand A are higher than the target of 5.2 times in every month except for April, of which inventory turnover ratio is slightly lower than the target.

Table 3 2015 Inventory Turnover of Production Line for Brand A

2015/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	151,203.69	38,615.72	6,821.84	7,977.36	204,618.60	73.90%	18.87%	3.33%	3.90%	68,934.30	4.21	5.23
February	132,448.95	42,923.99	4,395.24	7,977.36	187,745.54	70.55%	22.86%	2.34%	4.25%	70,104.78	4.43	5.66
March	148,309.92	44,701.33	8,291.10	7,977.36	209,279.70	70.87%	21.36%	3.96%	3.81%	85,111.84	4.66	5.96
April	142,051.64	50,334.58	2,672.73	7,977.36	203,036.31	69.96%	24.79%	1.32%	3.93%	66,182.13	4.51	5.84
May	119,111.08	49,271.03	6,206.26	7,977.36	182,565.73	65.24%	26.99%	3.40%	4.37%	83,995.40	4.74	6.23
June	153,226.66	22,084.14	4,460.75	13,150.59	192,922.15	79.42%	11.45%	2.31%	6.82%	99,529.68	5.04	6.47
July	170,565.30	19,014.49	4,940.89	13,150.59	207,671.28	82.13%	9.16%	2.38%	6.33%	87,072.58	5.09	6.38
August	175,024.52	12,048.32	5,451.75	12,870.77	205,395.37	85.21%	5.87%	2.65%	6.27%	91,317.53	5.17	6.34
September	172,744.06	17,356.13	5,219.11	8,773.09	204,092.39	84.64%	8.50%	2.56%	4.30%	97,804.22	5.27	6.37
October	164,864.39	5,327.69	4,871.51	8,809.83	183,873.42	89.66%	2.90%	2.65%	4.79%	94,314.46	5.38	6.40
November	127,745.56	2,880.00	15,051.67	13,978.38	159,655.61	80.01%	1.80%	9.43%	8.76%	90,776.52	5.53	6.50
December	97,153.32	20,094.70	6,004.20	14,452.41	137,704.64	70.55%	14.59%	4.36%	10.50%	88,867.03	5.71	6.72
Average	**146,204.09**	**27,054.34**	**6,198.92**	**10,422.70**	**189,880.06**	**76.85%**	**14.10%**	**3.39%**	**5.67%**	**85,334.21**	**4.98**	**6.17**

Table 4 2015 Inventory Turnover of Production Line for Brand B

2015/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	22,999.98	49,715.93	2,912.70	–	75,628.61	30.41%	65.74%	3.85%	0.00%	16,360.60	2.60	7.58
February	38,111.47	57,667.95	3,674.60	–	99,454.02	38.32%	57.98%	3.69%	0.00%	27,631.24	3.02	7.80
March	53,225.59	57,198.00	15,439.10	–	125,862.70	42.29%	45.44%	12.27%	0.00%	47,714.61	3.66	8.07
April	82,853.97	80,799.00	3,400.27	–	167,053.24	49.60%	48.37%	2.04%	0.00%	48,392.96	3.59	7.55
May	60,513.49	115,311.00	3,273.88	–	179,098.37	33.79%	64.38%	1.83%	0.00%	50,943.57	3.54	8.00
June	57,030.14	133,740.00	5,187.03	–	195,957.17	29.10%	68.25%	2.65%	0.00%	67,705.38	3.68	8.91
July	37,650.38	126,840.00	12,747.42	–	177,237.80	21.24%	71.56%	7.19%	0.00%	85,622.89	4.05	10.36
August	58,122.35	121,203.00	5,240.71	–	184,566.06	31.49%	65.67%	2.84%	0.00%	85,309.68	4.28	11.15
September	88,955.80	89,838.00	9,097.35	–	187,891.15	47.34%	47.81%	4.84%	0.00%	89,657.52	4.47	11.12
October	38,353.08	99,792.00	3,419.37	–	141,564.44	27.09%	70.49%	2.42%	0.00%	98,255.33	4.83	12.31
November	42,161.50	81,108.00	5,043.68	–	128,313.18	32.86%	63.21%	3.93%	0.00%	88,965.57	5.10	13.06
December	54,532.53	81,252.00	3,150.69	–	138,935.22	39.25%	58.48%	2.27%	0.00%	68,447.61	5.16	13.15
Average	**52,875.86**	**91,205.41**	**6,048.90**	**–**	**150,130.16**	**35.23%**	**60.62%**	**4.15%**	0.00%	**64,583.91**	**4.00**	**9.92**

Table 5 2016 Inventory Turnover of Production Line for Brand A

2016/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	76,313.02	11,163.72	4,324.40	14,452.41	106,253.56	71.82%	10.51%	4.07%	13.60%	65,186.60	8.52	9.70
February	69,660.71	17,944.97	5,748.51	14,452.41	107,806.60	64.62%	16.65%	5.33%	13.41%	22,650.08	5.69	6.75
March	82,017.32	11,848.26	2,424.16	14,452.41	110,742.16	74.06%	10.70%	2.19%	13.05%	50,729.43	5.91	6.91
April	90,915.04	17,837.12	5,186.07	14,452.41	128,390.64	70.81%	13.89%	4.04%	11.26%	29,965.62	5.11	6.01
May	105,311.18	16,181.44	4,243.69	14,452.41	140,188.72	75.12%	11.54%	3.03%	10.31%	68,747.95	5.46	6.38
June	126,258.49	9,896.34	3,680.97	14,452.41	154,288.21	81.83%	6.41%	2.39%	9.37%	84,707.09	5.85	6.71
July	121,898.91	8,640.00	751.91	11,186.56	142,477.38	85.56%	6.06%	0.53%	7.85%	90,150.74	6.24	7.08
August	116,108.33	6,240.00	4,995.20	11,118.17	138,461.71	83.86%	4.51%	3.61%	8.03%	82,758.55	6.46	7.24
September	98,182.83	4,906.27	2,304.55	11,132.56	116,526.21	84.26%	4.21%	1.98%	9.55%	91,710.64	6.87	7.65
October	105,648.81	9,137.12	9,135.26	8,906.69	132,827.87	79.54%	6.88%	6.88%	6.71%	37,550.31	6.52	7.24
November	80,915.10	7,561.13	4,625.51	8,934.99	102,036.73	79.30%	7.41%	4.53%	8.76%	70,481.07	6.71	7.44
December	73,871.51	4,080.00	1,295.90	9,899.12	89,146.54	82.87%	4.58%	1.45%	11.10%	42,442.03	6.69	7.40
Average	**95,591.77**	**10,453.03**	**4,059.68**	**12,324.38**	**122,428.86**	**77.80%**	**8.61%**	**3.34%**	**10.25%**	**61,423.34**	**6.34**	**7.21**

Table 6 2016 Inventory Turnover of Production Line for Brand B

2016/Month	Inventory-Material (THB)	Inventory Push Out-Material (THB)	Inventory-Finished Goods (THB)	Inventory-Provision/ Obsoleted/ Block Status (THB)	Total Inventory (THB)	Inventory-Material (%)	Inventory Push Out-Material (%)	Inventory-Finished Goods (%)	Inventory-Provision/ Obsoleted/ Block Status (%)	Sale	ITR	ITR (Without Inventory push out)
January	94,068.41	12,888.00	2,663.77	1,953.36	111,573.54	84.31%	11.55%	2.39%	1.75%	53,559.22	5.86	6.64
February	86,226.90	21,024.00	5,956.16	1,953.36	115,160.41	74.88%	18.26%	5.17%	1.70%	81,450.55	7.27	8.58
March	71,146.05	44,568.00	10,063.62	1,953.36	127,731.03	55.70%	34.89%	7.88%	1.53%	62,627.89	6.80	8.78
April	93,637.39	23,346.00	7,234.35	1,953.36	126,171.10	74.21%	18.50%	5.73%	1.55%	45,620.94	6.17	7.87
May	127,348.42	21,024.00	5,534.92	1,953.36	155,860.70	81.71%	13.49%	3.55%	1.25%	86,623.28	6.32	7.86
June	111,718.39	10,638.00	6,312.34	1,953.36	130,622.09	85.53%	8.14%	4.83%	1.50%	99,704.62	6.82	8.29
July	125,802.61	4,608.00	8,921.69	2,340.08	141,672.39	88.80%	3.25%	6.30%	1.65%	78,196.31	6.81	8.05
August	124,992.27	46,008.00	9,214.18	3,421.02	183,635.47	68.07%	25.05%	5.02%	1.86%	95,563.00	6.74	8.13
September	150,378.45	58,860.00	9,282.65	2,704.12	221,225.21	67.98%	26.61%	4.20%	1.22%	71,081.38	6.26	7.70
October	170,379.01	86,940.00	9,991.03	2,668.77	269,978.82	63.11%	32.20%	3.70%	0.99%	85,208.79	5.84	7.41
November	143,279.68	98,064.00	8,601.16	2,616.96	252,561.80	56.73%	38.83%	3.41%	1.04%	97,079.81	5.68	7.43
December	117,464.75	94,446.00	8,235.08	2,136.92	222,282.76	52.84%	42.49%	3.70%	0.96%	73,816.07	5.50	7.40
Average	**118,036.86**	**43,534.50**	**7,667.58**	**2,300.67**	**171,539.61**	**71.15%**	**22.77%**	**4.66%**	**1.42%**	**77,544.32**	**6.34**	**7.85**

From Table 6, raw materials account for the majority of total inventories at the average of 93.92% of the total inventory, which comprise 71.15% for on schedule production and the remaining 22.77% for postponed productions. Finished goods and obsolete inventory comprise 4.66% and 1.42% of the total inventory, respectively. The inventory turnover ratios in 2016 for production line of brand B track closer to the target of 6.8 times.

In all three years, it can be observed that most of the inventories for both production lines are raw materials. Also, finished goods for both production lines are kept at around 3–5% of the total inventory. The supply chain department indicated that in 2014, postponed productions start to be a problem for both production lines for brand A and brand B, but there are fewer amendments to production plans for brand A than those to production plans for brand B. From the year 2015, the postponed productions for brand A decrease significantly. Raw materials held for postponed productions of brand A decline from 24.02% to 14.10% and 8.61% in the year 2015 and 2016, respectively. This reflects in the continuing increases in the inventory turnover ratios of brand A throughout the three years and remain higher than the targets in the year 2015 and 2016 (See, Figure 1).

Figure 2 shows that the inventory turnover ratios of brand B in the year 2014 start to decline as the postponed productions begun. The postponed productions became even more problematic in the year 2015. Not only the number of postponed productions increases,

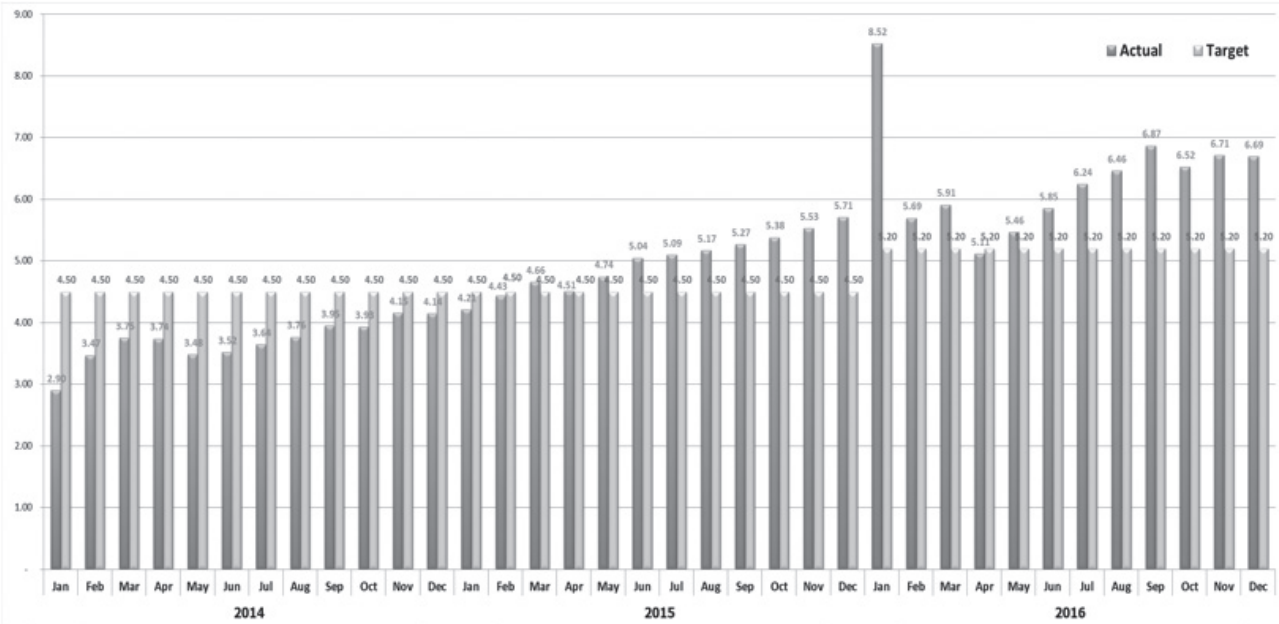

Figure 1 Comparisons of Inventory Turnover of Production Line for Brands A with the Targets

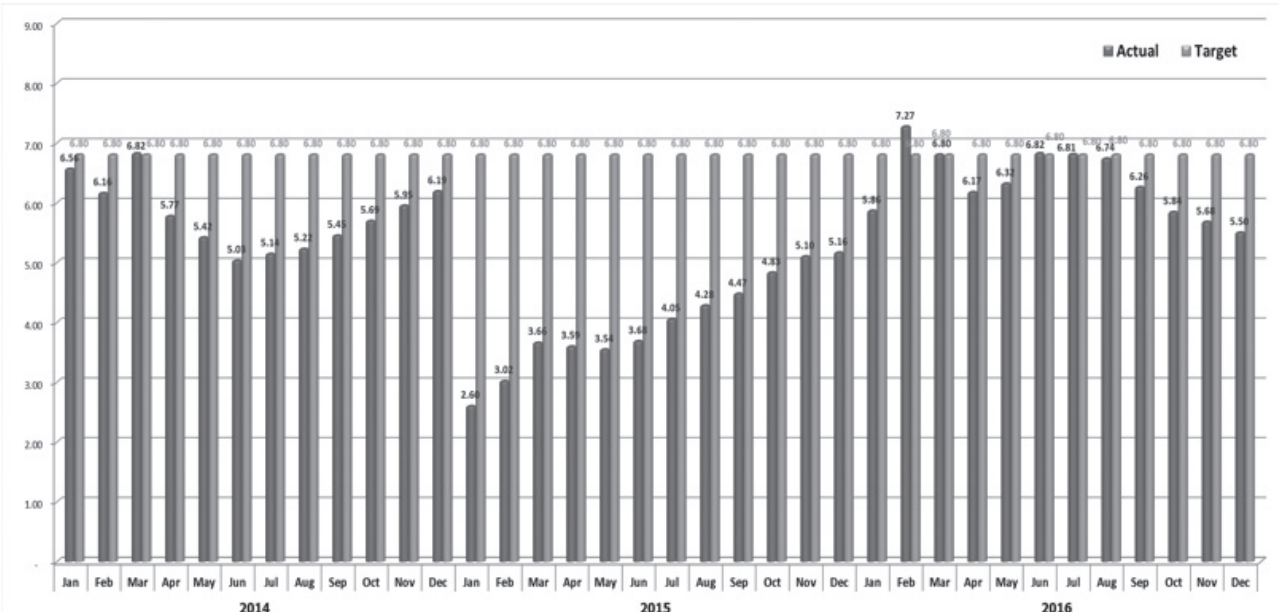

Figure 2: Comparisons of Revised Inventory Turnover of Production Line for Brand B with the Targets

but the period postponed also becomes longer from 1–2 months to 3–4 months. The inventory turnover ratios of brand B in 2015 become much lower than the target, although they improve and track closer to the target in the year 2016 when the issues resolved.

It is important to note that obsolete inventory is not an issue and remain at 0% for brand B in the year 2014 and 2015 when it suffers serious postponed production problem and the inventory turnover ratios being lower than the target. Once they track closer to the target in the year 2016, there are obsolete inventories at the average of 1.42% of total inventory and raw materials held for postponed productions at the average of 22.77% of total inventory. Similarly, while the inventory turnover ratios of brand A increase throughout the three-year period and meet the target in the year 2015 and 2016, postponed productions decline and obsoleted inventories increase in all three years. This suggests that postponed productions have a paradoxical relationship with obsoleted inventories. The larger the postponed production problems are, the smaller the obsolete inventory problems will be, vice versa. This means that eliminating postponed productions may result in obsolete inventories, unless adjustments as a result of changing demands can be done before issuing purchase orders for raw materials. However, when inventory turnover target is achieved, there are some postponed productions and obsoleted inventories. This suggests that brand A and B customers, when setting their targets, do expect some postponed productions just to keep obsoleted inventories to an acceptable level. Nevertheless, too many postponed productions would keep inventory turnover being lower than the target.

These amendments to production plans result in raw materials being held for production longer than they should be. When these inventories are excluded from the inventory turnover ratio calculation, the revised inventory turnover ratios improve (See Table 1–6). As discussed before, postponed production problem for brand B was worse than that of brand A. Hence, the degree of improvement in the revised inventory turnover ratios for brand B is greater than that for brand A. It can be concluded that postponed production is a major factor that contributes to inventory turnover ratios being lower than the target. However, an attempt to improve the inventory turnovers by eliminating postponed production per se may create obsoleted inventories. To achieve a more optimal solution, restructuring relevant operation processes also needs to be done. This will be discussed in the following section.

5. Discussions and Future Research

The major factor that causes inventory turnover ratios being lower than the target is postponed productions. Although demands are forecasted by the customers, changes in customer demands sometimes are very unpredictable and unavoidable. Improving the accuracy of demand forecasts by the customer company is beyond the scope of this study. Therefore, given the best available demand forecasts, restructuring the operations within the supply chain is needed to make it more agile to handle swift change in

customer demands. Several suggestions are made as follows.

Firstly, the company should try to reduce lead time required in the procurement processes. The more it can reduce, the better it can accommodate last minute amendments. One way is that the company should adopt EDI to communicate demand forecast and procurement information. The customer companies have used EDI between its office and plants in other countries. Extending the customer companies' EDI to connect with the company and its key suppliers will definitely improve accuracy of the information transferred and shorten the lead time required in the procurement processes.

Secondly, the majority of raw materials are bought overseas either by the parent company in Germany or from related companies in the U.S. For other raw materials, the customer companies have specified which suppliers to buy from. Where there is no designated supplier, the company is allowed to source the raw materials and submit them to the customer companies for approval before buying can be made. This requires longer lead time in procurement processes and inbound logistics than buying locally. Therefore, in addition to trying to reduce lead time by using EDI, the supply chain department may implement a plan to increase the number of raw materials that are bought locally from approved suppliers instead of importing them in a larger amount to save transportation costs. This also helps reducing lead time and transportation costs in the inbound logistics, inventories carried, and obsolete inventories.

Thirdly, the company should discuss the impact of postponed productions and reach to a conclusion on how to limit the number of postponed productions and shorten the period postponed. Currently, there is an agreement with both customers that the customer companies are responsible for all the costs resulting from cancellation of production plans. But there is no such agreement for postponed productions. This could be a measure to ensure that the customer company would review demand forecasts carefully before issuing production orders to the company.

Fourthly, operation processes relating to inventory recording and tracking system should also be improved. The company has used the SAP system, but there are some operation processes that can still jeopardize the accuracy of data in the system. For example, the items (either small or larger parts) issued to and moved back from the kitting processes should be counted and recorded immediately. It is not advisable to issue as a whole box, but only the quantity of the items to be used are recorded as issued quantity and return whatever is left in the box back to the storing location after kitting or manufacturing processes are done. The quantity of raw materials that are actually assembled and wait in the kitting area to be issued later to the production process should be reconciled with the balance before and after recording the issued quantity. Also, the manufacturing control system should be integrated with the SAP system so that work-in-process can be known before all the manufacturing processes finished. It is important

to properly record the quantity received and track them from issuing to the kitting processes till they either are assembled into finished goods or become spoilages.

Finally, the company is granted a BOI license, which offers tax privileges such as corporate income tax exemption, tariff exemption or reduction on import machinery and tariff exemption or reduction on import raw material. When raw materials become obsolete or spoilages, the company still has to keep them until the permissions for destroying such items are approved from the BOI. These permissions are currently applied for once a year. Although they are stored separately from ordinary raw materials and record in the SAP system accordingly, they are still counted as part of the total inventory. It is suggested that the company should apply for the permissions for destroying such items twice a year to reduce the costs of managing these inventories. This also helps improve inventory turnover of the company. However, it should be noted that this study only examined operations processes and inventory turnover to identify the causes of inventory turnover ratios being lower than the targets. Some recommendations on restructuring some of the operation processes that can help improve the inventory ratios were provided. However, it is left to future research to examine the impact of these recommendations and explore any further issues that remain to be discovered and resolved.

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