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DESIGN AND MANUFACTURE OF PERSONALIZED PRODUCTS

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Abstract: In this age of new technology, personalized production has become new a paradigm of manufacturing. Buyers are starting to expect that products should be closer to their individual needs and designer. Personalization aims to satisfy individual customers by offering individual and unique design and materials, which make a positive effect on customer satisfaction. Personalization represents a production paradigm that combines the personalization ability of craft production with the cost-efficiency of mass production. The different between mass customisaitn and personalisation is that in mass customization a list of options are given to the customer to choose whereas in personalised manufacture the customer is involced in the design of the product. This new paradigm opens up a new area for scientific research. In this paper we develop a model for personalized product design and manufacture. The paper also highlights technological advances to support personalized design and manufacture. At the end of this paper, an illustrative example will be given to show the use of the proposed model on a real application and its effect on customer satisfaction.

Key Words: Mass Customization and Personalization, Design

1. INTRODUCTION

Manufacturing has always been a very important sector for a strong economy. "Craft production" was the first manufacturing paradigm. In the healthcare industry, craft production still has its own market. While craft production has an outstanding advantage, which is to be able to manufacture personalized products, it has many disadvantages as well, such as high production cost and long lead time. Later by the creation of the assembly line and after that the moving assembly line, manufacturing could produce large numbers of products in a short period of time with high quality and low cost [1]. Mass production is the second paradigm which was a revolution in manufacturing. However as Joseph [2] stated, mass production is no longer effective. Jelinek and Goldhar [3] were two researchers who worked on mass customization and they focused on a relation between mass production and mass customization. The biggest disadvantage of mass production is the very

limited variety of products. In the 1980s, due to customer demand for high variety, manufacturers started to develop mass customization, the third manufacturing paradigm. In mass customization, customers were allowed to customize the product according to their preferences from a selection of available options, while the cost and speed of production is almost the same as mass production.

Customer needs and wishes changed in recent times and they tend to need a product which fullfils their own individual needs. They need a product which fits to their preferences in terms of money, body measurement, appearance and even services. These features can only be achieved with personalized led design and manufacture. Thanks to new technology such as rapid prototyping, flexible manufacturing and fast communication tools, the manufacturing industries are ready to move forward and to enter this new paradigm.

2. LITERATURE REVIEW

During the last two centuries ago, production paradigms have changed over time (Figure 1). Over a time period four major manufacturing paradigms have been identified as follows: Craft Production, Mass Production, Mass Customization, Personalized production.

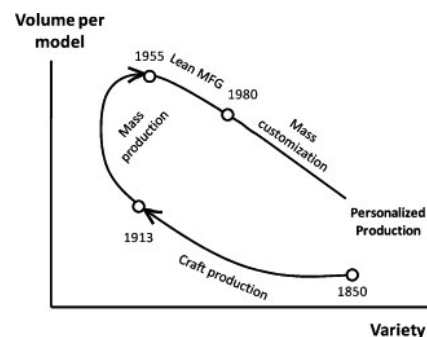


Fig. 1. Changes in manufacturing paradigm [4]

2.1. Craft Production

Humans started craft production since they appeared on earth, making clothes and tools for hunting. Craft production is defined as making and creating things according to the customer wishes. Usually products which

are produced by craft production are unique and each product is different from the other. Usually craft production uses a lot of manual work. In 1850, manufacturers started to produce automobiles and before that, they made carriages using craft production.

As mentioned earlier, craft production requires a lot of manual work, so usually workers need to be well skilled and even those who work on machines need to have a high level of skill. In this case the labour cost is high and making different parts of the product require a lot of time. Some craft production can still be seen these days in products such as luxury cars, shoes and suits. But the price of handmade products is so expensive that most people prefer to purchase the mass produced, lower cost alternative.

In craft production, first of all customers order and usually pay some or all the cost first. Then a product is designed especially for them or the customer can customize their product from a range of an available designs. After the design stage the product is made to "customer specification". As can be seen in the process, craft production is a "pull" type production, where the customer decides to buy a product then orders, then it is designed and at the end the product will be produced.

The principle of the craft production paradigm may be summarized as:

"Skilled workers, using general-purpose machines, make exactly the product that the customer paid for; one product at a time [5]".

2.2. Mass Production

In 1913, Henry Ford started to use mass production in automotive manufacturing. At that time, the market needed low-cost automobiles so he came up with this new method of production. Manufacturers are now using mass production for producing high consumption products. Agraval, et al [6] maintains that mass production is still useful, at least in the car industry.

Mass production is a "push" type manufacturing system and the business sequence is "design-make-sell". Because of the large quantity of the products, the cost is lower than other paradigms and as a result more customers can afford to buy the mass produced products.

In mass production, variety is usually very low while the volume and quality is quite high. In some cases moving assembly lines reduce the costs and workers do the same job again and again which helps to increase the speed of production and significantly also reduce the cost.

2.3. Mass Customization

In 1980 manufacturers started to offer a few more options for customers who were looking for variety in the products. At the beginning manufacturers offered a package of options which the customer had to choose and whenever a customer picked up the favourite package the production of product commenced.

Agraval, et al. [6] defined mass customization as "the ability to provide individually designed products and services to customers through high-process flexibility and integration". Nairqi [7] introduced mass customization as a production where "products can be produced with low cost, high quality and in time as mass production". B. Joseph Pine [8] defined mass customization as more like personalized production. He believes it is "providing

tremendous variety and individual customization, at prices comparable to standard goods and services with enough variety and customization that nearly everyone gets exactly what they want". Davis [9] and Pine [10] defined mass customization as a production strategy which focused on the broad provision of personalized products and services. It has been named as an important and strong key to competitive success in areas of manufacturing such as clothing, automobiles and computer manufacturing. [11], [12]

There are several researchers who have worked in different industries in terms of customization production, such as: the food industry [13], electronics [14], large engineered products [15], mobile phones [16], and personalized nutrition [17]. Authors have also presented special mass customization (MC) applications such as homebuilding [18] and the production of food [19]. Some research on mass customization has been done in the supply area. Topics that have been addressed include consumer readiness for mass-customization [20], the marketing of mass-customized products [21], and consumers' evaluation of customized offers [22].

Levi Strauss & Co started to create and sell customized jeans in the 1990s [11]. Customers could go to a retailers shop where the shop assistant would measure them and they could also design the jeans they like. The order was sent via the internet to the Levi's factory where a computer controlled machine cut the different patterns. It was later sewed manually. The whole process took about two to three weeks, and the jean cost about 35% more than the normal jeans.

Customized products are not available only in the clothing market. There are several car manufacturers such as BMW and FORD, which offer customized cars. Customers can design their own car on a website through an online tool kit. This design is limited to some parts of the cars and colours [11]. Another example of mass customization is Dell, a computer company which enables customers to choose the components of their PC as they like.

"MyVirtualModel" is a website where people can make their own avatar and try different cloth from retailers like Adidas, Best Buy, Levis and Sears. This new way of shopping is changing the nature of shopping where the customers can see how the product suits their body. This website has more than 100 million users [11].

Koren [5] defined two different strategies for mass customization in his book:

Strategy 1: Off-the-shelf variety of customized products

Strategy 2: Standard options installed on customized products

Production of garments is one example of the first strategy where are produced in different sizes and colours. Strategy 1 is a transition stage from mass production to full mass customization but it is still a "push" type production.

In strategy 2, the company provides a variety of standard options and customers can choose their favourite options. Mini Cooper and Dell are a very good examples of this strategy as the customers can choose from a limited option through a website. For example, customers can select from five different categories, Design, Package, Performance, Instruments and Accessories. All these five categories are divided into more sub-categories.

One of the important tools to achieve customized production is the use of a flexible manufacturing system (FMS). This flexibility allows the system to adapt to the customer's requirements caused by predicted or unpredicted changes.

Koren [5] mentioned that strategy 2 of mass customization involves:

1. Designing a product that can be enhanced by a variety of options
2. Selling the specific options to specific customers
3. Making (assembling) the product with the options that the customer selected

This type of manufacturing can be divided into two parts - the first part which is a "push" type manufacturing and the final assembly which is a "pull" system. So it can be called a "push - pull" business model.

As a broader definition of mass customization Koren [5] said mass customization is "Production of a wide variety of customized products, at mass production cost, attracts more customers and increases sales."

2.4. Personalized Production

Personalization was originally used in the relationship marketing and management [23]. Personalization has been called by different names such as individualization [24], one-to-one marketing [25], one of a kind production [26] and market-of-one Gilmore and Pine [27]. As was mentioned before, in mass customization there are standard options from where customers can choose their favourite option. But this choice is not the customer's choice that will 100% satisfy them. They just can choose between a limited numbers of options. People like to have something special, something to fit their preferences, characteristics and trends. The only solution is personalized production. Prahalad and Krishnan [28] said, "We are moving to a world in which value is determined by one consumer-created experience at a time".

In Personalized production, the design part is divided into two stages. In the first stage, product architecture and module interfaces are designed and the envelop of product variety and basic modules are established. The second stage takes place after selling the product. In this stage, customers play a very important role in designing the product. Feedback from customers' drives modifications in the design.

After interaction with customers, the product is modified and produced. The business sequence of personalized production is Design-Sell-Design-Make.

Hu [29] believes that customers can collaborate with manufacturers and also other consumers to create and innovate products. This co-design process is enabled by open product architecture, on-demand manufacturing systems and responsive cyber-physical systems involving user participation in design, product simulation/certification, manufacturing and supply processes.

Koren, et al. [30] defined open-architecture products (OAPs) as a fixed platform and modules that can be added later. The modules can be produced by small companies, therefore using OPAs, jobs will be created due to this cooperation between big companies and small ones.

One of the Issues of Business Week [31] states that many companies are moving to personalization. It gave some example such as, Chip N Dough (cookies, personalized cookie tins), Zyrra (personalized bras),

Choiceshirts (customized designs of shirts with personalized logos), Namemaker (giftwraps with custom slogans) and American Art Resources (customized artwork in healthcare facilities). Spreadshirt (customer-designed t-shirts), Zazzle (custom shirts, stamps) and CafePress (a variety of custom products including t-shirts, mugs, stamps, mugs, CDs, books, and other products) are also another example of personalization, [32]. Services also moved to personalization strategy which is more impressive than manufacturing industry. Now days we find a lot of Services such as, Credit cards, travel deals, insurance, hotel deals that are totally personalized.

3. PERSONALIZATION AREA

Personalized products are limited due to manufacturing, supply chain and sometimes due to cost. For example in a television, customers are unlikely to have any individual needs. It means customers' requirements are almost fulfilled with mass production with a few varieties. This logic is not the same in all areas especially the ones that individualized abilities and physical features are involved.

3.1. Healthcare

Healthcare and wellbeing is a very important area which is not only considered a necessity or only as a luxury, it's both of them and we need to make it as good as possible to fulfil the patients requirements.

This co-design process is enabled by The Open Product Architecture [30] on-demand manufacturing systems, and responsive cyber-physical system involving user participation in design, product simulation/certification, manufacturing, supply and assembly processes that rapidly meet consumer needs and preferences.

Elderly people have special needs due to aging disabilities. For example an old person needs to use a cane to walk due to weak muscles. Cane is a light walking aid which transfers the body weight to user's wrist. If a cane is used as an example, it varies in several parts, such as:

- Different style
- Length of shaft
- Different kind and size of grip

Some people just consider the appearance of the cane while the functionality is a lot more important. The cane should be made to suit their body i.e. when a person uses a cane, his/her elbow should be flexed 15 to 20 degrees when they are standing and top of the cane should reach the crease on the underside of your wrist.

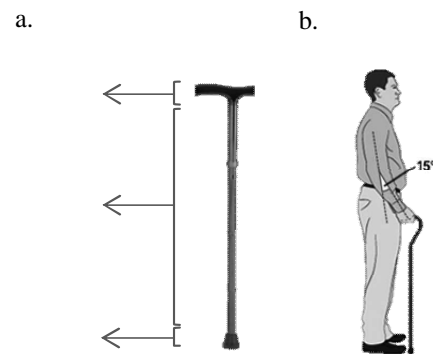


Fig. 2. a. Cane's parts b. Correct way of holding a cane

Height is one of the human characteristic which can be varying from short to tall. Kumar [33] believes that (1) length should be measured from the floor to the distal crease, or it can be determined by the formula

$$L = H \times .45 + .87$$

$$L = A \times .76 + .6 \quad (2)$$

where H is the height of the person in meters and A is the arm length measured in meters.

In a lot of cases, the cane is not fitted to the user so not only it doesn't help them, but sometimes may lead to problems. Although some canes are adjustable to the user's height, the adjustability is limited. The user normally chooses from the predefined increments which may or may not suit his/her height. Sometimes, a small user which is light and has weak muscles may carry a lot more weight due to the standard design of a cane. The weight of the cane may be reduced by better design and material selection.

Another issue which should be considered is the grip. When users are holding the cane, their finger and thumb shouldn't overlap. Again, like the height, hand size is varied. Moreover, sometimes due to some disease such as arthritis, congenital deformities, spasms and contractures, the user's hand doesn't work properly. In this case, some of the users can't hold the cane's grip easily or in a correct way.

As it can be seen here, personalized cane design can be solve many of these problems.

An article by Samantha Levine titled "Tailor-made Treatments" (U.S. News & World Report, November 16, 2002) elaborates on the applied research that aimed at solving the problems that women suffer at menopause. Menopause is one of the common diseases for women aged 45-64 in the United States. Most of them felt menopause keenly. In each of them the nagging issues associated with menopause vary. Does her hot flash shoot up her arms or cause a mild flush? Do night sweats keep her awake? Does she forget her ATM password? What are her odds of developing heart disease? Unfortunately, although there are a lot of symptoms and risks, the usual reaction has often been the same, two-hormone pills. Studies at Women's Health Initiative (WHI) shows that long term hormone replacement therapy can make more problems such as small risk of heart attacks, stroke, and breast cancer than it does solutions. The conclusion of the article is:

"One-size-fits-all therapy is not working for menopause-related problems. Individualized care must be the new treatment trend."

3.2. Fashion and Clothing Industry

Clothing industry has also gone through the same market history as others. At the beginning, clothes were produced in craft production, so everyone had to go to a tailor. The problem with this type of production was the capacity and lead time. Mass production revolutionized manufacturing and caused the speed of production to go up and the cost down. Although mass production has a lot of advantages, it has two outstanding disadvantages which are: limited style variety, colour and sizes. The customer's preferences are stylish clothes coincident to their needs and also fitting to their body. Personalized production may be the next revolution in manufacturing after mass production and mass customization.

3.3. Home and Office Furniture

People spend most of their time sleeping in a bed, work at a desk, or sitting on a chair to relax. Most of the equipment they use every day is made according to special standards. These standards are based on "normal" people with average height, weight and width. Do all the people have a standard body? The pictures below show the standard dimensions of a desk and office chair.

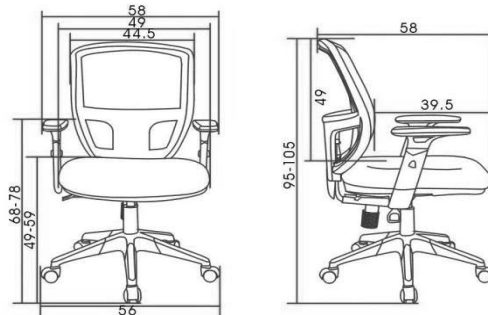


Fig. 3. Standard dimensions of a desk and chair.

4. PERSONALIZED PRODUCT MANUFACTURE

Design plays a very important role in personalized production. The designer should consider the customer's requirements and desires a lot more than other production paradigms. For personalized design and manufacture, the customer and designer should have a closer relationship where the customer needs should be fully understood.

Customers have always played an important role in the manufacture of products. In the first paradigm-craft production- customers first buy the product then the producer makes it according to their requirements. In this case the product is fully personalized where the customer can change almost all parts of the product. Craft production can be called a "low rate personalized production". In the second paradigm, mass production, customers play very minimal role in manufacturing process. Manufacturers almost force their product onto customers by providing few variations and cheap. Manufacturers design products with little consideration to individual customer desires and needs. In this case the lead time is very short and the price is very low, but the customer needs and desires are only partly fulfilled. At the beginning, in the mass production, customer where very happy as the price was considerably lower than craft production, the speed was higher and even quality was increased. Figure 4 shows the relationship of the customer to the design and manufactures of products under these three manufacturing paradigms.

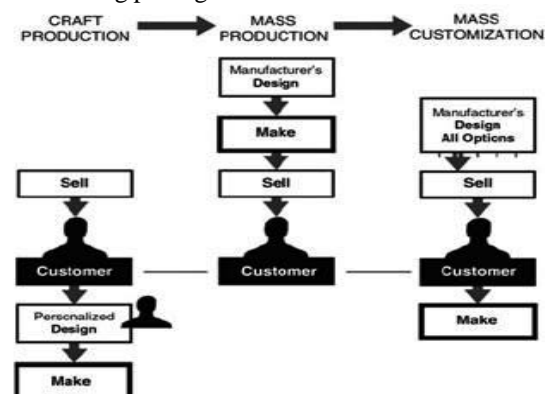


Fig. 4. Customer role in three paradigms[5].

After few years, this low variety was unpleasant for customers. Diversity is fast becoming more important than price. In this situation, manufacturers due to concerns of losing customers, they started to offer different types of product. The variety was increased until they started to let customer to customize their item. This customization is fairly limited and choosing from the options which have been provided. Nowadays customers are looking for something more personalized. They want a product which fits to their desires and characteristics.

A Systematic approach has to be followed in order to achieve sustainable manufacturing of products under the “Personalized Manufacture” paradigm.

4.1. Design Platform

Platform of the product can be named as the core of the product. This core has the most important features of the product which is the product identity. Although the product is personalized, the platform is the same for all and customers are not concerned about these fundamental parts. Sometimes, customers don't even have knowledge of it before making their selection. For example if the producer is going to make a chair, customers may not consider it important that the chair has 5 wheels or 6 wheels or how the mechanism works and looks like. So these parts are the same in all chairs no mater if they are personalized, customized or mass produced.

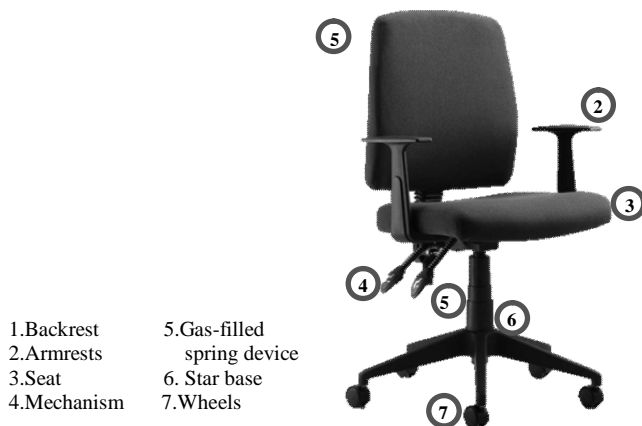


Fig. 4. Office chair's parts.

4.2. Customized Design

Only some parts and features of the product can be customized or worth to be customized. These varieties are limited and customers can choose them from a number of standard options. For example car manufacturers give some choices about items, such as, colour, wheel rim, sunroof, media player and etc. As it was mentioned before, customers can only pick from a list and it is limited to the options provided. It is considered that most ordinary customers don't care about the limitation for special parts. For example they don't care that they can pick their favoured colour out of a limited number of colours.



Fig. 5. Mini cooper's customization website.

4.2. Personalized Design

Design plays one of the most important roles in personalization. Although customization helps manufacturers to satisfy their customers, this satisfaction is for limited features. The challenge here is to find out which parts of the product should be produced in a mass production, which should be customized and which ones be personalized.

Parts which customers care a lot about it should be personalized, specially options which are related to the physical size and proportion. The customer's physical appearance is quite different in each person, e.g. long legs or short arm, etc. So to fully satisfy customer, these aspects should be considered in the design of the product. For example, the length of the cane (figure 2) not only depends on the user's height, but also it depends on his leg's length, arm length weather the user has disability which is common for the people who use cane.

The diagram Figure 7, shows a proposed manufacturing model to accommodate personalized manufacture. It shows the relationship between mass produced parts of the product that come under “Platform Design”, the customized parts of the product and most importantly the personalized features of the product.

The special feature of the proposed model is the ability of the customer to contribute to all three stages of design, “Platform”, “Customized” and “Personalized”. Another important feature is that each design category can be related to existing manufacturing systems hence enabling the model to be applied to current manufacturing environments with little change at the infrastructure level. This will be mostly achieved with modern technology in new flexible manufacturing processes, information communication advances and transportation.

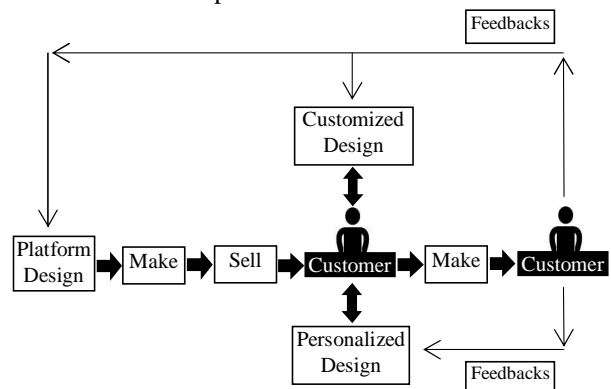


Fig. 7. Personalized Production Model

4. MANUFACTURING WORLD IS READY TO TAKE THE NEXT STEP

Almost all the modern factories are driven by computers with vast amount of data. Computers record everything that comes from other devices, such as sensors that monitor humidity, GPS trackers that fix location or callipers that measure a material thickness. By using this technology, not only machines become smarter, but also can track all the products, inventory which lead us to better product management. If something goes wrong in the factory these intelligent devices can either solve the problem or alert the operator or even manager's cell phone.

Engineers and designers have been using computer aided design and modelling tools for years. Computers not only help designers to design products, but also helps them to test them by using simulation programs and avoid costly physical tests. Now a days Cloud computing and inexpensive 3D scanners are transporting these methods out of sophisticated facilities and into the mainstream. 3D scanning is even possible with a smartphone. Also 3D printer or additive manufacturing is another new technology. 3D printer can print 3 dimensional objects in different materials including hard plastic, flexible plastic, ceramics, and metals with high quality at volumes as low as a single unit. The 3D printing technology is used for both prototyping and distributed manufacturing. Even young children can connect to internet and by using the tutorial design or make something new with CAD software and at then print it by 3D printer. 123 Design is free software made by Autodesk which allows everybody to design their own things which some years ago required mainframe computers to accomplish.

Robots can work 24h per day and 7 days a week, they don't get tired, don't need air-condition system, they can work in different situations and repeat a job for unlimited times. Most of the time robots can be more accurate, dextrous and faster than humans. According to a report by McKinsey Global Institute (2013), as robots become more popular in industry, they are becoming cheaper and also the expense associated with them has fallen about 50 % compare with human labour since 1990.

New technology in mechanical manufacturing processes have been created and developed in areas such as casting, forging, machining and welding. The new technologies are faster, more powerful and also with higher efficiency. For example water jet and laser cutting technology has been developed in recent years that enables manufactures to cut faster, with higher flexibility, quality and also more fitted to the customer requirements.

Internet is one by biggest inventions by humans. Now days internet can be found everywhere and with the help of smart phones, people can connect to the internet almost form everywhere. So this technology can be used to connect companies to customers. Companies can get feedback, orders, and surveys through the internet. Moreover customers can be literally connected to the production line, design their own products, take measurements of their house, even their body and send all the information to the manufacturer and make their personalized products. All this technology shows that now is the time to move on from mass production to personalized manufacture.

There is a very strong relationship between manufacturers and customers in personalized production.

The user plays a very important role in personalized production, from the initial concept to the final design. Traditionally customers had very low interaction with manufactures. It was hard to have a relationship with customers, due to distance and sometimes impossible to get feedback from a large group of customers. But now using fast communication tools, manufacturers can communicate with their customers very fast and efficiently. Moreover in personalized production, communication is not limited to getting feedback only, customers can also cooperate with to designing the product.

5. ILLUSTRATIVE EXAMPLE

Making a sauce for different chain restaurants is a good example of personalization. The sauce factory usually produces different sauces with different flavours for their customers. Most of the large chain fast food chains and restaurants have their special sauce which has a secret recipe and they want to be unique for that taste. Restaurants use their sauce in a different package. Usually they order sauce in a 10g, 30g, 50g, 200g, 600g, 700g, 1kg and 5kg packages. As it can been seen in this production, personalization can be used in this type of manufacture. As mentioned in the personalization model, some parts of the product are produced in mass customization – here the package is customized where customers choose their desires package through the options which factory prepare for them. They can't order something between the options, for example 65g package. It is not worth for the manufacture to make new packaging for the special customers and also the customers don't care that much that they should pick up a package from limited standard capacity. However, the sauce is completely personalized according to the customer's recipe.

6. CONCLUSION

In personalized manufacture, each customer has his/her own product which is produced individually for them. On the other hand in mass customization customer have to choose their preferred product through a standard and limited variety, which in most cases the product chosen does not fulfil the customer's requirements exactly. However, some researchers such as Lampel and Mintzberg [34], Squire et al [35], Huang et al [36] define product personalisation as pure customization which lead to the same outcome. In this paper a model was introduced for personalized production. According to our model, some parts of the product should be produced by mass production, some parts in mass customization and the rest in personalized production. By understanding the customer requirements and expectations, we can figure out which part of the product should be produced in which type of production. In this new model price, satisfaction and functionality of the product will hopefully be kept in a good balance. In this article, we also mentioned how new technologies in such as: Communication, Manufacturing, Supply chain- are essential to achieve personalized manufacture. Personalized product design and manufacture can also be a key to having a better economy, especially for small size markets.

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