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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 in the Small and Medium-sized Enterprise (SME) manufacturing industry. Most SMEs are facing challenges in the market change from Mass Production (MP) to Mass Customization (MC). This project applies an Analytical Hierarchy Process (AHP) model to develop a new business model to resolve the mass customization issue in the SME manufacturing industry. To validate the AHP model, the new business model is pilot-run, it is proven that the AHP result is close to the pilot-run. It shows that the Assemble-to-Order (ATO) model has the highest ranking and is a most suitable model in SME manufacturing for producing standard and slightly different customized products. The study provides a method that uses an AHP model for developing an integrated business model for SME manufacturers.

1. Introduction

In the current business environment, the purchasing behaviour is changing from standard products to customized products, such as choosing products with specific colours, 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 competition in the market, how to change the business model from MP to MC is a major issue most manufacturers are facing.

According to the statistics from the 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 [12][13][14][15]. In the EU, SMEs provide approximately 20% of all jobs in industry, and about 21% of the total EU GDP (Radziwona et al., 2014). There are a lot of SMEs around the world but many methods suggested for improving the performance are not practical (Thürer et al., 2011). Although SMEs represent more than 98% of all business units in their countries, their bargaining power is lower than large organizations and their pressure is higher than 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, can be formulated new business models and resource allocation for enhancing 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. Literature review

2.1. Market changed from standardization to customization

In the past few decades, E-commerce has changed customer behaviour from purchasing standard products to customized products, 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 (Graman and Bukovinsky, 2005). 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 economically (Heizer et al., 2017). The product development, manufacturing and logistics needed to provide flexibility and modularity (Traian and Aurel, 2015).

2.2. Different business models in manufacturing

In the MP era, most manufacturers were using the Make-to-Stock (MTS) business model. When the market changed from MP to MC, there are many different business models in the manufacturing environment, such as ATO, Make-to-Order (MTO) and Engineer-to-Order (ETO) (Olhager, 2003), and Configure-to-Order (CTO) (Aqlan et al., 2014). The difference in such models are related to the different positions of the Order Penetration Point (OPP). OPP is a point in the production process where the customer places an order for 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 (Haug et al., 2009). Figure 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 the processes are driven by customer-order.

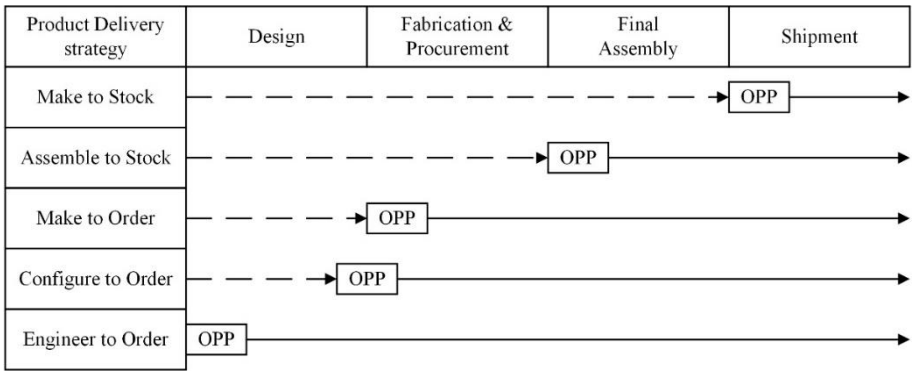

Figure 1. The OPP in MTS, ATO, MTO, CTO and ETO models

2.2.1. Model of make-to-stock

The MTS model is suitable to produce standard products of low variety and in high volume (Graman and Bukovinsky, 2005). 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 Figure 1, the OPP is located in the shipment phase.

2.2.2. Model of assemble-to-Order

The ATO model uses forecasting, but it 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 Figure 1, the OPP is located in the final assembly phase.

2.2.3. Model of make-to-order

The MTO model provides mass variety, high levels of customized products, but with high operating costs (Graman and Bukovinsky, 2005). 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 Figure 1, the OPP is located in the fabrication and procurement phase.

2.2.4. 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 efficiency of mass production (Aqlan et al., 2014). In the ATO and MTO models, manufacturers can configure the products based on the customer order, and in the CTO model, it allows customers to configure the finished product that they want to buy. As shown in Figure 1, the OPP is located between the design and fabrication & procurement phase.

2.2.5. 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 Figure 1, the OPP is located at the design phase, so that the delivery time will be very long and includes engineering design, material acquisition and manufacturing time (Akinc and Meredith, 2015).

2.3. Time postponement and form postponement

According to Graman and Bukovinsky (2005) and Heizer et al. (2017), 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 to 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.

2.4. Limitation in production for mass customization

According to James and Mondal (2019), MC has a lot of limitations, involving many parameters such as product variety, batch size, and changes in product design, so that it decreases machine efficiency.

2.5. 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 multi-criteria decision-making to tackle problems involving both intuitive and rational factors (Barker & Zabinsky, 2011). According to Chan (2002), the AHP method was used to define which model is optimal. 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 (Chan and Chan, 2010). This method helps to choose the best from numerous alternatives, which are assessed using a few criteria (Saaty and Vargas, 2012).

2.6. The key performance index

According to Welborn (2005), the performance indexes for measuring mass customization are “customer influence”, “product scope”, “product cost” and “lead time”. In using such indexes, the strategy which 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 (Thakkar, et al., 2009).

2.7. Research gaps

According to Thürer et al. (2011), there are many SMEs around the world, but many of the methods they use for improving performance are not practical. Therefore, this project tries to design an AHP model to organize and analyse which models are optimal when developing a new business model for a case company. It is very important to define the weighting and function of each aspect of a new business model. Then the new business model is pilot run and validates the AHP and new business model compared.

3. 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 results between the AHP model and the pilot run. Figure 2 shows the roadmap of the research methodology which includes five phases for the implementation of the proposed framework.

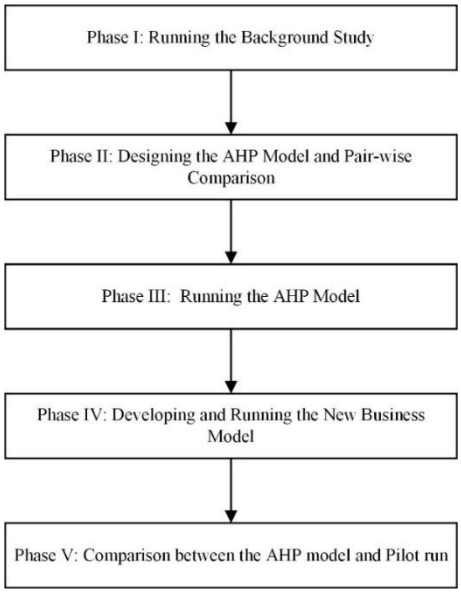

Figure 2. Roadmap of the Research Methodology

3.1. Running the background study

This project studies the current business models and operational processes of SME manufacturers when they are facing the change from MP to MC. It also studies the resources in the company and the competition in that industry.

3.2. Designing the AHP model and pairwise comparison

In order to present an example in solving the business model selection problem in the manufacturing industry, we take the criteria such as profit, flexibility, variety, and delivery time into account for supporting the business modelling. AHP is used to prioritize the models in sequence for decision making. AHP is a popular approach to create a multi-criteria decision-making model to tackle problems involving both intuitive and rational factors (Barker & Zabinsky, 2011). According to Alonso and Lamata (2006), in order to implement AHP, there are four steps in developing the AHP model; they are AHP structure design, questionnaire design for pairwise comparison, matrix construction and consistency checking, and selection based on overall score.

AHP is a multi-criteria decision making method for selecting alternatives based on a set of criteria. It is a three level hierarchy with goal, 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 of importance	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 a_{ij} = (1, 2…n) is the quotient of weights of the criteria. Referring to (1), every element a_{ij} where i, j = (1, 2 …n) is the quotient of weights of the criteria.

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

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

3.3. Running the AHP model

The AHP model uses the free educational software Super Decision [16], and implements AHP which was developed by Thomas Saaty and his team.

3.4. Developing and running the new business model

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.

3.5. Comparing between the AHP model and pilot run

After 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 model.

4. 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.

4.1. 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 business. One of the reasons is that the labour and material costs per Stock Keeping Unit (SKU) in using the MTS model

are lower than for MTO model, and the delivery time is shorter than for the MTO model. However, it uses the MTO model to handle all the customized products and current products for the wholesale business, so that it does not need to stock a lot of 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

4.2. Problems faced by the company

As the customer requirements are changing from standard products to customized products, the business models MTS and MTO cannot fulfil 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 Minimum Order Quantity (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 cancelled due to the large volume in MOQ, long delivery time and high production cost and selling price. Besides, ABC is unable to improve the business strategies to attract new customers, so that there is much surplus stock in the warehouse. As a result, ABC wants to develop a business model to improve its business.

4.3. Designing the AHP model and pair-wise comparison

Figure 3 shows an AHP that is designed for selecting and weighting 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 improve the company profit. Seven criteria are Profit, MOQ, flexibility, inventory control, delivery time, revenue from existing customers for the customized products 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 around the world.

The seven criteria in the AHP model:

- Profit (B1)
  Profit is a key criterion that companies need to consider when developing a business model. If the sales or quantity increase within a period, it means that 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 sales order.
- Flexibility (B3)
  Flexibility measures the degree of customized products and variety, and high product flexibility could increase the product variety and degree of customization.
- Inventory control (B4)
  Inventory control measures the amount of finished goods idle in the warehouse. When there is a lot of inventory, it will affect the cash flow and need increased area in the warehouse. Besides, the products need to be written off or obsoleted due to metal rusting and colour fading.
- Deliverability (B5)
  Deliverability means the products 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.

- Revenue from existing customers for customized products (B6)
  Revenue from existing customers for customized products is another criteria to be measured in the new business model. One of the KPIs of the new business model is product flexibility for handling different degrees of customized products. If the revenue from existing customers for customized products is increasing, it means that existing customers want to purchase customized products.
- 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 between existing and new customers.

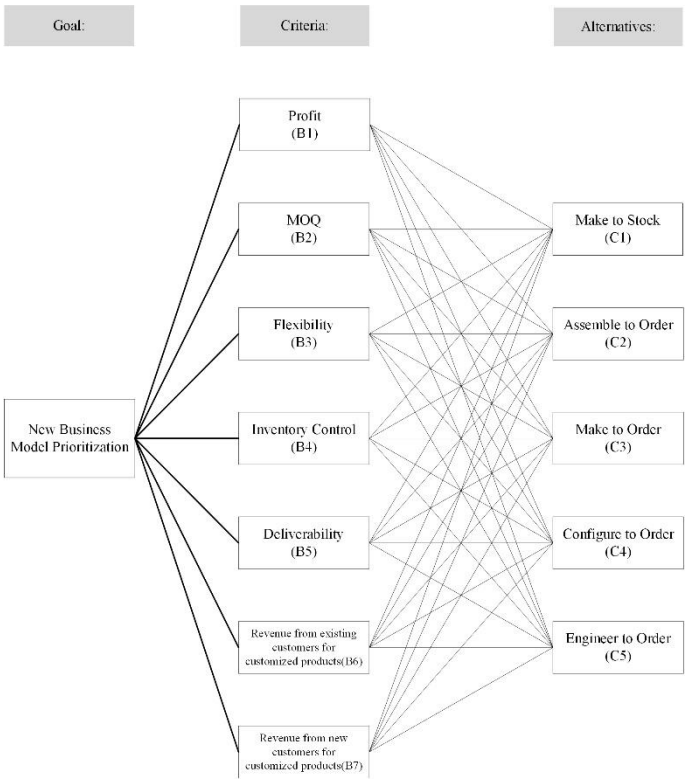

Figure 3. AHP structure for new business model prioritization

4.4. *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. Figure 4 shows the relationship between five models with different degrees of customized products. The MTS model produces standard products and the ATO, MTO, CTO and ETO models produce different degrees of customized products.

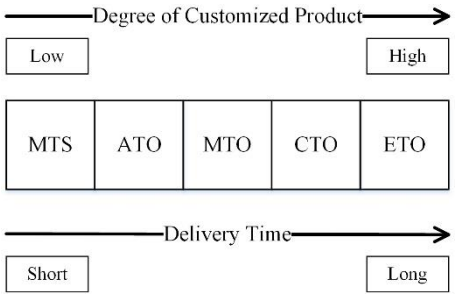

Figure 4. Five different models and degree of customized products

5. Results and discussion

5.1. 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, figure 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.

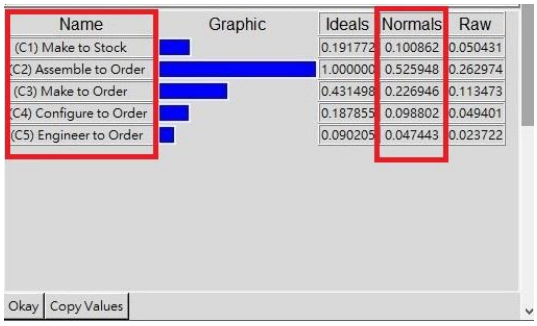

Figure 5. One set of the overall synthesized priorities for the alternatives.

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%, then 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. It means that 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

5.2. 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 (from 35.8% - 42.3%). The company director is an all-around person and focuses on long term revenue rather than short term revenue so that the second and third-ranked criteria are “Revenue from a 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 that 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 customized product
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

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 of the criteria (except deliverability), so that they are the most suitable models for ABC to improve its current problems.

5.3. Developing the new business model

Based on the AHP results, the new business model is developed (Figure 6) and named as 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 standard products, 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 is used to run the unique customized products, and the fifth-ranked ETO model is used to run the almost different customized product.

	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

Figure 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 not only integrates five MTS, MTO, MTO, CTO, and ETO models but also provides a synergic effect on the products.

5.4. Running the new business model

After a trial run of the new business model in ABC for four months, it was found that the sales volume increased by 29% (Table 5), and the percentage of all the finished goods in the warehouse decreased by 62% (Table 6).

Table 5. 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%

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

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%

From the pilot run, the trend of different customized products increased rapidly, especially as the slightly different customized products increased by 41% (Table 7), but the standard products decreased by 42% (Table 5). 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 products. In using the new business model, the selling price, delivery time and MOQ are the same between slightly different customized products and standard products. This is the reason that the sales volume of slightly different customized products is higher than the standard products.

Table 7. 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%

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, then 18% of products are produced by the MTO model, and 8% of products are produced by the MTS model.

Table 8. Different models in producing the products

Model	Before	After (Average in 4 months)	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%

5.5. 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 are the same, and their percentages are very close. It is proven that the AHP model and the new business model seems to be able 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. From the results, it is proven that the AHP model provides a valuable method in setting priorities, allocating resources, and establishing the business model.

Table 9. Results of the AHP model and Pilot run of different models

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 is proven that it can improve the performance to handle the customized product with better efficiency and effectiveness. It improves the product flexibility and variety, it decreases the cost and selling price of the slightly customized product to standard product, it shortens the delivery time of the slightly customized product to the same as the standard product, and it reduces the surplus in the inventory.

6. Conclusions

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. 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 different customized products. It is proven that the new business model can improve the sales volume and product flexibility and decrease the surplus in the warehouse.

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 provides a valuable method in setting priorities, allocating resources, and designing the business model. To enhance the qualitative nature of the new business model, interviews from a large number of companies from different types of manufacturing industries should be undertaken, therefore improving the data quality of the AHP model and real data.

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