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The Dilemma of Toyota Production System Implementation: A Case Study of Taiwan Machine Tool Industries

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Abstract *Recently, many enterprises have implemented the Toyota production system (TPS) in order to improve their production performance and competitiveness. However, some of those enterprises which implemented TPS couldn't improve performance, even led to worse production performance. Dr. Goldratt thought the reason enterprises adopted TPS finally failed was due to their basic production environments was different of Toyota. Toyota Production System is built up in a stable environment, but most companies weren't stable as Toyota. Besides, enterprises implemented TPS did not follow the Ohno's four steps may also lead to poor performance. This study discusses whether Taiwan Machine Tool Industries is in three different dimensions of the instability of the production environment. Also, we study that in the unstable environment, the companies follow Ohno's four steps could have better improvement than which not follow.*

Key words Toyota Production System, Ohno's Four Steps, Unstable Environment

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1. Introduction

Toyota production system (TPS) developed by Taiichi Ohno in 1950 has been successfully applied to Toyota company, and the system is a major factor for achieving Toyota company so successfully. TPS continues to improve Toyota in production processes, supplier management, distribution pattern, research innovation, and creates current stable production environment. In production part, Toyota can cost down effectively. Average profit of Toyota is 70% higher than industry average in sale part. The results indicate that Toyota is quite successful in implementation of TPS. In recent years, many companies have implemented TPS, they hope use TPS to improve company constitution and enhance the competitiveness of enterprises. Although there are many successful cases of implementation of TPS, but these cases cannot reach high achievement similar to Toyota. Besides, from the literatures studying about enterprises which implement TPS, we can find many failure cases about foreign companies applying TPS. For example, in Pardi's (2007) study, cumulative loss for Toyota Burnaston factory (TMUK) and France factory (TMMF) is more than 3 billion Euro from 1989 to 2001. Swamidass's (2007) study shows that thousands of manufacturing companies implemented TPS and inventories of partial companies continuingly increase and cannot reduce effectively after implementing TPS. Therefore, many people begin to question why the companies follow Toyota to implement TPS but have led failure.

Goldratt (2008/2009) thinks the failure reason for companies implementing TPS is production environment having different basic dimensions. Goldratt mentions that TPS proposed by Taiichi Ohno is suitable for Toyota production environment. There are three different facets of environmental stability for

Toyota as follows: (1) product Life Cycle; (2) demands for each product; and (3) overall production loading; those are main assumptions for implementing TPS. However, most companies might be in three kinds of environmental instability, resulting in implementing TPS failure. Another failure reason may be that enterprise implements incorrectly TPS. Goldratt (2008) mentioned that there are Ohno's four steps for Taiichi Ohno to develop TPS. First, we must improve production flowing performance. Second, leading the operation function for time points that factory does not produce. Third, local efficiency must be abolished. Final, we should continue to improve. In general, enterprises do not improve production flowing performance to implement TPS and fall into local efficiency. Companies improve one of all production performance and do not consider overall performance.

From the literature reviewed above, we can see that some companies implement TPS but cannot improve company's overall performance and possible reasons are that TPS is not suitable applied to different production environment and enterprises do not obey Ohno's four step for production improvement. On the other hand, from the TPS concept developed by the Theory of Constraints (TOC) concept and we can find that implementation concept of TOC is similar to TPS. From the case for enterprises implementing TOC, the results show that TOC still implements Ohno's four steps to improve production under unstable production environment and enterprises can obtain significant effect in short time. Therefore, this study would verify the concept proposed by Goldratt (2008), and evaluate whether unstable production environment and incorrect implementation are major reason to cause implementing TPS failure.

2. Literature review

2.1. Manufacturing historical perspective

Manufacturing industry is built by two thinkers, Henry Ford and Taiichi Ohn. Ford utilizes the flow lines to reform mass production method. Taiichi Ohno improves mass production method to higher level by Ford's view point; that is today's TPS. TPS causes industry to change the understandings of inventory; assets become liability. Henry Ford and Taiichi Ohno improve production by obeying Ohno's four steps as follows (Goldratt, 2008): (1) improving flow performance is primary goal of operation; (2) The primary objective should be transformed into a set of pragmatic mechanisms to lead the operation function for time points that factory does not produce; (3) local efficiency should be abolished; and (4) a focus program for balancing flow performance should be ready.

2.2. Toyota production system (TPS)

The main idea of TPS is to eliminate waste in order to find more potential problems by reducing inventory, and to explore real problems. TPS would discover real reason and regulate it. In the organizational culture, TPS trains talented person and commits continuous improvement. The two important factors of TPS are just in time (JIT) and Jidoka (Womack *et al.*, 1990; Liker and Meier, 2006; Womack and Jones, 1996; Sugimori *et al*., 1997).

2.3. Toyota production environment

Pardi (2007) investigates Toyota production environment, and he finds that enterprise must meet following three facets to implement TPS efficiently: (1) ensure stability of long-term cooperation between company and employees; (2) market demand is stable and under controllable state; (3) reliable resiliency of suppliers. Pardi (2005) studies European Toyota factories and the results show that the factory conditions do not meet the three facets, resulting in the implementation of TPS failure. The TPS development took 20 years for such a good performance since 1965. Pardi believes that there must be a long-term index for implementing TPS. Otherwise the business owner will fail to implement TPS. Goldratt (2008) considers that required assumption of TPS production environment is a stable environment, and production environment requires stability with three different facets as follows: (1) producing procedure and product are no significant change in a period of time; (2) demand for each product is stable within a period of time; (3) total load for using resource of order is stable.

2.4. Theory of Constraints (TOC)

TOC is proposed by Dr. Goldratt in 1986 (Umble *et al*., 2006; Wu *et al*., 2013; Huang *et al*., 2014). Dr. Goldratt believes that there are bottlenecks in every system and bottlenecks limit the output of the entire system. Therefore, if you want to enhance output of the overall system, it is necessary to carry out bottlenecks. TOC most utilizes practical production management method such as buffer management (BM) and simplified drum-buffer-Rope (S-DBR). Schragenheim (2006a/2006b/2006c/2009) thinks S-DBR has the following advantages: (1) a simple and efficient method of production planning; (2) focus on schedule of capacity constrained resource (CCR) to deplete CCR production capacity; (3) on-time delivery of orders; (4) provide optimum production plan. However Schragenheim also considers: (1) even if the actual internal capacity constraints exist, but main limitation of system still comes from the demands of the market; (2) production scheduling bring about reducing flexibility to respond to the market, but if changing schedule for response to market will increase the complexity of management and control; (3) ultimate goal for establishing a protection buffer is to effectively use a buffer to ensure smooth delivery orders, therefore it only requires a single buffer with integrity protection; (4) complex production environments, such as reflux, multi-machine, multi-bottleneck, for the schedule are big challenge.

2.5. Buffer management (BM)

BM will set priorities for processing according to consumed degree of buffer time. The position located on left side of timeline is green area, and most orders in this area are just feeding orders. Orders in green area have enough production time, and in the production process, the production time of orders in this area will usually be consumed then orders go into the yellow zone. Yellow zone is also known as the alert zone, in other words, we only observe whether there are occurrences of abnormal conditions for orders in this area, and you need not take action without exception of condition. Production time of orders is consumed complete in yellow area, and then the orders will go into red area. Red area is driven work area when orders enter this area, necessary action would be taken to avoid that orders cannot be reached on time delivery caused by time consumed in red area.

3. Research method

In this study, TPS implementation by machine tool manufactures is taken as an example to analyze the failure reasons for implementing TPS, including: (1) TPS may not suitable be applied to different production environments; and (2) enterprises do not implement TPS to improve production by exactly following Ohno's four steps.

3.1. Establish research hypotheses

Hypotheses of investigation established by this study are divided into two part, instability of environment, and whether following Ohno's four steps to analyze the failure reasons for implementing TPS by enterprises.

Hypothesis 1: machine tool industry is in the instability of the short product life cycle, and cannot effectively implement TPS.

Hypothesis 2: machine tool industry is under the situation that demand of each product during a period is unstable, and industry cannot effectively implement TPS.

Hypothesis 3: Machine Tool Industry is under the situation that entire production load is unstable and industry cannot effectively implement TPS.

Hypothesis 4: In an unstable environment, machine tool manufacturers implement TPS to improve production without following Ohno's four steps. The results lead to poor implementation performance.

Hypothesis 5: In unstable environment, machine tool manufacturers implement TOC by effectively following Ohno's four steps and production procedures are significantly improved in a short time.

3.2. Sample source

3.2.1. Qualitative research

This study uses qualitative research to verify five hypotheses and utilizes general interview guidance method. Some vital issues provided by interviewers to elicit interview emotion, then respondents can freely explore or survey or ask within a limited time. The method is suitable for group interviewers and individual in-depth interviews. Respondents would be focused on pre-designed issue and interviewers can be very free to observe the surrounding environment and the respondents' reactions.

3.2.2. Interview Outline

Interview outline of this study is divided into two parts: production environment of machine tool industry and method for implementing TPS, such as Table 1.

Table 1. Interview outline

Investigate the machine tool industry production environment	Investigate the method for implementing TPS in machine tool industry
The company's overall operating information	The steps for implementing TPS
Production-related issues	Implementation of standardized operations
Market of machine tools and sell	Implementation of JIT
Products and Services	Implementation of Jidoka
Product life cycle and new product development	Implementation of leveling

3.2.3. Data recording and analysis

During the interview process, we will consult respondents' agreement to take interviewers' sound recording all the time. After the end of the interview process, we make a complete document by sound recording content, and create a text file. During the study process, we hope truly reflect the opinions, practice, and their own experiences for the researchers who participate with the study.

3.2.4. Related data recording and analysis

Because interview data may not really investigate the machine tool industry production environment and improves the analysis of the performance. Therefore, we apply related financial information collected from machine tool manufacturers to this study and let subsequence analysis effective. The major collected data are as follows: balance sheet, income statement, operating capacity, profitability, growth rate, marketing portfolio and revenue statistics of the products.

3.2.5. Investigate the comparison of performance improvement

Performance indicators discussed in this study are the following three points:

1. Due-date performance (DDP): We utilize Hit-rate (before and after implementing TPS and TOC) obtained by interview to compare Hit-rate enhancing rate during implementing time.
2. Production lead time (PLT): PLT is the time from receiving orders by client to ship. We utilize PLT improving information (before and after implementing TPS and TOC) obtained by interview to compare PLT reducing rate during implementing time.
3. Inventory value (IV): Swamidass (2007) uses TI/S (TI = total inventory, S = total sales) to investigate inventory growth trend after implementing TPS. In this study, we utilize TI/S, sales and inventory correlation coefficient, revenue and inventory growth rate, and inventory value, IV of raw materials or work-in-process (WIP) to investigate IV improvement results (before and after implementing TPS and TOC), respectively.

3.3. Study object

In this study, Taiwan's machine tool industry is as the research object, we investigate production environment of machine tool industry and TPS implementation method. This study utilizes 16 machine tool manufacturers to be in-depth interviewed and the interview results would be discussed (Table 2).

Table 2. Study object

Interviews company	Research objectives
16 company (A~P)	Investigate machine tool industry production environment
A, B company	Investigate method for implementing TPS
C company	Investigate method for implementing TOC

4. Empirical Analysis

4.1. Investigate machine tool industry production environment

Goldratt (2008) believes that TPS should meet some assumption such as, long product life cycle, demand of each product is stable, total product load is stable. Enterprises are able to implement TPS smoothly by obeying three assumptions. However, most industries are in three kind unstable environments, and the performance of implementing TPS is poor. This study analyses whether machine tool industries are in three kinds unstable environment, and analyzes the reasons that TPS is not successful to be implemented.

Hypothesis 1: To investigate whether enterprises with a short product life cycle of instability cannot effectively perform TPS

According to interview information, most of machine tool manufacturers think that the product life cycle are about 5-7 years; while lead time of new product (from design to completion) is about 3-6 months. However, the machine tool industry is not like other industries which will regularly launch new models. Machine tool manufacturers would consider the needs and reaction of customs and the posted new product models from machine tool fair and analyze whether the new models can bring new business opportunities. Then, manufacturers would irregularly launch new products. We know that product life cycle of machine tool is long and developing time of new product accounts for a small part of the product life cycle. Therefore, in fairly long period time, the producing procedures of machine tool product are not changed violently. Take an example, if product life cycle is five year and development time of new product is six months, then new product can still survive 4.5 years on market. New product development lead time take only a small part (1/10) of entire life cycle. Therefore, PLT for new product does not waste too much sales opportunities. Summing up the above, we can find that product life cycle in machine tool industry is very long and the results do not support the hypothesis 1.

Hypothesis 2: To investigate whether enterprises cannot effectively implement TPS when the demand of each product is unstable over a period of time

Abid and Özkan (2009) consider that the main reasons for affecting instability of customer demand are the problems for information flow between customers. Enterprises cannot know the actual demands of customers in the case of blocking information flow. According TMBA (Taiwan machine tool & accessory builders' association, TMBA) in 2008, the output value of Taiwan's machine tool statistics reports note that Taiwan's machine tool products for export values are up to 78%, while domestic sales account only 22%. Currently, the sales of Taiwan’s machine tool industry are almost carries out by agents, and the export market accounted for 80%. Therefore, there are information asymmetry problems among machine tool manufacturers for demands of terminal customers. Manufacturers cannot know exactly quantity and types of orders from agents and draw up manufacturing modes for producing product by agents’ orders. Therefore, the overall actual customers’ demands conditions are not controlled by manufacturers. As the mentioned above, machine tool manufacturers cannot get order information directly from customers and the situation results to order demand to be uncertain.

This study analyzes whether product demand of machine tool industry is unstable using company's financial statements. Taking product demand of F Company as example, this study analyzes situation of product revenue for three products in each month and utilizes one way ANOVA to analyze whether average of each product revenue is equal from 2005 to 2009 using year as affecting factor. If the difference is significant then we analyze whether the average difference of product revenue each year is significant by Fisher LSD. The study results show that the averages of product revenues for three kinds of products in 2005 to 2009 are significantly different, and averages of product revenues generated by post hoc analysis for each year are most significantly different, which means that the order demands of three kind products in each year are very different. We can infer that annual order demands for each manufacturer's standard models in machine tool industry may be significantly different. From revenues tables of products for different company, we can find that demands of orders for standard machine tool model are continuous and demands of other products are most sporadic. The demands at different time are uncertain and sporadic. From the above, because there are is problem in order demand for that information does not flow and order demand is unstable. Therefore, machine tool industry is in the instability of each product demand over a period of time.

This study concludes that scholars consider that unstable product demand is the factor for implementing TPS inefficiency and concludes two points as follows: (1) Patrick *et al.* (1987) consider that TPS adopts demand-pull Kanban production and if magnitude of demand change is more than 10 percent then it will lead to ineffective implementation of Kanban system; and (2) Pardi (2007) considers that when market demand is under unpredictable fluctuations and level production will not be implemented effectively. For effective implementing level production, company must control demand stability to reduce the volatility of the production plan (Coleman and Vaghefi, 1994; Hampson, 1999).

Machine tool industries now are in the situation where demand of each product is unstable over a period of time. Demands of three standard models change violently in F Company. The magnitude of changes in monthly demand are most greater than 10%, even up to 200%, and most product demands are sporadic in machine tool industry. There are some problems caused by implementing TPS in unstable demand environment as follows: (1) Using Kanban system will lead to confusion of production line and even makes production line halt. Because Kanban system is pull production while variations of post-process receiving quantity increasing, it will lead to more requirement for more manpower and equipment spare; (2) Company cannot effectively implement level production. Unlike Toyota, general companies cannot arrange accurately production schedule and effectively implement level production to reduce variation of production line. Production demand of Toyota is quite stable. If machine tool manufacturer schedule production under unstable fluctuation of demand then it would result in that production quantity is more than demand quantity, excess inventory caused by manufacturing; and (3) Kanban system requires that factory permanently retains container of each product between two work centers. In other words, factory need permanently hold inventory of each product. However, most demands of products for machine tool manufacturers are sporadic. Retaining inventory of each product would result to excessive inventory. Summing up the above, the results verify the hypothesis 2.

Hypothesis 3: To investigate whether factory cannot effectively implement TPS when entire production load is unstable

Each product order demand of machine tool industry is very unstable and has unpredictable fluctuations of demand. The results would cause the asymmetric situation among order demand and manufacturing capacity. Facing on temporary load of resources will lead to that these companies usually have rather poor due-date performance (DDP). This study investigates whether machine tool industry is in the situation that entire producing load is unstable using product sales combination of three kind standard models from 2007 to 2008 for F Company and related financial statements. Monthly production capacity load of three kind standard models for F Company is calculated from that annual production capacity is divided by 12 months. We find that fluctuations of monthly production sales quantity are very large. Monthly production quantity is often greater than average production load or is significantly less than production load, which means that the total production of each product using a variety of resources load situation is quite unstable. When agents receive too much order and demand of order will be greater than

total production load capacity to result in poor DDP. In off-season, low order demand would result in excessive idle production capacity. Therefore, we can know that machine tool industry is in the instability of the overall production load.

Implementing TPS under overall production load unstable environment will make Kanban system cannot deal with temporary demand which exceeds production capacity. Assuming that production load of a work center is lower than production capacity of this work center and production load of a work center is greater than production capacity of this work center next week. Kanban system would prevent early production and result in delivery missed in two week later. Orders of Toyota are fairly stable, but Toyota still establishes the way to receive order and delivery commitments to customers. Therefore, Toyota can constrain the change of product combination from this month to next month and effectively implement level production. Further, Toyota would let Kanban system not to delay customer delivery because of production capacity overload. However, machine tool manufacturers cannot force their customers to establish such favorable conditions like Toyota. Pardi (2007) believes that companies can effectively implement TPS in the condition that market demand is stable and controllable state. Machine tool industry is in the environment that order demand and overall production load are unstable. Machine tool manufacturers cannot forcibly provide delivery time to customers. Therefore, implementing TPS by Machine Tool Company would make Kanban system cannot work effectively. Further, it would lead to confusion on production line and delays delivery time provided by customers. Summing up the above, the results verify the hypothesis 2.

4.2. Whether enterprise implements TPS and TOC by following Ohno's four steps

This section analyzes that whether enterprise implements TPS and TOC by following Ohno's four steps, and discusses problems caused by not following Ohno’s four steps.

4.2.1. Implementation modalities for machine tool manufacturers implementing TPS

This section would take machine manufacturers A and B which in-depth implement TPS as investigation objects. The two companies implement TPS in September 2006. This study finds the steps for implementing TPS by two companies as follows: (1) implement 5S improvement activities for production site; (2) standardized operations; (3) improve production efficiency; and (4) improve production quality and reduce product defect rate. The two companies do not improve production by following Ohno’s four steps. This study also finds that these companies do not change production mode to pull production (start production from the actual market demand). Some discussions are as follows:

1. Improving the flow properties of the operation is primary goal

The primary goal of improving the flow properties is to facilitate the flow of the WIP in each production process and reduce quantity of WIP inventory. According to interviews, we find that internal production processes in A and B companies are the three steps, casting, machining and assembling. In the process for implementing TPS, the companies do not improve the flow properties of the entire production process and only improve assembly plant performance. The companies change sentinel production to line production and divide production into eight workstations. Then, companies cut required assembly production for each workstation by time. Aassembly plants use the pull production of single-piece flow production mode. Pull production means that if back-project requires production resource, it would acquire the necessary quantity of production resource from front-project. Quantity of production generated by front-project is in according with how many quantities to be acquired. After implementing TPS, assembly processes time of both companies is significantly reduced (original time is more than 20 days and it is reduced to six days now, reduction rate reaches 60%).

However, changing production process of assembly plant to line production is only partial change in all production process and companies do not change the flow properties of all production process. There is no a method to improve flow properties in two production process for casting and machining. Casting and machining plants may not know which order should be produced first. It will lead to confusion on production and cause that assembly plant cannot work together effectively with front end of line. There may be material shortage problem during assembly process and it would delay product delivery. In

addition, line production is only suitable for certain large standard production models, and is not suitable for all production models. This study finds that TPS was not effective in improving the flow properties of the entire production process of the plant. Although, TPS can reduce production time of assembly plant but it cannot reduce effectively all PLT. The reasons are that the processes of casting and machining cannot produce according to order priority, and then they delay the entire PLT of assembly line. Therefore, comprehensive implementing TPS can effectively improve overall flow properties.

2. Guide the operation function for when not production

According to Little's Law, we can find that if quantity of WIP is higher, PLT will be pulled longer (Little, 1961). Taiichi Ohno mentions that assets would be transformed to liabilities because of inventory. He also thinks that overproduction is the fundamental waste, because it leads up to the other waste. Therefore, we should control the timing for not to produce in producing process and must have a method to suppress order. The method can reduce the quantity of WIP and avoid more waste and cut down PTL. TPS uses Kanban system to lead when not production. The basic requirement for using Kanban system is that production site must be converted to production flow. However, A and B companies do not improve the flow properties of entire internal processes and it is difficult to produce effectively by implementing Kanban system. Production line of assembly plant is based on pull production to control when not production. However, according to interview we find that TPS plan production on the basis of standard machine. Therefore, it would lead to produce excessive WIP under unstable demand environment. Further, excluding production line, the other production processes do not have method to control when not production. Other processes will be based on load capacity to produce too many WIP, resulting in excess inventory.

3. Local efficiencies must be abolished

Based on above analysis, we can find some conclusion as follows. Both of two companies do not have method to lead when not production, and will implement planned production. Each production process could continue produce because of enough production capacity and it may produce too many productions. Excessive WIP would be transformed to inventory and it is wasteful. Therefore, it do not meet the purpose of local efficiency must be abolished.

4. A focus program of balanced flow properties must be ready

A balanced flow property focus method means an activity which makes production smoother and reduces PLT and continues improvement. Both of A and B companies start to implement 5S production environment improvement, implement production line, improve quality and fall into local optimization improvement method from step 4. The companies do not implement former three steps in reality and cannot achieve the purpose of entire improvement. Machine tool industries implement TPS starting from production site, productivity and quality improvement. We can find that machine tool industries do not have a method to exactly know the production priority and to guide when not production. The reasons would result to the problems such as production line confusion, wrong production priorities, excess WIP, long PLT and poor DDP.

4.2.2. Implementation modalities for machine tool manufacturers

In this section, we would investigate the case study about enterprises implement TOC and follow Ohno's four steps. This study takes interview C company as research object, and C company implements TOC in September 20008. The TOC implement processes of company C are as follows:

1. First, company changes company production planning model. Planned production (Make-to-Stock, MTS) is transformed into pull production (Make-to-Order, MTO) which starts production by market demand. Order demand of each product is quite unstable and most products are fragmented demand. Planned production will lead to produce excess unnecessary WIP.
2. Company changes production priorities method to management method based on time and inventory buffering. The buffer states of all kinds of processes are as operation priority to improve the flow properties of entire production process. Therefore, each processing center clearly knows which you must produce first and the PLT can effectively be cut down.
3. C company uses S-DBR production scheduling approach and utilizes capacity constraint resources (CCR) as feeding material mechanism. CCR is the most important part of production processes. In order to

make production process smoother, Using CCR effectively as schedule planning can make production capacity planning and production feeding clearly. In production capacity resource of non-CCR, company will not produce while no production feeding to avoid excesses WIP. Companies do not seek to maximize the utilization of each resource and just take advantage of CCR production capacity resources.

Summing up above, we can find that C Company implements TOC according to Ohno's four steps and effectively improves the overall fluency of production. (1) use time buffer and inventory buffer in BM to improve the entire production process flow performance and control inventory; (2) control when not producing mechanisms by SDBR scheduling method to meet CCR production capacity which is production feeding mechanism; (3) abolish local efficiency and does not seek to maximize the utilization for non-CCR resources; (4) continuous improvement is to make SDBR production scheduling and BM mechanism more robust.

4.3. Investigate performance improvement generated by enterprise implementing TPS and TOC and verify hypotheses 4, 5

This session would investigate and verify whether hypotheses 4 and 5 are established. In this study, A, B and C Company's financial statements and interview data are as evaluation foundation for investigating improvement performance. We assess whether improving production in accordance with Ohno's four steps will affect performance improvement of company. The investigated performance indicators are Hit-rate, PLT and IV.

4.3.1. Due-date performance (DDP)

After A and B companies implement TPS for three years, Hit-rate of A and B companies are increased to reach 85%, 80%. Average Hit-rate of company C is approximate 39% in 2008. After implementing TOC, average Hit-rate of company C is increased to reach 80%. Since April 2009 Hit-rate was maintained at more than 95% of DDP. The results show that production feeding method using SDBR production scheduling could properly assess production capacity load situation. Flow properties could effectively be improved by BM and delivery time can be determined properly for customers. Production performance can be significantly improved in a short time.

4.3.2. Production lead time (PLT)

PLT of company A and B are reduced to reach 45 days after A and B companies implement TPS for one year. Because companies do not improve overall production flow properties, PLT cannot effectively be reduced. PLT of company A and B reduce to reach 30, and 21 days after A and B companies implement TPS for three year. Companies transform production mode of assembly plant to flow line production and shorten PLT of assembly plant. Therefore, entire PLT can be significantly reduced. However, PLT of company B is reduced to reach 21 days. The reasons are that company B implements TOC in 2008 and utilities BM to improve production flow properties performance of casting and machining. Thus, performance is improved significantly. PLT of company C is reduced from 45 days to 30 days after company C implements TPS for one year. We can obviously see that implementing TPS by following Ohno's four steps would significantly improve performance. Company improves production flow properties and leads when not production using BM. Production processes coordinate stand-alone sending material operation to reduce quantity of WIP. Therefore, production line can obviously understand which product we should produce, and company can reduces PLT significantly.

4.3.3. Inventory value (IV)

This study collects related financial information of companies A and C and compares inventory performance improvement of implementing TPS and inventory performance improvement of implementing TOC. We analyze financial report data for every six months and collect financial data from 2001 to 2009. This study uses variance of IV to judge whether companies could reduce IV by implementing TPS and TOC. Subsequence, we investigate correlation coefficients of inventory and revenue for each company, TI/S and analyze whether all kinds of items in inventory reduce after implementing TPS.

1. The correlation coefficient of total net operating revenues and inventories

From correlation coefficient which is calculated by the total amount of revenue and inventory (Correlation coefficient), we can find that there are no significant differences in correlation coefficient of company A, C before implementing TPS, and the values are 0.59 and 0.69, respectively. The correlation coefficient of company A is 0.59 before implementing TPS and the correlation coefficient of company A reduces to reach 0.14 after implementing TPS. The results show that the relationship between revenue and inventories is low linear correlation. The relationship between revenue and inventories is not significant. The correlation coefficient of company C is 0.69 before implementing TOC and the correlation coefficient of company A increases to reach 0.98 after implementing TOC. The results show that the relationship between revenue and inventories is high positive correlation. Inventories will be synchronized with the revenue growth. In general, net operating income and IV belong to positive linear relationship. In other words, inventories will increase while revenues increase. From correlation coefficient, we can find that there is no significant positive relationship between revenue and inventory of company A. When revenue in 08Q4 reduced 7.36% but the inventory went up 18.87%. In 09Q2 and 09Q4, revenue sharp declined 79% and 64% and inventory only reduced 18% and 20%. Implementing TPS does not make company reduce inventory. In the case of productivity increased by implementing TPS, company produces excess products because company does not lead when not production and does not abolish local efficiency. Company A would forecast demand of one year and carries out 10% planned production. Therefore, company A does not produce in accordance with the actual demand and it would lead to excess inventory. The results make inventory increase after implementing TPS.

There is significant positive linear relationship between revenue and inventory for company C. Inventory significantly reduces while revenue reduces significantly. Company C implemented TOC in September 2008. Because there was financial crisis in 2008, revenue decreased approximate 69% (09Q2-09Q4). Inventory was reduced 45% by implementing TOC (09Q2-09Q4). Implementing TOC transforms production mode from planned production to pull production. Further, production site must be restricted material feeding. Because excess material feeding would cause too many WIP, and it could makes production line confusion. The results would lead to IV significantly declined.

2. TI/S ratio

This study compares the performance generated by implementing TPS and the performance generated by implementing TOC by using TIS value. The ratio of company A was about 35% in 2004 to 2007. The ratio was increasing after 2008 and IV is 16 times to revenue in September 2009. The results show that there are too many inventories in the company. During financial crisis, there are too many inventories, excessive production and the products produced without according to actual order and the results lead to high inventory level. The inventory value is significantly higher than revenue in 09Q2 and the results mean that implementing TPS cannot reduce inventory value of company. The ratio of company C is about 28% in 2004 to 2007. The ratio was getting higher and higher after 2008. Although, ratio is significantly higher than average ratio, inventory value does not exceed revenues on the case of significantly revenue declined. Because of implementing TOC by company C, inventories are controlled effectively.

3. The average inventories addition and reduction in all kinds of items after implementing TPS and TOC

IV contains the raw materials and materials, semi-finished products and WIP inventory value. In the investigating topic for implementing TPS and TOC by enterprise, getting materials ready is very important for that how to use lower inventory to meet required material in production process. Material inventories of company A increase significantly 65.77% and material inventories of company C just increase slightly 1.06%. In order to meet production requirement, TPS prepares many raw material inventory. As well as, TOC utilizes lower raw material inventory to meet requirement for getting material ready in production process. The value of WIP increase about 60,000,000 after implementing TPS by company A. TPS does not reduce the value of WIP, which means that company produces excess WIP, and there is no effective control on the production line. The value of WIP reduces about 240,000,000 after implementing TOC by company C. TOC follows Ohno's four steps and effectively controls quantity of WIP on production site.

From the results above, we can verify the hypotheses 4, 5. Hypothesis 4: In an unstable environment, machine tool manufacturers implement TPS to improve production without following Ohno's four steps. The results lead to poor implementation performance. Hypothesis 5: In unstable environment, machine tool manufacturers implement TOC by effective following Ohno's four steps and production procedures are significantly improved in a short time.

5. Conclusions

From empirical study, we can find that machine tool industry stay in demands for each product environmental instability and overall production loading environmental instability. Company inefficiently implements TPS under the two unstable environments. Then, the result would cause that Kanban system cannot be efficiently implemented; levelized production cannot be implemented; delivery time for customer would be delayed. Implementing TPS without following Ohno's four steps would lead to low implement performance. Under the same unstable environment, implementing TOC by following Ohno's four steps would let performance to be improved significantly in short time. This study finds that enterprise performance could be significantly improved by implementing Ohno's four steps efficiently, even in unstable environment. How to effectively improve the flow properties of production, guide mechanism when not produced by repealing local efficiency and continuous improvement Ohno's four steps is the conditions must be done by enterprise when implementing TPS. Further, performance of company would be significantly improved.

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