# Development of a New Business Model of the SME Manufacturing Industry from Mass Production to Make-to-Customization

George Chien and Felix Chan



August 5, 2020

# Development of a New Business Model of the SME Manufacturing Industry from Mass Production to Make-to-Customization


**ABSTRACT**

**Purpose -** In this new era, due to the market competition, there are a lot of pressures in the manufacturing industry and SME Companies. Most of the manufacturing companies are facing challenges, such as increasing product variety, small lot size and short delivery time, but there is lack of a suitable and practical methodology to solve such problems. This study is mainly based on drilling down into an SME manufacturing company, exploring the limitation in its current business model and determining the boundaries of its operation process when facing the current market situation.

**Design/methodology/approach -** This research paper, based on a multidisciplinary literature review provides a holistic perspective on the affecting factors new business model development. A new business model is developed: Make-To-Customization, two-phase operation process and standardization modular design to solve the above problems for an SME Company, and then trial run the new business model in the manufacturing company.

**Findings -** The results prove that the new business model and the new operation process not only solve the problems in product variety, small lot size and short delivery time, but also create a synergic effect for transformation of the surplus to business opportunities, and improve the efficiency and effectiveness in the operation.

**Originality/value** – The study provides a clear roadmap for exploratory and cost-effective solutions for other SME manufacturing companies to achieve continuous improvement of their business model.

***Keywords****:* Standardization; Continuous Improvement; PDCA Cycle.

**Paper type:** Research paper

# 1. INTRODUTION

E-commerce is changing purchasing behavior from traditional channels (wholesale, retail, and physical shops) to Omni-channels. Due to the market change, traditional trading and manufacturing companies also run their retail business - Business to Customer (B2C) - through the E-commerce channel so that end customers can directly contact and purchase the products through the e-commerce route. Due to the end customers frequently requesting products with personal characteristics, such as choosing products with specific colors, styles, or even names or logos, thus the business process in manufacturing has changed a lot. It has changed from Mass Production (MP) to Mass Customization (MC), and includes mass product variety, small lot size, and short delivery time.

From the above, problems arise such as how to increase the product flexibility and variety; how to shorten the product delivery time; how to improve the surplus of the finished goods; how to improve the cost saving; and how to solve the limitation in production for MC products. These are the key factors those most manufacturing companies are facing.

Small and Medium-sized Enterprises (SME) have been a crucial factor for growth in countries all over the world. According to the statistics from the European Union (EU), the United Nations and the World Trade Organization (WTO), SMEs represents 99% of all business units in the EU; 98% in the USA; 99.5% in Mainland China and 98% in Hong Kong. It has been shown that SMEs are not only contributing to employment but also economic development in the global and regional economic recovery.

On the other hand, due to SMEs bargaining power being lower than large organizations, they are facing a lot of internal and external forces. These include organizational infrastructure, competitive strategy, organizational learning style, and position within the supply chain structure. According to Radziwona et al. (2014), in the EU, SMEs provide approximately 20% of all jobs in industry, and the manufacturing activity represents about 21% of the total EU GDP. Although there are a lot of SMEs in the world, many approaches to improving performance are not practical for them and the Make-To-Order (MTO) companies which represent an important sector of the economy (Thürer et al., 2011).

There are a lot of external forces driving product variety, mass customization and short delivery time, but there are a lot of limitations in production in fulfilling such requirements, especially for SMEs. In 2019, James and Mondal mentioned that the setup times cause a loss of valuable time and production efficiency due to a high variety of products in MC. According to Lee and Pinedo (1997), setups are sequence dependent because they depend not only on the next job to be processed, but also on the previous job processed.

The objective of this paper is to analyze the root causes and determine the key issues that need to be improved in the business model of the SME manufacturing industry when they are facing the change from MP to MC (product variety, small lot size and short delivery time). We develop a new business model and new operation process for the SME manufacturing industry by implementing has refined business model described in this paper.

# 2. LITERATURE REVIEW

## *2.1. From Mass Production to Mass Customization*

The business process of manufacturing has changed a lot in the past few decades. It changed from MP to MC, then to small batch customization of products and short delivery time. MC is the rapid, low-cost production of goods that fulfill increasingly unique customer requirements. However, MC is not only about variety, but also about making precisely what the customer wants economically (Heizer et al., 2017). According to Graman and Bukovinsky (2005), MC implies the ability to customize a large volume of products and deliver them at close to MP prices, and it adopts the approach of creating variety and customization through flexibility and quick response.

The revised system was redesigned and the product development, manufacturing and logistics were affected in order to provide modularity and flexibility (Traian and Aurel 2015).

## *2.2. Overview of different Business Models in Manufacturing*

In the past, most of the manufacturing companies were using the Make-to-Stock (MTS) business model to handle MP. Due to the current market change from MP to MC, there are now different business models in the manufacturing environment, such as Assemble-to-Order (ATO), Make-to-Order (MTO) and Engineer-to-Order (ETO) (Olhager, 2003) and Configure-to-Order (CTO) (Aqlan et al., 2014). The different of those models are related to different Order Penetration Point (OPP), the OPP means the stage in the manufacturing value chain where the customized product is linked to a specific customer order (Olhager, 2003). OPP provides a way of distinguishing between manufacturing approaches, defining the point in the manufacturing process where a product is linked to a customer order (Haug et al., 2009). Figure 1 shows the OPP in five models, the dotted lines depict the production activities that are forecast-driven, and the straight lines depict customer-order-driven activities.

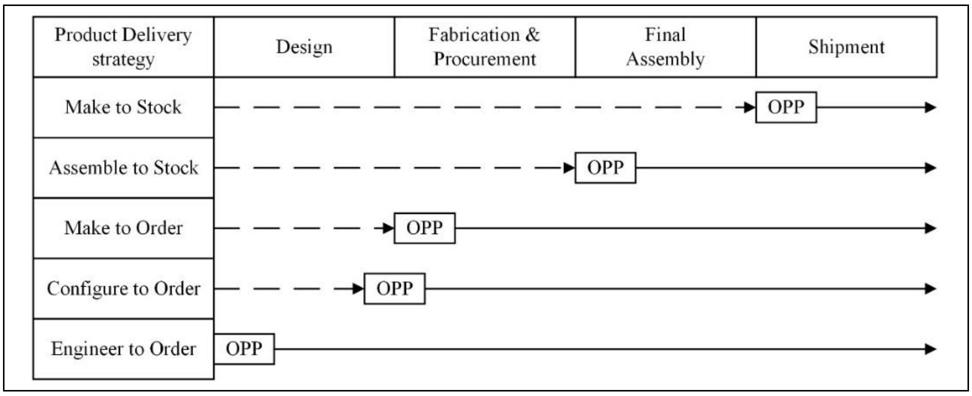


Figure 1. The OPP in MTS, ATO, MTO, CTO and ETO models

## *2.3. Overview of other methodologies for Mass Customization*

Time Postponement and form postponement are other methods of using inventory differentiation to solve the MC problems (Graman and Bukovinsky, 2005, Heizer et al., 2017). Time postponement delays the differentiation tasks of the operation tier as late as possible in the production flow process. House paint is an example of time postponement, where a unique color selected by a customer will be produced by adding the necessary pigment after customer confirmation. Form postponement is to standardize the upstream stages as much as possible so that the product remains generic longer. Standardization of components effectively delays the point of product differentiation through increasing component commonality and modularization. Dell computers use the form postponement method, where a specially configured computer will be assembled from standard components, modules and subassemblies after receiving the sales order

### *2.4. Internet of Things and Cloud Manufacturing*

Internet of Things (IOT) and cloud manufacturing provide another direction to solve the customized / personalized products (CPP) problem that used to be solved by the collective efforts from consumers, manufacturers and third parties (Yang et al., 2017). IOT provides real-time sensing and fast transmission capability of data, and can greatly facilitate remote operation in manufacturing activities and efficient collaboration among stakeholders. However, the method does not seems to provide communication among the machines in the production line. On the other hand, the cost of robots for the production line may not be affordable by SMEs.

### *2.5. Cellular Manufacturing*

Cellular manufacturing involves using multiple cells in an assembly line, and each of these cells is made up of one or more different machines to complete a certain task. Usually the cells are arranged in a "U-shape" design whereby it can allow an inspector move less and more easily in observing the whole process.

According to Torabi and Amiri (2012), cellular manufacturing focuses on shop floor control and it may be more effective in small and medium production sizes, and is suitable for products with steady demand. It may not be suitable for product with a high variation in demand and /or product mix.

### *2.6. Flexible Manufacturing and Three Dimensional Printing*

According to Tien (2011), there are a number of technological advances that can better enable MC, such as flexible manufacturing and three dimensional printing. Flexible manufacturing, sometimes referred to as rapid prototyping, is a key MC enabler, and depends on advanced computer and communication technologies. In the current technology, Three Dimensional (3D) prototyping uses the Computer-Aided Design (CAD) software to develop Two Dimensional (2D) layers of discrete thickness products, such as dental parts, hearing aids, knee replacements and other replacement parts. Although it can quickly develop customized models and eliminate the use of tooling or molding, the materials are limited to resins, thermoplastics, ceramics, composites or metal powders. In 2017, Murmura stated that 3D printing was mainly used for prototyping, but it has gained much attention as the process has proven to be compatible with industrial manufacturing beyond prototyping.

### *2.7. Limitation of Mass Customization*

According to James and Mondal (2019), there are a lot of limitations in the real MC environment. They found out that MC decreased machine efficiency, due to a lot of parameters involved such as product variety, lot size, changes in product design, and complexity in business process etc.

### *2.8. Customer Behavior*

For the customer, the advantage of MC is provided in the large product selection. Usually the price of MC is most likely lower and the delivery time is shorter than the full tailored product. A number of papers mentioned MC, and Haug and Piller analyzed the recent state of MC practice by answering four basic questions: “Do customers need customized products?”, “If yes, what prevents them from purchasing these offerings?'', ''Do we have the enabling technologies for MC?'', and ''why do many firms fail during and after the introduction of MC?'' (Haug, 2009; Piller, 2004).

The motivation for a company to switch from MP to MC is to allow customers to join the co-design process but keep the costs of products close to those of MP. It will also improve the internal processes, and let the customers modify the existing products. Besides, there is less price competition in customized products so that it could increase the market share of sales for customized products (Hsu, et al., 2014).

### *2.9. Research Gaps*

From the above, there are research gaps on how manufacturers handle the product variety in small lot sizes and in short delivery time. Even in Industry 4.0 papers, most focus on information flow in the supply chain and in inventory control, but few focus on physical flow of the production methods to handle the small lot size in customization. The methods of solving the production issues when facing the wide variety, small lot size and short delivery time are neglected. Therefore, in this project, we develop a new business model and new operation process for SME manufacturing companies to handle these situations.

## 3. RESEARCH METHODOLOGY

### *3.1. Running the Background Study*

This project analyzes the root causes and determines the key issues that need to be improved in the current business model of an SME manufacturing company when they are facing the change from MP to MC, small lot size and short delivery time. The roadmap of the research methodology includes five phases for the implementation of the proposed framework, as shown in Figure 2. The study includes the current business models and operation processes, addressing the problems faced, the limitations of the production processes and the limitations of product design.

### *3.2. Development the New Business Model and New Operation Process*

The project is based on the design of a new business model for the SME manufacturing industry and defining and identifying the criteria and Key Performance Indexes (KPI) to measure the improvement in the new business model. Further, the new operation process is also designed to run with the new business model, and restructured product design. The new business model is then fine-tuned and a feasibility study undertaken to ensure the requirements are fulfilled.

### *3.3. Strategic Management of Pricing, Delivery time and MOQ*

Strategy management for the selling price, delivery time, and MOQ is a hot topic in the marketing approach and in customer behavior. How to set the equilibrium point directly affects the result of the sales volume. Before implementing the new business model, the company should adopt strategy management for price setting, product delivery time and MOQ.

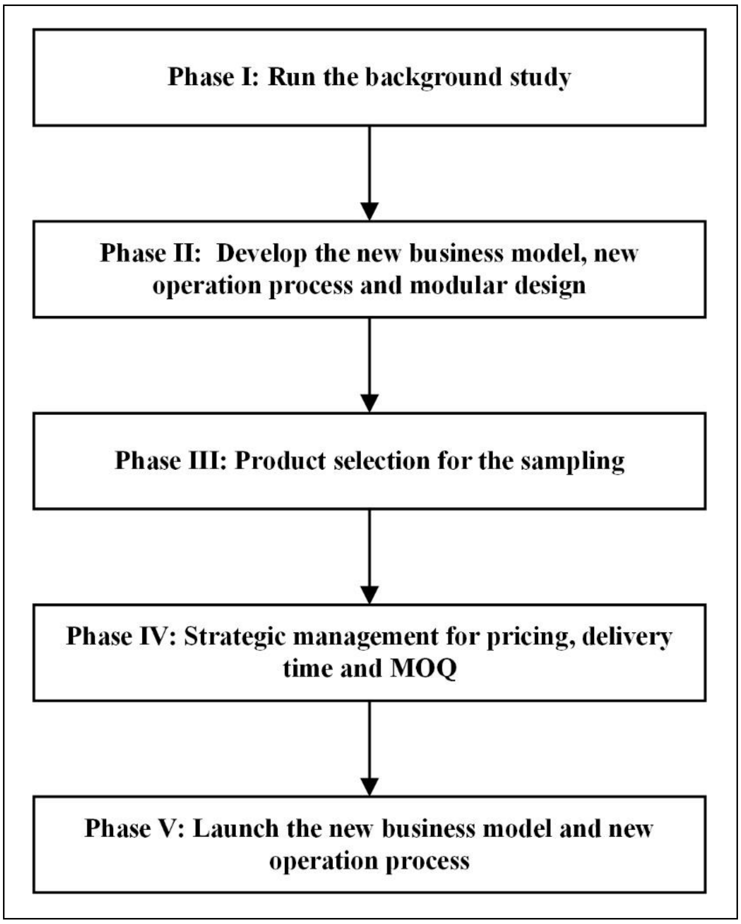


Figure 2. Roadmap of the Research Methodology

# 4. RUN THE BACKGROUND STUDY

## *4.1. Company Background and Current Business Model*

Marxu Company Limited is a leading classic tin toy and gift company in Hong Kong and has the largest tin toy factory located in Shanghai city. Its activities include manufacturing, and wholesale and retail business. It has its own brand – Saint John - and its markets include China, Hong Kong, France, Germany, Spain, Japan, Australia, the United Kingdom and the USA.

In the Marxu business model, MTS and MTO models are used independently to handle different kinds of business. Table 1 shows that Marxu uses the MTS model to run new design products and current products for retail, Business to Customer (B2C) from the e-commerce and retail shop. One of the reasons is that the labor and material costs per Stock Keeping Unit (SKU) in using the MTS model are lower than the for MTO model, and the product delivery time is shorter than the MTO model.

On the other hand, it uses the MTO model to produce all the customized products and current products for the wholesale business, thereby it does not need to keep a lot of finished products, and the delivery time in the wholesale business is sufficient for production and product delivery.

Table 1. Marxu business models

| | **Wholesale Business** | **Retail Business** |
|---|---|---|
| **New Standard Product** | MTS | MTS |
| **Current** | MTO | MTS |

| | | |
|---|---|---|
| **Standard Product** | | |
| **Customized Product** | MTO | MTO |

The Marxu operation process contains eight key phases: they are Product Design, Mold Making, Tinplate printing, QA & QC in Calibration, Tinplate Toasting, Tinplate stamping, Assembling & Packing, and QA & QC in Finished Goods. Table 2 shows the Marxu operation process.

Table 2. Marxu operation process.

| | |
|---|---|
| (Phase I)<br>Product Design | (Phase V)<br>Tinplate Toasting |
| (Phase II)<br>Mold Making | (Phase VI)<br>Tinplate Stamping |
| (Phase III)<br>Tinplate printing | (Phase VII)<br>Assembling & Packing |
| (Phase IV)<br>QA & QC<br>(Calibration) | (Phase VIII)<br>QA & QC<br>(Finished Goods) |

As the customer requirement and ordering are changing from standard products to customized products, the business models MTS and MTO cannot fulfill the requirement for product variety, small lot size, and short delivery time. After examining the problems faced, it was found that there are specific limitations in the production processes and product design.

*4.2. Limitation in Current Operation Process*

There are totally three operation processes with limitations: tinplate printing, tinplate toasting and tinplate stamping.

{i} The limitation in tinplate printing

The tinplate printing also belongs to process manufacturing. Before running the tinplate printing process, the following steps are taken for printing materials. Figure 3 shows the procedure of tinplate printing.

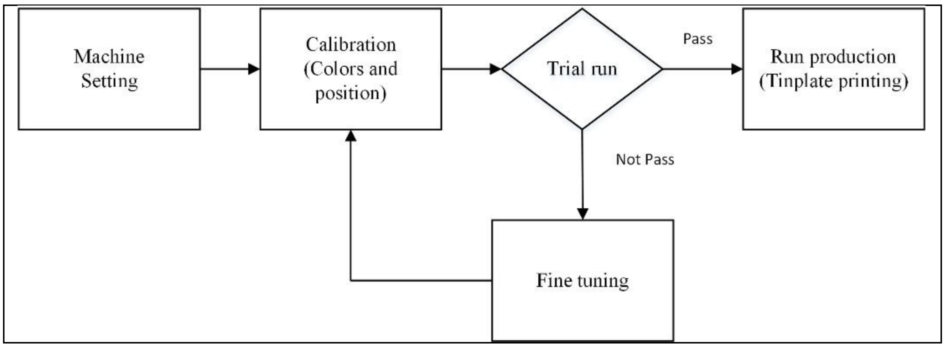


Figure 3. Marxu operation flow of tinplate printing

The key factors that need to be considered for tinplate printing are

- Time consumption during the machine setting
- Material wastage and labor time during the trial run and calibration

Therefore, Marxu sets an economic lot size in tinplate printing as 1000 sheets.

{ii} The limitation in tinplate toasting

The tinplate toasting also belongs to process manufacturing.  Same as tinplate printing, before running the tinplate toasting, the toasting machine needs to run a sequence of preparation procedures, as shown in Figure 4.

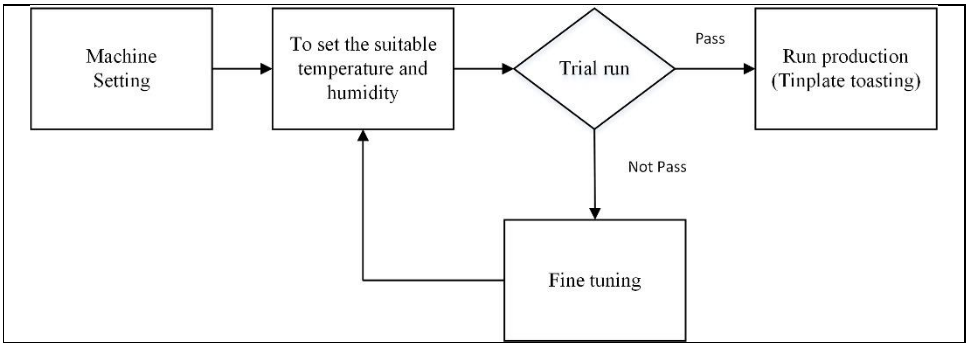

Figure 4. Marxu operation flow of tinplate toasting

The key factors that need to consider for the tinplate toasting are

- All the tinplate printing products must run the tinplate toasting within a short period
- Time consumption during the machine setting
- Resource (electricity) waste during turn start-up of the tinplate toasting machine to constant temperature and humidity

Therefore, Marxu sets an economic lot size in tinplate toasting as 1000 sheets.

{iii} The limitation in tinplate stamping

The tinplate stamping belongs to discrete manufacturing.  Marxu contains 12 sets of stamping machines in the production department, it could run 12 kinds of different parts concurrently.  Before running the tinplate stamping, it needs to run a sequence of preparation procedures.  Figure 5 shows the steps of preparation procedures.

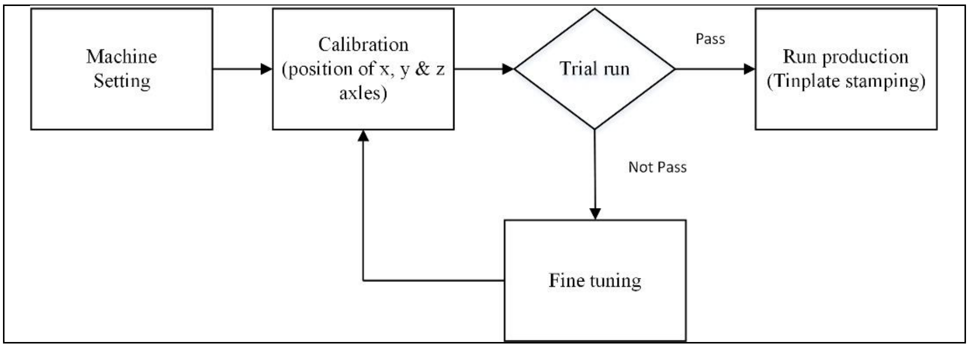

Figure 5. Marxu operation flow of tinplate stamping

The key factors that need to consider for the tinplate toasting printing are

- Time consumption during the machine setting
- Material wastage during the trial run

Therefore, Marxu sets an economic lot size in tinplate stamping as 500 sheets.

From the above limitation in the current business model and operation process, Marxu sets the MOQ to 300 units per item for the current standard products and 1000 units for the customized products in the wholesale business.

### *4.3. Product design*

The product design is based on the method of classic tin toy design so that most of the product designs do not consider product flexibility, mass variety, and standardization. New products need to go through all the phases of the operation process, and most of them are not be interchangeable or add-ons to other parts or modules to improve the product flexibility and mass variety.

Further, there are many products that do not have modular design or standardization thereby the parts in product A cannot be shared with product B. This is one of the reasons for the limited product flexibility and mass variety. Owing to the above reasons, the cost and the selling price of the customized products are very high, and the product delivery time of customized products is very long.

# 5. DEVELOP THE NEW BUSINESS MODEL, NEW OPERATION PROCESS AND MODULAR DESIGN

## *5.1. Develop the New Business Model*

There are a lot of criteria and constraints that need to be fulfilled when developing a new business model for SMEs.

{i} Limited resources in SMEs

Most SMEs have limited resources, so the initial and running costs of switching and applying the new business model should be as low as possible.

{ii} Easy to switch from the current business model to the new business model

The new business model needs to be exchanged and implemented easily from the current one, so that the switching process could involve a seamless integration.

{iii} To improve the product variety

The new business model needs to be flexible and cost-effective to handle the product variety and customized products.

{iv} To decrease the order quantity of MOQ

The new business model can decrease the order quantity per item, so as to improve the sales order and sales quantity, but would not increase any surplus in the inventory control.

{v} To improve the product deliverability

The new business model could improve the product deliverability and shorten the product delivery time.

{vi} To improve the inventory control

The new business model can improve inventory control and decrease the surplus in the warehouse.

The new business model is developed (Figure 6) and named as Make to Customization (MTC). It breaks through the current business model from wholesale and retail to the degree of customization and short delivery time. It also improves the two independent MTS and MTO models to five integrated MTS, ATO, MTO, CTO, and ETO models.

In the MTC, the MTS model is only assigned to handle the short delivery time of the new standard products. The ATO model used to process the long delivery time of the new standard products, all the current standard products, and all the slightly different customized products. The MTO model is used to process partially different customized products, the CTO model is used to handle unique customized products, and the ETO model is used to run the almost different customized product. From the above, the MTC not only integrates five individual models but also has a synergic effect on the products.

| | Delivery Time | |
|---|---|---|
| | Short | Long |
| New Standard Product | MTS | ATO |
| Current Standard Product | ATO | ATO |

| | Degree of Customization | | | |
|---|---|---|---|---|
| | Slightly different | Partially different | Unique | Almost different |
| Customization Product | ATO | MTO | CTO | ETO |

Figure 6. New Business Model - Make to Customization

### *5.2. Develop the Two-Phase Operation Process*

To implement the MTC model, a new operation process was developed and named as "Two-Phase Operation Process" (Figure 7). In the current operation process, the MTS and MTO models are run separately, and in the new business process, five models are integrated using one intelligent business process. The principle of the Two-phase operation process is time postponement, and the mechanism separates the process of the whole production into two phases, phase I and phase II.

{i} Phase I

In phase I, the process is based on sales analysis and forecasting, and the minimum stock level to produce and assemble the parts, common-parts and standard products, and then transfer them to the warehouse. Besides, it will process the customized parts after receiving the sales order and using ATO, MTO, CTO, or ETO models for processing.

{ii} Phase II

In phase II, it will run the final assembly and shipment process. This process will be run immediately after the Phase I process when using the MTS model; after receiving the sales order handled by the ATO model, or after completing the further process for customized component in Phase I when using the MTO, CTO and ETO models.

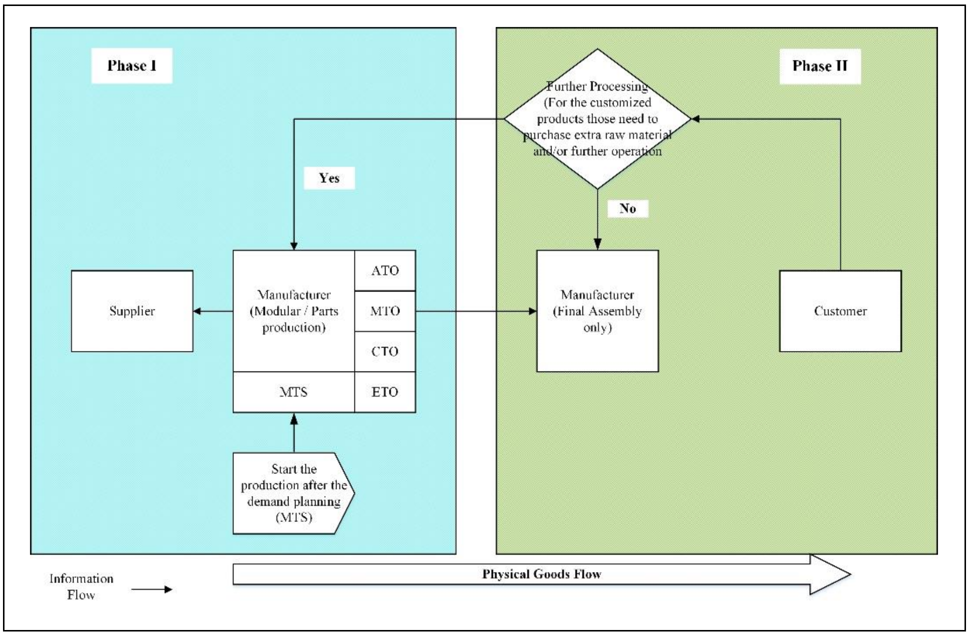


Figure 7. Two-Phase Operation Process

### *5.3. Product Reengineering: Modular Design and Standardization*

To improve the efficiency and effectiveness of the new business model and the Two-phase operation process method, module design and standardization should be applied. Although module design is a general design method, it is new to the traditional or tin toy industry.  Figure 8 shows the module design products of parts such as arm, head, and cap, could be interchangeable, thus they could use the ATO, MTO, CTO, and ETO models to produce different degrees of customized products.  It can improve the product flexibility, variety, and shorten the production time.

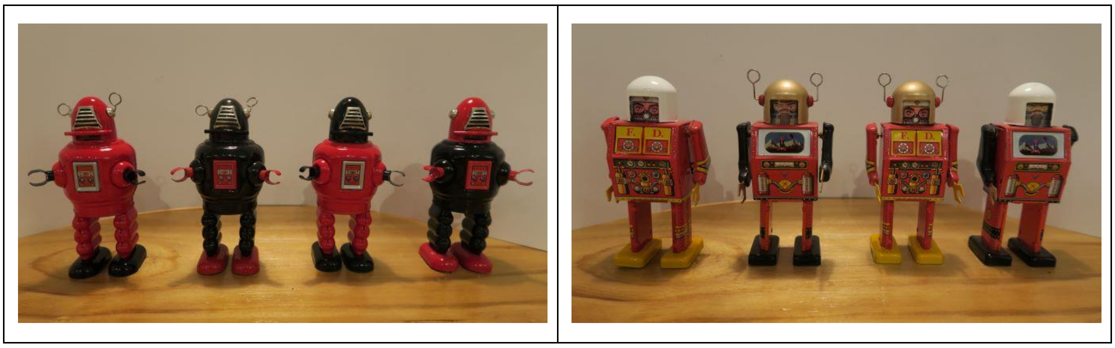

Figure 8. Products with modular design

### *5.4. Product selection for the Trial Run Sampling*

The new business model and the Two-phase operation process will run for four months, and all the selected products for sampling need to cover all kinds of models in the MTC. In the sample selection, all the samples of the standard products and customized products must include five different models, so there are 25 kinds of samples to be selected.

### *5.5. Strategy Management for Pricing, Delivery Time and MOQ*

In order to determine the competition in customized products, the strategy is to set up an equilibrium point among the selling price, product delivery time and MOQ to avoid negative the customer buying behavior (Figure 9).

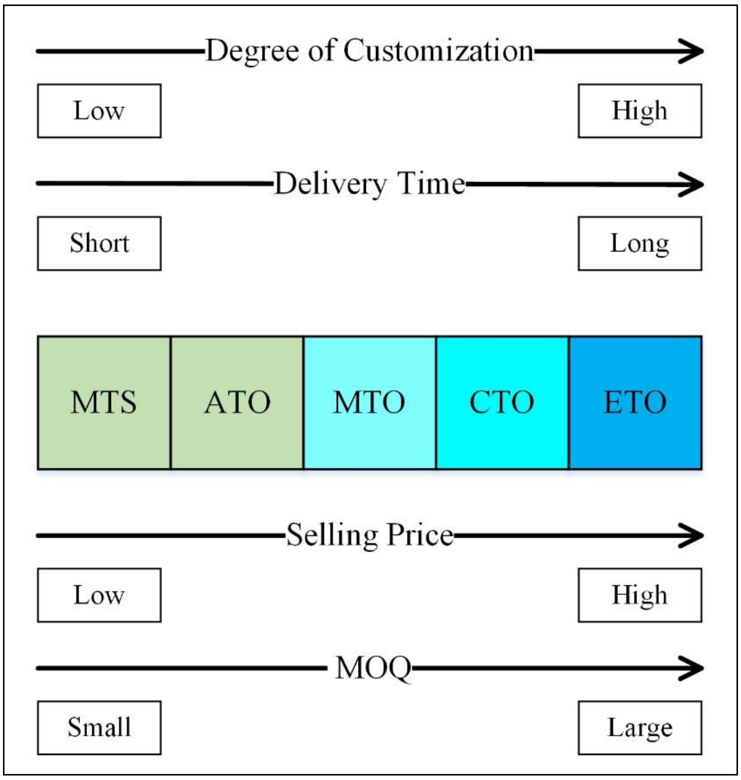


Figure 9. Strategy of the degree of customization, delivery time, selling price and MOQ

For the standard and slightly different customized products handled by the MTS and ATO models, due to the production cost and time being very close, then the selling price, delivery time and MOQ for those products will be the same. Besides, the MOQ quantity is reduced from 300 to 50 units per item, and the product delivery time is one day for delivery (Table 3).

For the partially different and unique customized products handled by the MTO and CTO models, due to the production cost and time decreasing, the selling price is set to around 20% more than the standard product, and the product delivery time is shorter than the current customized product, and the MOQ is reduced from 1000 to 200 units per item. Same as partially different customized products, the almost different customized products handled by the ETO model, the MOQ is reduced from 1000 to 300 units per item.

Table 3. Summary of the Pricing, delivery time and MOQ for different models

| | **Before** | | **After** | | | | |
|---|---|---|---|---|---|---|---|
| | **MTS** | **MTO** | **MTS** | **ATO** | **MTO** | **CTO** | **ETO** |
| **Degree of Customized Product** | Standard Product | Customized Product | Standard | Standard /Slightly different | Partially different | Unique | Almost different |
| **Delivery time** | 1 day | Longer than standard product | 1 day | | Shorter than current customized product | | |
| **Selling Price** | - | Higher than standard product | Same | | Lower than current customized product | | |
| **MOQ (Unit)** | 300 | 1000 | 50 | | 200 | 300 | |

## 6. RESULTS AND DISCUSSION

The proposed new business model with the Two-phase operation process and module design enables the manufacturer to solve the current problems in the market – mass customization, small in lot size, and short delivery time. After a trial run of the new method in the case company for four months, it was found that the sales quantity increased, and the number of inventory in the warehouse decreased.

Furthers, the MTC model can reduce the quantity of MOQ, and shorten the product delivery time for most of the customized products, so that it can improve the sales volume and decrease any surplus in inventory.

### *6.1. Improving the Sales Quantity*

As customized products are controlled by the MTC model, the total sales volume is increased by 29%. Table 4 shows the comparison of the sales volume before and after the proposed model.

Table 4. Summary of four months sales quantity

| Product | Before | After (Average in 4 months) | Percentage of Improvement |
|---|---|---|---|
| **Standard** | 4,100 | 2,375 | -42% |
| **All Customized Product** | 1,500 | 4,875 | 225% |
| **Total (Unit)** | 5,600 | 7,250 | 29% |

Table 5 shows that sales volume of slightly different customized products is 41% of the total sales volume, highlighting the trend in the demand for different customized products, especially as the slightly different customized products is increasing rapidly, but standard products is seen reverse. In the past, the selling price of slightly different customized product was higher than the standard products, the delivery time was longer, and the MOQ was higher. After using the MTC model to produce slightly different customized products, the selling price, product delivery time, and MOQ are the same as for the standard product. This is the reason that the demand from the market is for slightly different customized products.

Table 5. Detail of four months sales quantity

| Degree of Customized Product | Before | After (Average in 4 months) | Percentage |
|---|---|---|---|
| **Standard** | 4,100 | 2,375 | 33% |
| **Slightly different** | | 2,975 | 41% |
| **Partially different** | | 350 | 5% |
| **Unique** | 1,500 | 1,400 | 19% |
| **Almost different** | | 150 | 2% |
| **Total (Unit)** | 5,600 | 7,250 | 100% |

### *6.2. Reduce the Surplus in the Inventory*

After using the MTC model, the percentage of all the finished goods in the warehouse is decreased by 62%. Table 6 shows the summaries of the finished goods in the warehouse. For standard products, the percentage of finished goods decreased by 74% (It decreased from 6000 units to 1550 units). For all the customized products, as some items were using non-modular design products, so the surplus slightly increases 200 units.

Due to the economic lot size in production being 1000 units, all the surplus finished goods are kept in the warehouse. After using the MTC and the Two-phase operation process, the surplus for different customized products is improved. The MTC transforms the surplus to improve product flexibility and variety and shortens the product delivery time.

Table 6. Summary of the stock data (finished goods)

| **Product** | **Before** | **After** (The end of last month) | **Percentage of Improvement** |
|---|---|---|---|
| **Standard** | 6,000 | 1,550 | 74% |
| **All Customized Product** | 900 | 1,100 | -22% |
| **Total (Unit)** | 6,900 | 2,650 | 62% |

### *6.3. Shorten the Product Delivery Time*

In the MTC, the ATO model meets the target – it could complete the final assembly process and start the product delivery within one day (Table 7). There is no doubt that the delivery time of the MTS model is the shortest, but it limits product variety and flexibility. The ATO model includes the advantages of product variety, flexibility, and shortens the product delivery time. It proves that the ATO model can replace the MTS model for handling all the standard and slightly different customized products in these four months successfully.

Table 7. Summary of the product delivery time for slightly different customized product

| **Product** | **Before** | **After** |
|---|---|---|

| | | |
|---|---|---|
| **Current Standard Product** | 1 day | 1 day |
| **Slightly different Customized Product** | Longer than 1 day | 1 day |

For the partially customized products, the product delivery time in using the new MTO model is faster than the current MTO model. For the unique customized products, the production time in using the CTO model with module design is 50% shorter than using the current MTO model without module design.

### *6.4. Decrease the Minimum Order Quantity*

By implementing the MTC model, it reduces the quantity of the MOQ for the standard products from 300 to 50 units, and customized products from 1000 to 50- 300 units. After running the revised MOQ for four months, there is not only an increase in the sales volume but also the redundancy of the final product was improved. Table 8 shows the MOQ for all products.

Table 8. Summary of the MOQ per item

| **Product** | **Before (Unit)** | **After (Unit)** |
|---|---|---|
| **Current Standard Product** | 300 | 50 |
| **All Customized Product** | 1000 | 50 - 300 |

## 7. CONCLUSIONS

In the Marxu production line, the economic lot size for production is set to 1000 units so that the MOQ of the standard and customized products is set to 300 and 1000 units, resulting in a large surplus of the final products in the warehouse.

After using the MTC model with the Two-phase operation process and module design for four months, even reducing the MOQ quantity, it remedies the surplus for different customized products and speeds up the delivery time for a modular design product. It turns out that after reducing the order quantity, increasing the product variety, and shortening the product delivery time, it can not only improve the sales volume and product flexibility but also decreases the inventory surplus.

It shows that customers prefer slightly different customized products compared to standard products, if the price, product delivery time, and MOQ between two kinds of products are the same. Otherwise, they prefer the standard product rather than the customized product.

On the other hand, partially different, unique, and almost different customized products belong to the niche market, where most customers accept a higher selling price, longer delivery time, and higher MOQ.

In the current business model, with overstocking in the warehouse, it will affect the cash flow and the overhead costs in inventory control. In using MTC model, due to the five models being integrated, the whole operation process is split into two phases and adopt modular design product; therefore the surplus will create the synergic effect, and will transform the surplus to business opportunities and improve the operation efficiency and effectiveness.

As the MTC model and the Two-phase operation process have only ran for four months, future research will be based on carrying out continuous improvement through the Plan-Do-Check-Act (PDCA) cycle approach for improving the model and process.

## REFERENCES


- Aqlan F., Lam S. S. and Ramakrishnan S., 2014, An integrated simulation – optimization study for consolidating production lines in a configure-to-order production environment. *International Journal of Production Economics* 148, pp. 51–61
- Graman G. A. and Bukovinsky D. M, 2005, From Mass Production to Mass Customization: Postponement of Inventory Differentiation. *The Journal of Corporate Accounting & Finance*, Wiley Periodicals, Inc. pp. 61-65
- Haug A., Ladeby K., Edwards K., 2009, From engineer-to-order to mass customization. *Management Research News*, Vol. 32 Issue: 7, pp.633-644
- Heizer J., Render B. and Munson C., Operations Management: sustainability and supply chain management, 2017. *Pearson*, 10th edition, pp. 284 – 286; pp. 441 – 468
- Hsu W. T., Lu Y., and Ng T., 2014, Does competition lead to customization? *Journal of Economic Behavior & Organization* 106, pp.10–28
- James C.D. and Mondal S., A review of machine efficiency in mass customization. *An International Journal*, Vol. 26 No. 2, 2019, pp. 638-691
- Olhager J., 2003, Strategic positioning of the order penetration point. *International Journal of Production Economics*, 85, pp. 319–329.
- Piller F. T., 2004, Mass Customization: Reflections on the State of the Concept. *The International Journal of Flexible Manufacturing Systems*, 16, pp.313–334.
- Radziwona, A., Bilberg, A., Bogers, M., Madsen, E.S., 2014, The smart factory: exploring adaptive and flexible manufacturing solutions. *Procedia Engineering* 69, pp. 1184–1190.
- Source of SME in China, available at: http://www.gov.cn/zwgk/2011-

07/04/content_1898747.htm

- Source of SME in EU, available at: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en
- Source of SME in HK, available at: https://www.success.tid.gov.hk/english/aboutus/sme/service_detail_6863.html
- Source of SME in USA, available at: https://ustr.gov/issue-areas/small-business
- Thürer M., Silva C. and Stevenson M., 2011, Optimising workload norms: the influence of shop floor characteristics on setting workload norms for the workload control concept. *International Journal of Production Research*, Vol. 49:4, pp. 1151–1171
- Tien J. M., 2011, Manufacturing and services: From mass production to mass customization. *Journal of Systems Science and Systems Engineering*, Vol.20(2), pp.129-154
- Torabi S.A. and Amiri A. S., 2012, A possibilistic approach for designing hybrid cellular manufacturing systems. *International Journal of Production Research*, Vol. 50, No. 15, pp. 4090–4104
- Traian M. and Aurel T., 2015, From Mass Production to Mass Customization of LED Lighting Systems - Case Study. *Applied Mechanics and Materials*, Vol 760, pp. 671-676.
- Yang C., Lan S., Shen W., Huang G. Q., Wang X., and Lin T., 2017, Towards product customization and personalization in IoT-enabled cloud manufacturing. *Cluster Computer*, 20, pp. 1717–1730