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Note

Toyota Production System and J-Cost Theory: Proposing a New Theory for Quantifying Lead Time Reduction

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Keywords

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1. Introduction

Until today the Toyota Production System (TPS) has been introduced to a number of companies all over the world. It has also been found effective in enabling on-sight improvements. However, there have been no management accounting methods that could numerically explain effects of TPS. This paper therefore aims to propose a new theory to quantify actual performances of on-site improvement[i].

2. Toyota's on-site improvement and its problem of measurement

2-1. The basic framework of TPS

Every company has its own philosophy reflected in its business activities (Tanaka [2005]). Toyota's foremost value is to seek sustainable prosperity of the company while contributing to society, through the means of increasing the market share and thereby making profits. This philosophy shapes TPS, which has two pillars that are respectively called "Just-In-Time" (JIT) and "Jidoka", which is translated as "autonomation". In addition, TPS contains four elements, each of which is explained below.

(1) Respect for "people":

Toyota adopts a no-layoff policy. Instead of firing its employees, the company attempts to solve relevant problems by enhancing teamwork in the workplace, which is valued as a fundamental source of energy. Underlying this approach is that Toyota accepts its employees, or "people", as they are and support them in maximizing their potential to the fullest extent. When a worker makes a mistake, its cause is thoroughly investigated rather than blaming the individual.

(2) Shogyo Mujo, which means the impermanence of all things:

This fundamental idea in Buddhism regards nothings as permanent. A company is also an organic creature that keeps changing in a dynamic environment. Thus, without making constant efforts, no business is likely to survive. This means that every company is bound to continuously make a progress. Today is a day to prepare for tomorrow.

(3) Kyozon Kyoei, which refers to coexistence and co-prosperity:

Sustainable business inevitably requires working in harmony with all stakeholders such as customers, employees, suppliers, shareholders and so on. Specifically, Toyota offers valuable products to customers, provides its employees with a sense of satisfaction, and brings wealth to shareholders. With these conditions met, the company in engaged in business competitions in the market. And then, the only way to beat rival businesses is to increase the speed of cash to cash

cycle. This is the reason for implementing JIT.

(4) Genchi Genbutsu, which can be translated as “go and see for yourself”:

A problem can arise on site. This means a clue to a solution can also be found on site. It is important to ask why the problem has occurred repeatedly, and then the real cause of the problem can be identified.

The above-mentioned philosophical elements are embedded in TPS’s two pillars, namely Jidoka and JIT.

2-2. Two pillars that support TPS

(1) Jidoka

Jidoka (autonomation) is a management principle developed by Sakichi Toyoda, an inventor and the founder of the Toyota Group, during the process of invention of his own automatic loom in the Meiji era. If the machine has the ability to “check the result of the work”, then it could solve the problem immediately and never let the problem flow into the later production lines when any abnormality is detected. His idea was then further developed as “visualization of problems: visual control”. This led to the later creation of important concepts such as “autonomy “ and “built in the quality at the production process”. Furthermore, it is considered to be the ultimate form of Jidoka to constantly aim for high goals and continue to make improvements.

(2) Just-In-Time (JIT)

Just-In-Time is a concept developed by the founder of Toyota Motor, Kiichiro Toyoda. The idea is that the company could compete with “BIG3” even with a small amount of money, if it does not hold a large amount of inventory and turns it effectively. Moreover, there are two aspects of Just-in-time: inventory reduction and lead-time reduction.

a) Inventory reduction

Few inventories in the plant means that the company will run out of stock when 1) quality defect occurs, 2) employees’ attendance is poor, or 3) equipment breakdown happens, creating a tense situation within the plant. This tension creates liveliness and fosters teamwork.

b) Lead-time reduction

There are two aspects of lead-time reduction.

・Lead-time reduction from order receipt to delivery

The amount of stock at the customer site changes depending on the number of days after the order is placed and delivered. If delivered the next day, it can be run without stock. Since

Toyota dealers do not have to pay money on extra stocks, they usually prefer to have the delivery on the following day. Therefore, shortening the lead-time from order receipt to delivery enhances market competitiveness (Value Up) and can also increase profitability.

However, dealing orders with finished goods inventory threatens the profitability of the company. Therefore, it is necessary to reduce the volume of in-house inventory while shortening the lead-time from order receipt to delivery.

・Lead-time reduction from material receipt to delivery

Shortening the lead-time while receiving raw materials and then processing them into finished goods, and finally delivering to customers will help to reduce inventories and improve cash flow. Lead-time reduction will lead to the improvement of the company's profitability without causing any inconvenience to the people involved in the company.

In other words, the departments at the head office such as product planning & design should work on the company's profit margin improvement (including cost reduction), and the work floor should focus on lead-time reduction. This is the essence of TPS.

2-3. The reality of on-site improvement by TPS

When implementing TPS, we first work on securing quality (Jidoka). An inspection of all manufactured products takes place to prevent any defective products from flowing out, and if any defect is found in the inspection it will be immediately reported to the department in charge. In order to prevent a recurrence of defection, the line can be stopped and the cause is searched. We constantly make further improvements in the manufacturing process to assure quality of products.

Next, we sort and organize things in order, and thereby create more space and visualize redundant work. Deleting extra work and freeing up people can help to form an improvement team and generate more enhanced results. We use such freed-up man-hour to repair equipment or increase the setups of machines or transportation. This helps to make the production process flow smoothly like a stream.

In many cases, steady changes occur for one to two years, and the workplace gets improved. Specifically, changes are observed in four spheres, namely that; a) the plant becomes more spacious; b) equipment failure and defect rates drop sharply; and c) excessive personnel become available even after forming improvement teams and sending workforce to other plants; and d) work-in-process inventory gets reduced and lead-time shortened.

However, it is only the amount of cost reduction imposed on the factory that is taken into account. The Key Performance Indicators (KPI) does not pay attention to non-monetary factors, such as how much lead-time is reduced.

The biggest pressure on the work plant is a reduction of labor costs. In fact, any work plant is

likely to be forced to achieve a several percent of man-hour reduction each year. However, it is common that the work plant hits the ceiling within a couple of years and runs out of any means of further costs reduction. In reality, there remain other factors that should be worked on, such as inventories and lead-time. However, there is no method to evaluate reduction of them. This lack of evaluation method is the major reason that some companies fail with TPS within a few years.

2-4. Accounting theory to properly evaluate JIT improvement

Quality (Q), Cost (C) and Delivery (D) reflect efforts made by the work floor. An excessive pursuit of C and imposition of its work on the work floor can result in dysfunctional behavior. For example, being so desperate to reduce man-hour cost, managers may be tempted to eliminate investment into education and training of workers, which probably have no immediate negative impact. Moreover, they may be tempted to reduce product inspection, equipment inspection or maintenance work, and again this may have no immediate visible effect. However, a skipping of necessary procedures or halting investments in personnel can ultimately cause a tragic failure.

In contrast, TPS focuses on assuring Q by Jidoka and pursues lead-time reduction (D), instead of imposing C on work floor. Then profitability follows. This is called the Toyota Way. Working on D is more potentially effective than C.

Toyota people are dispatched to many companies facing a bankruptcy crisis, and have turned around their business by implementing TPS. In fact, Toyota itself is also growing steadily. Because the Toyota Way has made a huge achievement, it means TPS must be in a good direction. But unfortunately, there is no accounting methods or techniques that explain or techniques that can fully explain why pursuing lead-time reduction (D) will result in cost reduction (C) while securing quality by Jidoka (Q). There is no one who complains about the importance of quality (Q), so the problem is the relationship between cost reduction (C) and lead-time reduction (D). We need a new theory to clarify the relationship between the two.

To illustrate the problem in a simple way, we can consider the following question: if a company carries a 10,000-yen product for an extra day, how much will it lose?

3. New theory for breaking the wall (J-cost theory)

3-1. Problems with the profitability evaluation method

Since the profitability is generally evaluated by the following formula, it is considered that reducing the cost will improve the profitability.

$$\text{profit} = \text{selling price} - \text{cost}$$

This means how long it takes for a product to sell does not influence the profit it brings. That is,

if goods purchased for 100,000 yen are sold for 110,000 yen, profitability will be the same whether they is sold in one month or ten months. However, in the case of money lending, if you lend 100,000 yen, it is better to receive 110,000 yen in one year, not in two years. It is calculated as following.

One year later: yield = 10,000 yen / (100,000 yen × 1 year) = 0.10 / year

Two years later: yield = 10,000 yen / (100,000 yen × 2 year) = 0.05 / year

The unit of the denominator in this formula becomes something unheard – [yen-year] (i.e., 100,000 yen × 2 years). The amount of money lent [yen] is multiplied by the time [year]. In another example, the amount of work is calculated as number of worker [man] × time [hour] = [man × hours] = [Man-hour]. The unit [Man-hour] is familiar due to its frequent use. People often say things like, "This work requires eighty man-hours." Similarly, the unit [yen-year] could also be practical, but the problem is that we are not used to it.

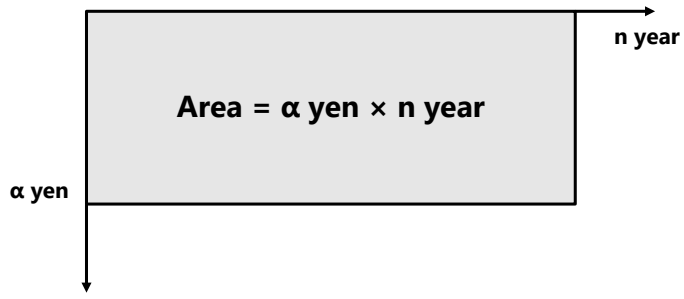
If depositing "α" yen and receiving "θ" yen for "n" years, the interest amount "π" yen is calculated as (π yen = θ yen – α yen), and interest yield is calculated as (π yen / (α yen × n years)) = π / (α · n) [annually].

The denominator represents the area in the following figure, but has no specific term to present it in accounting. So we define this area as the "amount of money invested" or "volume of capital invested".

As showed in Fig.1, the interest yield is calculated as follows when receiving interest "π" yen after depositing "α" yen for "n" years.

Interest yield = π yen / (α yen × n years) = π / (α · n) [annually]

Fig.1 Meaning of denominator



The denominator represents the area of the rectangle in the Fig.1. There is no specific term to present this area in accounting, so we define the area as the "amount of money invested".

In any kind of business, we purchase raw materials first, then process them into a product. It then sells at a certain price after a certain time. Materials purchased at a certain original cost are processed with an input of costs and time. And then they become finished goods, and are shipped

to customers. In exchange for goods, the company collects money. This process of generating profit is similar to the savings. So the profitability of one unit is calculated as follows.

Profitability = profit π yen / (average cost α yen × average lead time n days)

Fig.1 shows the relationship between cost reduction (C) and lead-time reduction (D). A shorter vertical axis means cost reduction (C), and a shorter horizontal axis means lead-time reduction (D).

So the difference between the cost and selling price is the profit. In principle, this mechanism, which can easily be overlooked in products that flow to the factory in large quantities, is common across all sorts of businesses. Our focus is on one unit of the product.

3-2. Improvement evaluation method based on interest yield

The improvement evaluation method is defined as follows drawing on the savings' interest yield.

JIT evaluation method = profitability = the amount of profit / the amount of money invested

Because the total cost (C) spent on the product is a function of time,

Total cost C = C (t)

Therefore, the amount of money invested for a certain production line is the integral value of the total cost C (t) for that period. When the integral value of each production line can be substituted by solid or trapezoidal area Si, the amount of money invested becomes as follows:

The amount of money invested = Σ (Si)

3-3. Clarification of unit

This research involves three kinds of Yes-related unit:

[Yen]: representing the amount of money, e.g. sales, dividend, expenses, etc.

[Yen × day]: representing the amount of money invested, e.g. investment, inventory, working capital, etc.

[/Day]: representing profitability, e.g. yield, interest rate, etc.

The unit of [Yen × Day] was not actively used and defined in accounting. Therefore, this research names the use of this unit as J-Cost Theory.

3-4. J-cost diagram

We pick one unit of the product, and follow the flow from order receipt to delivery. We then find out what cost at what timing is input to the manufacturing process. And then we draw a graph

that the horizontal line shows the lead-time and vertical line the cost. This is called "J-Cost diagram".

We name the amount of money invested represented by the "area" such as a, b, and c as "J cost". As a whole, the amount of money invested = the total of J-cost = a + b + c + ... + h + i. It could be formulated as follows:

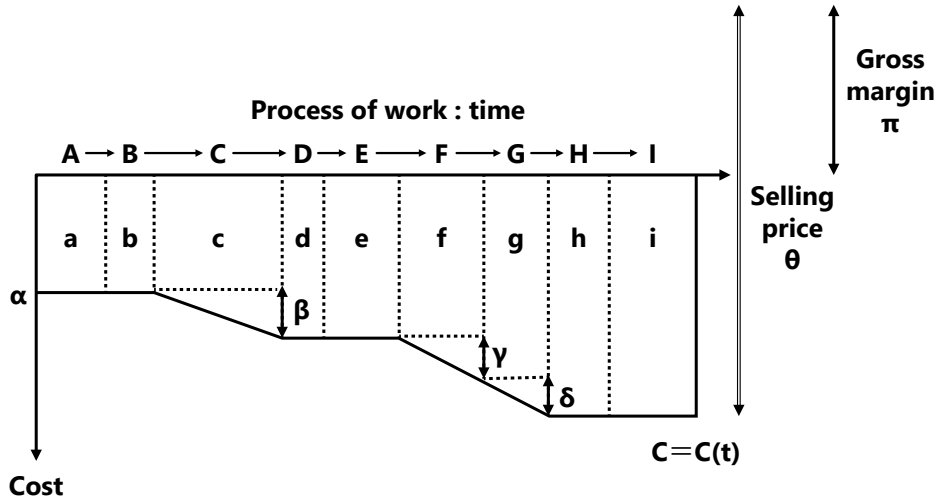
$$\text{J-cost} = \int C(t)\, dt \ [\text{yen} \times \text{day}]$$

In this way, it is possible to evaluate the profitability by using the amount of money invested.

The word of "J" is an initial letter of JIT system. Although it is the amount of money invested, in order to differentiate with the normal cost reduction, this research names it as "J-cost".

Since the gross margin represents the core ability of the work floor and the aim of this research is to evaluate the work floor, the term gross profit is adopted here. The numerator of the evaluation method is the gross profit "π" yen when the selling price is "θ" yen.

Fig.2 J-cost diagram



(e.g.) α, β, γ, and δ represent respective costs spent for each of the processes A – I.

$$\text{Gross margin } \pi = \theta - (\text{total costs input to the production line})$$
$$= \theta - (\alpha + \beta + \gamma + \delta)$$

The difference in profitability in each car model before and after the improvement quantifies how much improvement has taken place on the work floor. The unit is per day or per year.

Profitability = gross margin / the amount of money invested

= Gross margin / total J-cost

If the gross margin is unknown, the improvement could be evaluated by the profitability improvement rate as follows.

total J-cost before improvement / total J-cost after improvement

The above is the outline of “J-cost theory”.

4. Conclusion

An increase of capital efficiency is one important issue in the field of management accounting. Both the manufacturing and sales departments can play a role here. In the cash-to-cash cycle, the manufacturing section can reduce both excess inventory and lead-time. Sales can try to collect accounts receivable as soon as possible. Indeed, a reduction of lead time is the key to increasing capital efficiency and can be realized by implementing JIT. In order to measure the impact of time reduction, this paper has proposed and illustrated J-Cost Theory. It is claimed to be useful as it quantifies an actual consequence of on-sight improvement.

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Notes

[i] Masatomo Tanaka, one of the authors, was devoted to on-site improvement activities at the factories of Toyota Motor for 25 years since joining the company. He then moved to the head office, and worked on improvement activities within the Toyota Group as a manager of the Production Research Department and the Logistics Department. He later became a professor at Monotsukuri University. Currently he is the director of the J-cost Research Institute. J-cost theory has been applied in several companies and proved useful. At present, Tanaka and his colleagues are trying to introduce it to more companies, with the cooperation from companies that have already learned the effects of J-cost theory.

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