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Developing an integrated business model in the manufacturing industry – An AHP approach

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ABSTRACT

Due to the market competition in the current business environment, there are many pressures on the Small and Medium-sized Enterprise (SME) manufacturers. Most SMEs face challenges changing the market from Mass Production (MP) to Mass Customization (MC). The purpose of this study is mainly based on drilling down into an SME manufacturer, exploring the limitation in its current business model, and determining the boundaries of its operation process. This research paper designs an Analytical Hierarchy Process (AHP) model to develop a new business model to resolve the MC issue in SME manufacturers. The aim of the new business model should be to improve company profit. Thereby seven criteria in the AHP model are profit, Minimum Order Quantity (MOQ), flexibility, inventory control, delivery time, revenue from existing customers, and new customers for customized products. The methodology is pilot-run the new business model and compares the results among the AHP, current, and new business models. The results prove that the new business model solves the problems in MC and creates a synergic effect on the business. The study provides a method that uses an AHP model for developing an integrated business model for SME manufacturers.

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1. Introduction

In the current business environment, purchasing behavior is changing from standard products to customized products, such as choosing products with specific colors, styles, or photos on the products. Therefore, the business process has changed from Mass Production (MP) to Mass Customization (MC) for mass variety, small lot size, and short delivery time. Due to the market competition, most SME manufacturers are facing how to change the business model from MP to MC.

According to the statistics from Mainland China, the European Union (EU), Hong Kong, and the US, Small and Medium-sized Enterprises (SMEs) represent over 98% of all business units in their countries [1]–[4]. In the EU, SMEs provide approximately 20% of all jobs in the industry

and about 21% of the total EU GDP [5]. There are many SMEs worldwide, but many methods suggested for improving performance are not practical [6]. Although SMEs represent more than 98% of all business units in their countries, their bargaining power is lower than that of large organizations, and their pressure is higher than that of large organizations.

Due to the traditional business models being limited for MC products, many SME manufacturers want to implement new business models for MC products. This project develops a new business approach by using an Analytical Hierarchy Process (AHP) model to solve the mass customization issue in the SME manufacturing industry. By designing an AHP model, based on the results of the model rankings, new business models and resource allocation can be formulated to enhance the business market share. To validate the value of the AHP model, the new business model is pilot run then the results are compared.

2. Method

2.1. Literature review

A. The market changed from standardization to customization

In the past few decades, E-commerce has changed customer behavior from purchasing standard products to customized products, and the business process of manufacturers has changed from MP to MC, with small batch size and short delivery time. MC indicates producing a large volume of customized products and delivering them close to MP prices with product variety, flexibility, and quick response [7]. In the past, MC meant rapid and low-cost production that fulfilled the MC requirements, but now customers want MC not only in product variety but with precision and economics [8]. Product development, manufacturing, and logistics are needed to provide flexibility and modularity [9].

B. Different business models in manufacturing

Most manufacturers used the Make-to-Stock (MTS) business model in the MP era. When the market changed from MP to MC, there were many different business models in the manufacturing environment, such as ATO, Make-to-Order (MTO) and Engineer-to-Order (ETO) [10], and Configure-to-Order (CTO) [11]. The difference in such models is related to the different positions of the Order Penetration Point (OPP). OPP is a point in the production process where the customer orders a customized product. It provides a way of distinguishing between manufacturing approaches and defining the point in the manufacturing process where a product is linked to a customer order [12]. Fig. 1 shows the OPP in five different models, the dotted lines showing that the production processes are driven by forecasting, and the straight lines indicate that the processes are driven by customer order.

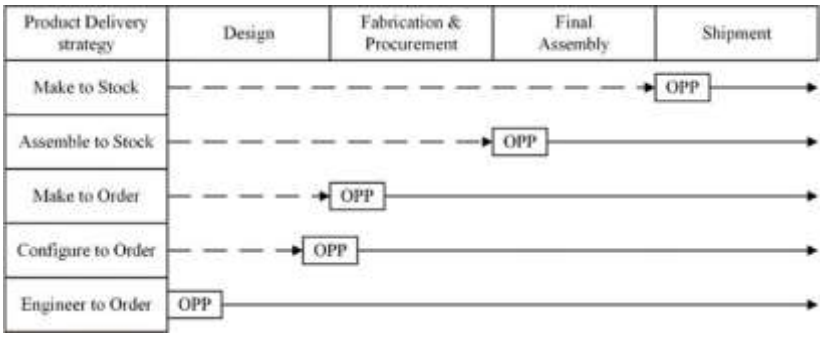

Fig. 1. The OPP in MTS, ATO, MTO, CTO, and ETO models

- Model of make-to-stock

The MTS model is suitable for producing standard products of low variety and high volume [7]. In the MTS model, products are created before receiving a customer order.

The delivery time is short, but it needs a lot of final products. As shown in Fig. 1, the OPP is located in the shipment phase.

- Model of assemble-to-Order
  The ATO model uses forecasting but runs the final assembly process after receiving the sales order. The advantage of the ATO model is in producing a variety of products from limited components, and it can start the final assembly process after receiving the sales order. As shown in Fig. 1, the OPP is located in the final assembly phase.
- Model of make-to-order
  The MTO model provides various customized products and high operating costs [7]. Due to the raw materials being purchased and produced after receiving a customer order, the delivery time is longer than using the MTS and ATO models. As shown in Fig. 1, the OPP is located in the fabrication and procurement phase.
- Model of configure-to-order
  The CTO model produces and keeps the components to a forecasted plan, then assembles the components after receiving the sales order. The advantages of the CTO model are the flexibility of mass customization, delivery time, and mass production efficiency [11]. In the ATO and MTO models, manufacturers can configure the products based on the customer's order. The CTO model allows customers to configure the finished product they want to buy. As shown in Fig. 1, the OPP is located between the design, fabrication & procurement phases.
- Model of engineer-to-order
  The ETO model provides an environment with ultimate customization. The final product may not be modified in terms of specifications but may be required to change the design and production methods. As shown in Fig. 1, the OPP is located in the design phase, so the delivery time will be very long and includes engineering design, material acquisition, and manufacturing time [13].

C. Time postponement and form postponement
According to [7], [8], time postponement and form postponement are other methods of using inventory differentiation to solve MC problems. Time postponement delays the operation process for differentiation tasks as late as possible in the production flow process. Form postponement standardizes the components and effectively delays the point of product differentiation through increasing component commonality and modularization.

D. Limitations in production for mass customization
According to [14], MC has many limitations involving many parameters, such as product variety, batch size, and changes in product design, so it decreases machine efficiency.

E. Analytical hierarchy process model
In order to prioritize the performance of different business models, we use the AHP method to prioritize different models in sequence for decision-making. AHP was developed by Saaty in 1970 and is a popular approach for multicriteria decision-making to tackle problems involving both intuitive and rational factors [15]. According to [16], the AHP method defined optimal models. It is one of the decision-making methods with a set of related criteria to provide the priority for each criterion and support sensitivity analysis of the results [17]. This method helps to choose the best from numerous alternatives [18], assessed using a few criteria [19].

F. The key performance index
According to [20], the performance indexes for measuring mass customization are "customer influence," "product scope," "product cost," and "lead time." Using such indexes,

the strategy that has the most significant impact on MC capabilities can be identified. Moreover, we use the AHP to develop the importance of the attributes and the strategies in the new business model. The Key Performance Index (KPI) of the Supply Chain for the SME includes source, make, deliver, procurement, manufacturing, replenishment, and customer order [21].

G. Research gaps
According to [6], many SMEs worldwide, but many methods they use to improve performance are not practical. Therefore, this project tries to design an AHP model to organize and analyze which models are optimal when developing a new business model for a case company. It is very significant to define the weighting and function of each aspect of a new business model. Then compares and validates the AHP model with the results after the pilot run.

2.2. Research Methodology

This project studies the current business model of an SME manufacturer when facing the challenge from MP to MC, small lot sizes, and short delivery times. We design an AHP model to determine the ranking and priority of different models, then, based on the results, develop the new business model. Finally, we compare the AHP model and the pilot run results. Fig. 2 shows the roadmap of the research methodology, which includes five phases for implementing the proposed framework.

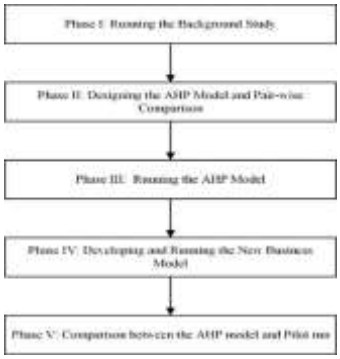

Fig. 2. Roadmap of the Research Methodology

A. Running the background study
This project studies SME manufacturers' current business models and operational processes when facing the change from MP to MC. It also includes the resources in the company and the competition in that industry.

B. Designing the AHP model and pairwise comparison
In order to present an example of solving the business model selection problem in the manufacturing industry, we take the criteria such as profit, flexibility, variety, and the delivery time into account for supporting the business modeling. AHP is used to prioritize the models in sequence for decision-making. AHP is a popular approach to creating a multicriteria decision-making model to tackle problems involving both intuitive and rational factors [15]. According to [22], to implement AHP, there are four steps in developing the AHP model: AHP structure design, questionnaire design for pairwise comparison, matrix construction and consistency checking, and selection based on the overall score.

AHP is a multicriteria decision-making method for selecting alternatives based on criteria. It is a three-level hierarchy with goals, criteria, and alternatives. After identifying the criteria and alternatives, a questionnaire is designed and distributed to the decision makers, asking them for the weighting and the importance ratio when running a pairwise comparison. Table 1 shows the relative importance nine-point scale and the description.

Table 1. Relative importance scale and its description

Intensity ofimportance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or Demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

After collecting the questionnaires, an evaluation matrix is used to summarise the result of the pairwise comparison. The result of the pairwise comparison from the N criteria can be summarized in an (n x n) evaluation matrix A in which each element aij = (1, 2...n) is the quotient of weights of the criteria. Referring to (1), every element aij where i, j = (1, 2 ...n) is the quotient of weights of the criteria.

$$A = [a_{ij}] = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \qquad a_{ii} = 1,\ a_{ij} = \frac{1}{a_{ji}},\ a_{ij} \neq 0 \tag{1}$$

For the Consistency Ratio (CR), Saaty proposed that if the CR is more than 0.1, the matrix is defined as inconsistent.

C. Developing and running the new business model

The AHP model uses the free educational software Super Decision [23] and implements AHP, which Thomas Saaty and his team developed.

D. Comparing the AHP model and pilot run

After running the AHP model, the results are used to develop the new business model. The advantage is to increase the precision and improve the performance of the new business model and prepare for resource allocation. Then the new business model will launch four months after the pilot run.

E. Running the AHP model

After the pilot running of the new business model, we compare the results to measure the precision of the AHP model. The AHP model provides a clear roadmap and cost-effective solution for other SME manufacturers to enhance their business models.

2.3. Case Study

ABC Company Limited is a leading classic tin toy and gift company in Hong Kong and has the largest tin toy factory in Shanghai. Its activities include manufacturing, wholesale and retail business. It owns its brand – Saint John - and the markets include China, Hong Kong, and other countries.

A. Running the background study

ABC uses the MTS and MTO models to handle different kinds of business. Table 2 shows that it uses the MTS model to produce new design products and current products for retail. One of the reasons is that the labor and material costs per Stock Keeping Unit (SKU) in using the MTS model are lower than for the MTO model, and the delivery time is shorter than for the MTO model. However, it uses the MTO model to handle all the customized and current products for the wholesale business so that it does not need to stock many finished goods.

Table 2. ABC business models

	Wholesale Business	Retail Business
New Standard Product	MTS	MTS
Current Standard Product	MTO	MTS
Customized Product	MTO	MTO

B. Problems faced by the company

As the customer requirements are changing from standard products to customized products, MTS and MTO business models cannot fulfill the requirements for mass customization, product variety, small lot size, and short delivery time. Since the economic lot size in the production lines is set as 1000 units, ABC sets the MOQ as 300 units per item for the current standard products and 1000 units for the customized products in the wholesale business.

Therefore, many sales orders are canceled due to the large volume in MOQ, long delivery time, high production cost, and selling price. Besides, ABC cannot improve its business strategies to attract new customers, so there is much surplus. As a result, ABC wants to develop a business model to improve its business.

C. Designing the AHP model and pairwise comparison

Fig. 3 shows an AHP that is designed for selecting and weighing the models that are the most beneficial to ABC. It is a 3-level hierarchy with goals, criteria, and alternatives. To prioritize the models, all the top management in ABC confirmed that the aims of the new business model should be to improve company profit. Although determining the MTS, ATO, MTO, CTO, and ETO models are based on the products that will be produced, due to the limited resource, they may not implement all the models or focus on the suitable models for their business strategies. Seven criteria are profit, MOQ, flexibility, inventory control, delivery time, revenue from existing customers, and revenue from new customers for the customized products are defined. These seven criteria are the KPI for the new business model in ABC and are similar to most SME Companies worldwide.

The seven criteria in the AHP model:

- Profit (B1)
  Profit is a critical criterion that companies need to consider when developing a business model. If the sales or quantity increases within a period, the profit increases. It is one of the KPIs to measure the performance of the business model.
- The MOQ in sales order (B2)
  In the current business model, ABC sets the MOQ to 300 units for a standard product and 1000 units for a unique customized product. In the new business model, ABC needs to decrease the quantity of the MOQ to improve the small lot size and sales volume.
- Flexibility (B3)
  Flexibility measures the degree of customized products and variety, and high product flexibility can increase product variety and degree of customization.
- Inventory control (B4)
  Inventory control measures the number of idle finished goods. When there is much inventory, it will affect the cash flow and the need to increase the area in the warehouse. Besides, the products must be written off or obsoleted due to metal rusting and color fading.
- Deliverability (B5)
  Deliverability means the products are deliverable to the customer and measures the time to deliver to the customer after receiving the sales order. Nowadays, most customers want their products as soon as possible, so product delivery time is one of the criteria in the AHP model.
- Revenue from existing customers for customized products (B6)
  Revenue from existing customers for customized products is another criterion to be measured in the new business model. A KPI of the new business model is product flexibility for handling different degrees of customized products. If the revenue from existing customers for customized products increases, existing customers want to purchase customized products. So this criterion measures the sales volume of the customized products of existing customers.

- Revenue from new customers for customized products (B7)
  Revenue from new customers for customized products is another indicator to measure the new business model. The attraction of customized products may be different between existing customers and new customers, so this criterion is to measure the sales volume of the customized products of new customers.

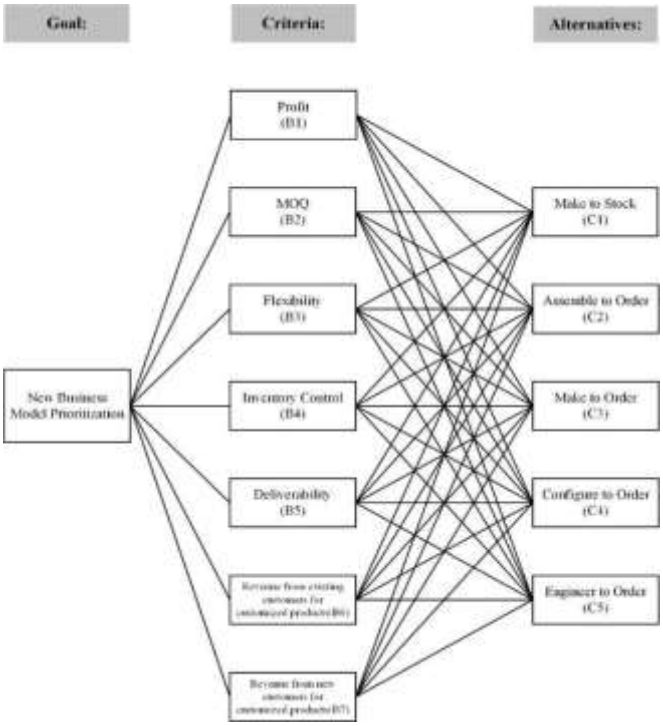

Fig. 3.AHP structure for new business model prioritization

D. Selecting different models for the alternatives

Due to the new business model needing to handle different kinds of customized products, the alternatives include five models: MTS, ATO, MTO, CTO, and ETO models. Fig. 4 shows the relationship between five models with different degrees of customized products. The MTS model produces standard products; the ATO, MTO, CTO, and ETO models handle different degrees of customized products.

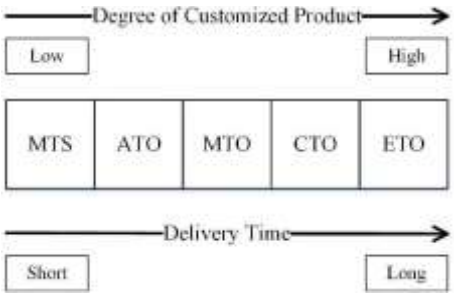

Fig. 4. Five different models and degrees of customized products

3. Results and discussion

3.1. Summary of the overall score in AHP models

The proposed AHP model ranks and prioritizes different models in developing a new integrated business model. After running the AHP model, Fig. 5 shows that the ATO model has the highest weighting of 52.6%, followed by the MTO, MTS, CTO, and ETO models at 22.7%, 10.1 %, 9.9%, and 4.7%, respectively.

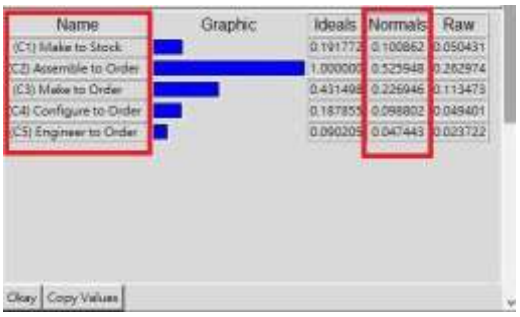

Fig. 5. A set of the overall synthesized priorities for the alternatives.

Table 3 shows the summary results after running the AHP model, where the ATO model has the highest weighting of 52.4% to 53.7%, followed by the MTO and MTS models, which occupy 20.1% to 22.7% and 10.1 to 13.3% respectively. The CTO and ETO models have fourth and fifth weighting. After considering the seven criteria, the ATO model has the highest priority or weighting in contributing to ABC or other SME manufacturers.

Table 3. Summary of the AHP model of overall weighting score

Item	Position	MTS	ATO	MTO	CTO	ETO
1	Company Director	10.1%	52.6%	22.7%	9.9%	4.7%
2	Sales Manager	12.0%	53.7%	20.1%	9.9%	4.3%
3	Operation Manager	13.3%	52.4%	21.5%	8.9%	3.9%
	Ranking	3	1	2	4	5

3.2. Global weights and final ranking

Table 4 shows the overall weights of the criteria, and it is clear that profit is the main criterion from all the top management (35.8% - 42.3%). The company director is all-around and focuses on long-term revenue rather than short-term revenue. Hence, the second and third-ranked criteria are "Revenue from new customers in the customized product" and "Revenue from existing customers in the customized product." However, the sales manager is more concerned about the short-term revenue, so the second and third-ranked criteria are opposite to the company director - "Revenue from existing customers in the customized product" and "Revenue from a customer in the customized product." Inventory control seems to be the lowest priority to consider. On the other hand, the operation manager focuses on production with second and third-ranked criteria of product flexibility and delivery time.

Table 4. Summary of the overall weight of criteria

Item	Position	Profit	MOQ	Flexibility	Inventory control	Deliverability	Revenue from existing customers for customized product	Revenue from new customers for customizedproduct
1	Company Director	35.8%	7.5%	8.1%	2.6%	8.2%	15.8%	22.0%
2	Sales Manager	42.3%	10.3%	10.0%	1.9%	7.6%	16.2%	11.7%
3	Operation Manager	35.9%	3.2%	21.0%	5.8%	18.5%	7.8%	7.8%
4	Ranking	1	6	4	7	5	3	2

Based on Table 4, item 4 shows the final ranking of the seven criteria: "Profit," "Revenue from new customers for customized product," "Revenue from existing customers for customized product," "Flexibility," "Deliverability," "MOQ" and "Inventory control."

The results show that the ATO and MTO models have the first two highest rankings from most criteria (except deliverability), so they are the most suitable models for ABC to improve its current problems.

3.3. Developing the new business model

Fig. 6 shows the new business model developed and named Make to Customization (MTC). In the MTC, the weighting of different models is based on the ranking in the AHP model. The ATO model has the highest ranking and is assigned to handle new and current standard products and slightly different customized products. The second-ranked MTO model is used to process partially different customized products, and the third-ranked MTS model is used to produce speedy new standard products. The fourth-ranked CTO model runs unique customized products, and the fifth-ranked ETO model runs almost different customized 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
Customized Product	ATO	MTO	CTO	ETO

Fig. 6.ABC New Business Model

The MTC model breaks through the current business model from wholesale and retail to different degrees of customized products. It integrates five MTS, MTO, MTO, CTO, and ETO models and provides a synergic effect on the products.

3.4. Running the new business model

Table 5 and Table 6 show that the sales volume increased by 29%. The percentage of all the finished goods decreased by 62% during the pilot run.

Table 5. Summary of the sales volume

Product	Before using new business model	After using the new business model (Average)	Percentage of Improvement
Standard	4,100	2,375	-42%
All Customized Product	1,500	4,875	225%
Total (Unit)	5,600	7,250	29%

Besides, the MTC model can reduce the quantity of MOQ and shorten the product delivery time for most customized products, improving the sales volume and decreasing the surplus inventory.

Table 6. Summary of the stock (finished goods)

Product	Before using new business model	After using the newbusiness model (at the end of last month)	Percentage of Improvement
Standard	6,000	1,550	74%
All Customized Product	900	1,100	-22%

Table 5 and Table 7 show that all customized products increased rapidly, the slightly different customized products increased by 41%, but the standard products decreased by 42%. In the past, the selling price of the customized product was higher, the delivery time was longer, and the MOQ was higher than the standard product. In using the new business model, the selling price, delivery time, and MOQ are the same between slightly different customized and standard products. This is why the sales volume of slightly different customized products is higher than the standard product.

Table 7. Detail of pilot run sales volume

Degree in Customized Product	Before using the new businessmodel	After using the new business model (Average)	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%

Table 8 shows the weighting of different models before and after using the new business model. In the new business model, 66% of products are produced by the ATO model, the MTO model produces 18%, and the MTS model produces 8% of products.

Table 8. Different models in producing the products

Model	Before using new businessmodel	After using new business model(Average)	Percentage
MTS	4,100	575	8%
ATO	-	4,775	66%
MTO	1,500	1,300	18%
CTO	-	450	6%
ETO	-	150	2%
Total (Unit)	5,600	7,250	100%

3.5. Comparison between the AHP model and pilot run

Table 9 shows the validation results between the AHP model and pilot run, in which the ranking of the AHP model and the pilot run is the same, and their percentages are very close. It is proven that the AHP model and the new business model seem to solve the current problems in ABC. Although the ATO model has the highest ranking in both the AHP model and pilot run, other models such as MTS, MTO, CTO, and ETO still show contributions to the business. The results prove that the AHP model provides a valuable method for setting priorities, allocating resources, and establishing the business model.

Table 9. Different models in producing the products

Item	Position	MTS	ATO	MTO	CTO	ETO
AHP model						
1	Company Director	10.1%	52.6%	22.7%	9.9%	4.7%
2	Sales Manager	12.0%	53.7%	20.1%	9.9%	4.3%
3	Operation Manager	13.3%	52.4%	21.5%	8.9%	3.9%
4	Ranking (AHP model)	3	1	2	4	5
Pilot run						
5	Percentage	8%	66%	18%	6%	2%
6	Ranking (Pilot run)	3	1	2	4	5

After using the new business model, it proves that it can improve the performance to handle the customized product with better efficiency and effectiveness. It increases the product flexibility and variety, decreases the cost selling price, shortens the delivery time of the slightly

different customized products as the standard products, and reduces the surplus in the inventory.

4. Conclusion

The purpose of this study is to develop a new business model by using the AHP approach to solve the mass customization problem in the SME manufacturing industry. The new business model aims to improve company profit. The seven criteria in the AHP model are profit, MOQ, flexibility, inventory control, delivery time, revenue from existing customers, and new customers for customized products. After running the new business model, even reducing the MOQ quantity and increasing the product variety, it still decreases the delivery time and reduces the surplus for customized products. It is proven that the new business model not only can increase the sales volume and product flexibility but also decrease the stock.

From the AHP model and pilot run, both have the same rankings in ATO, MTO, MTS, CTO, and ETO models, with similar results in weighting. Although the ATO model has the highest ranking, other models such as MTS, MTO, CTO and ETO still provide a synergic effect on the business. The results show that the AHP model provided a valuable method for setting priorities, allocating resources, and designing the business model. Many companies leveraged this new business model interviews from different manufacturing industries and increased the accuracy of the AHP model and its pilot run.

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