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Product Design for Mass-Individualization

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Abstract

This paper suggests that Mass-Individualization, which is based on a consumer product that consists of an open hardware platform and multiple modules that are interfaced with the platform, will constitute the next paradigm in product design. Customers will be able to adapt the open platform to their needs by integrating modules of their choice into the platform, thereby constructing individual products that fit their exact needs. Large manufacturers will produce the platforms, and small companies will invent and produce modules that could be interfaced with the open-platform products. Smartphones is an example of an open-platform product, and the Apps that are designed to run on smartphones are examples for modules. Each customer downloads certain Apps that fit his/her needs, thereby creating an individual smartphone. The Apps, however, are software modules. The modules that are considered in this paper are hardware modules. Open-platform products will create a new paradigm in product design and utilization that we call the Mass-Individualization paradigm. The Mass-Individualization paradigm will boost the economy by (1) creating many new jobs in module production companies and (2) increasing the level of sales of consumer products.

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1. Introduction

An open product is a product designed so that hardware components (i.e., modules) can be easily added to its original structure in order to adapt the product features to the desire of the individual user. For example, PCs are open products – new hardware components can be easily interfaced with a PC to allow new utilizations. The smart iPhone has an open architecture that allows the addition of Apps that are adding features to the original phone.

In Mass Customization the product architecture is closed, and the manufacturer designs all the components that can be integrated into the product. The buyers choose the components and options that fit their desire and requirements, but often the availability of options limits the customers' needs (e.g., audio systems for cars).

A product with an open hardware platform provides potential module developers access to the architecture without many proprietary constraints. The original equipment manufacturer (OEM) of an open-platform product (1) builds a product that enables adding external modules, and (2) publishes explicit standards and instructions that allow potential developers to integrate their innovative modules into the main product, adding thereby new features to this product.

Examples of open-platform products may be the interior of automobiles, kitchen cabinets, refrigerator interior, office chairs, smart houses, industrial machines, and hospital beds. For example, modules may be added to open-platform hospital beds to facilitate individual patient's limitations and the type of his/her disease. The open-platform interfaces in all these products should be publically defined to enable module integration that enables adapting the product to uses desired by customers.

We define an open-platform product as follows: *An open-platform product is one with a platform that allows easy integration of modules from different sources into the product in order to fit its functionality exactly to the user's individual desire and needs.*

We believe that numerous innovative hardware modules may be invented for integration into common open-platform consumer products. To estimate the potential market of such modules and their impact on the economy let us look at the

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Apps market. According to the market research firm Gartner [1], 102 billion Apps were downloaded in 2013. Although 90% of them were free, they still generated $26 billion sales.

The European App economy employs 1 million developers and 800,000 people in marketing & support posts [2], and it created revenues of €8.1 billion in 2013 [3].

Although that each hardware module for futuristic open products will have just a small market share, the total market for hardware modules for a variety of open-platform consumer products will be by far larger than the Apps market, and it will create more jobs. These jobs will include also simple production and assembly jobs, and not only jobs that require high education as needed for Apps development. Of course hardware modules will not be free as many Apps are, and hardware modules will be more expensive than downloading Apps, but that means that the market potential for hardware modules will be probably by far larger than the Apps market reported above. Furthermore, when more buyers will demand open products, it will extend the scale and scope of modules, which, in turn, will expand the number of module manufacturing companies, and this will provide even larger boost to local economies.

We believe that an economy that encourages open hardware products will flourish. The large corporations will manufacture the main product platforms (equivalent to smartphones) and numerous small businesses will invent and produce hardware modules. As people learn of the potential advantages of open products, the society will demand additional such products. Public demand for them will grow and they will become widespread across societies and nations. This, in turn, will lead to the establishment of many new module design companies, resulting in a massive expansion of the economy.

The interior of private airplanes is designed and built to meet the needs of the individuals that buy the plane. Similarly assume that customers were offered the opportunity to design the interior of their new cars. Such a scenario would include a variety of modules (e.g., storage compartments, microwaves, mini-refrigerators, beds, dog baskets) that customers could choose from and arrange in their car according to their individual preferences. (Of course, subject to safety and manufacturing constraints.) As a result, the interiors of cars, of the exact same model, will differ greatly from one another, creating thereby a large mass of individual, unique cars. The OEM of the open platform product, usually a big firm, will not develop and produce these modules. However, to ensure safety constraints the firm will have to approve the modules before their integration into the main product.

We call this new paradigm “Mass-Individualization” because a large mass of products is produced, but each one is tailored to the needs of the individual buyer. It is a paradigm in which products are built with their critical functions by large companies (as with smartphones), and include an open platform that enables the integration of hardware modules. The selection and fit of these modules requires consumers to be involved in the design of their final individual products. In mass-individualization the creative act of the buyer yields the final product, and the number of options depends on the creativity and ingenuity of many companies that produce modules.

2. Comparing Product Design Paradigms

We would like to observe the transitions from Mass Production, to Mass Customization, and to the new paradigm of Mass Individualization. In all these three paradigms there are three basic actions: Design the product, Make the product, and Sell the product. The differences are (1) in the sequence of the three operations, and (2) in the customer’s role and involvement in buying the product.

In ***Mass-Production*** the product architecture is unified. Products are designed and built by the manufacturer and then offered for sale, hopping that customers will buy them. The sequence of actions is simple: Design –>Make –>Sell.

In ***Mass Customization*** the product architecture is modular. All modules are designed by the product manufacturer, and offered to customers as optional product choices. The customer selects the modules that s/he wishes (sometimes from a very large variety), and then pays for the product. Only then the product is made and delivered. (A good example is Dell computers.) The sequence of actions is: Design –>Sell –>Make. This sequence is illustrated in Figure 1.

In mass-customization even if some customers feel as if they are designing their product, the truth is that they are NOT involved in the design of their products. They are simply selecting an option.

In ***Mass Individualization*** the sequence of the three operations is more complex, and is depicted in Figure 1 [4]. The sequence is as follows:

1. The manufacturer designs the product platform with a large variety of possible interfaces for new modules, and defines the interfaces.
2. The customer selects a platform and searches on the Internet for desired certified modules that fit the selected platform. Different vendors may produce the modules. Then the customer designs his/her final personal product with all the selected modules.
3. The customer orders and pays for the platform (the main product; equivalent to the smartphone) as well as for the selected modules.
4. The modules are sent to the manufacturer and the final product is made.

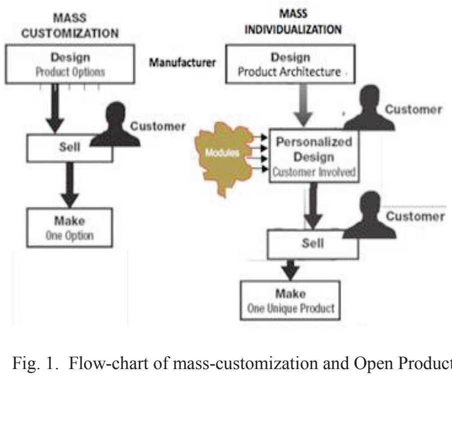

Fig. 1. Flow-chart of mass-customization and Open Products

Note that two design stages of Mass Individualization are illustrated in Figure 1: Design by the manufacturer and design by the customer. It is important to emphasize that in the second design stage, the customers are involved in designing the options of their product to fit their exact individual needs and desires. They can order certified modules from different vendors, or design and build their own modules (subject to OEM approval). In the mass-individualization paradigm the customers are involved in the design process! This is a new challenge of this paradigm.

Table 1 expresses the three paradigms and their corresponding features in term of (a) product architectures, (b) type of product built, and (c) the changing role of the customer in each paradigm.

Table 1. Several classes of product architectures

Paradigm	Product Architecture	Product Built	Customer's Role
Mass Production	Unified	Identical product	Choose a product
Mass Customization	Modular	Product built with one option	Choose among offered options
Mass Individualization	Open-Platform	Customer designed	Involved in final product design

3. Examples of Futuristic Open-Platform Products

We present below two examples of open products: (1) A futuristic open-platform interior of automobiles, and (2) Office chairs.

3.1. Automobile Interior

An excellent example of a potential open-platform product is an automobile interior [5, 6]. We assume that automobile manufacturers will continue to produce cars as they do today, but the interior of the car will be an open space that buyers can design according to their needs by interfacing certified modules into the open interior. The software equivalent to these modules is the Apps that are added to smartphones. An extreme example of a futuristic car interior is shown in Fig. 2.

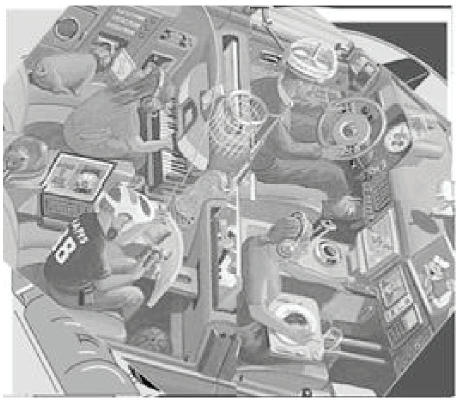

Figure 2: Futuristic car interior

Since the automobile interior is not part of the core business of automobile manufacturers, designing cars with open interiors has the potential to be a very successful new line of business for automobile manufacturers.

For a vehicle with an open-platform interior, the manufacturer designs the platform architecture (e.g., installing rails to which modules can be attached for safety). The manufacturer will also create a database, or library, of certified interior modules, such as file cabinets, musical instruments, dog baskets, refrigerators, game consoles, and special car seats, as shown in Figure 2 and in Figure 3. The platform manufacturer will produce only a small part of the available interior modules, whereas most of them will be invented and manufactured by numerous companies specialized in automobile module production. All modules will be certified by the manufacturer for safety and power interfaces. This database will be accessed over the Internet.

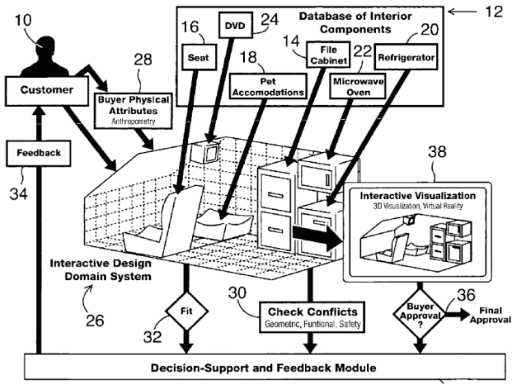

Fig. 3. The customer selects modules from a database, using this Interactive Design Domain System

The manufacturer will create a set of allowed usage constraints. These constraints are of three types: safety (such as unsafe seat position), functional (such as not enough electric power to support a particular combination of devices), and geometry (such as the fridge door hits the file cabinet). Then, the customer generates a personalized car design by selecting modules and placing them in the interior of the automobile using the specialized Interactive Design Domain (IDD) System shown in Figure 3. This figure is taken from a 2006 patent application [7] in which the IDD system constitutes the core of the method of this invention.

The Interactive Design Domain System allows the buyer to select a car model and its displayed interior space (from a corresponding database), enter the chosen interior modules (from a given database of modules approved by the manufacturer) to the car interior space, place them in a preferable location and arrangement, and view the result both motionless and in a simulated motion environment.

The buyer's design process is repeated until final buyer approval is achieved. The final design is stored digitally and sent to the car manufacturer. The buyer orders the needed modules, and the module manufacturers deliver them to the final assembly location. Finally, the automobile manufacturer uses the digital information to manufacture the vehicle with the interior modules selected and bought by the buyer. An alternative may be that the car leadership will be responsible for the final assembly of the car interior.

3.2. 3.2. Office Chair

For products that do not need safety regulations, the customers themselves may carry out the last steps of module assembly and integration into the platform. An example of such products is the final assembly of office chairs (Figure 4). The large company supplies the chair and small companies supply modules such as wheels, arms, and lumbar to support the lower back. The buyer assembles these modules at his office. Obviously, final assembly of complex products with safety regulations, like automobiles, will require professional assembly [8].

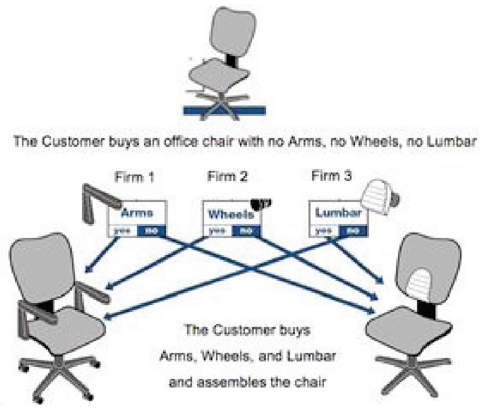

Fig. 4. The assembly of OAP office chair

Open-platform products offer more than exact fit to the buyer's needs and desire; they offer also sustainability and adaptability, as explained below. Used modules that are not needed anymore by the original buyer can be sold (e.g., on e-bay) or easily recycled. It was demonstrated that reuse of modules contributes to sustainability [9] Moreover, the customer may maintain the original product for a longer time, because it can be fitted to new requirements by changing modules, rather than the whole product.

Adaptability means that when new customer requirements emerge during the life of the open product, its interfaces can accommodate the new requirements by adding or switching modules [10, 11, 12].

To summarize, the Mass Individualization paradigm offers benefits to both customers and the economy:

For customers:
- Having products that exactly fit their needs
- When their needs change, customers can easily modify their products

For the economy:
- Many new small companies that design and produce modules will be established.
- A considerable number of new jobs will be created in these companies.

4. Challenges of Product Design Software

Making the Mass Individualization paradigm a reality requires innovations in three areas:
1. New CAD software for product design
2. Assembly of a huge variety of modules into platforms, and
3. Cyber-physical systems to facilitate interactions between buyers and manufacturers of platforms and modules.

In this paper we elaborate only on the first one. The challenge in product design is to define the functions of a graphical-aided software package to be used by ordinary consumers for the final design of their products. At present, numerous software packages are available for the interior design of kitchens. But only modules produced by the company that offers the software are available for selection by the customer. Designing with open-platform products, however, is more complex. An unsophisticated buyer should be able to check and see his/her final product by simple visualization means. An example is the Interactive Design Domain System shown in Figure 3 above.

The interior design of ordinary automobiles is not personalized today, even though automobile manufacturers are gradually moving towards openness in their products. Today OEMs design their cars, including the interior, without any customer involvement, though customers are given many options from which they can select. All these options are well designed to fit the specific automobile. The number of options is always limited, because offering too many options will complicate the final assembly.

Caravans are one specific branch of the automotive industry in which customers, if they wish, are involved in designing the caravan interior, but with the help of professionals employed by the manufacturer. In the most common form of caravan personalization, customers define their lifestyle and needs and select different types of standard appliances (each of which has several options), as offered, for example, by Orion Caravans [13]. Customers can select modules such as roof-mounted or side-mounted air conditioners, refrigerators, microwave or convection ovens, gas or electric stoves, grills and ovens, LCD TVs. These modules are then arranged in the caravan to satisfy the customer's needs.

Nevertheless, for the paradigm of open-platform car interior to become a reality, a CAD system for non-professionals should be developed and offered to the public. With the aid of this CAD system, even non-professional laymen should be able to design their car interiors. We assume that several car manufacturers will offer platforms, and that each of them will have a large database of possible modules produced by different companies. Each module will be supplied with its dimensions, electricity consumption, costs, etc. The car manufacturer will have to approve all the offered modules.

This CAD system should be interactive and have graphic capabilities, with a simulation mode. It should provide both engineering and solid views as output. Finally, note that:
1. The buyer's design must be bound by the constraints set by the manufacturer. These constraints may include interface points, safety requirements, packaging space, electricity

constraints, etc. The CAD software should take these constraints into account.
2. Since the manufacturer is ultimately responsible for the car, the manufacturer must approve the final design proposed by the buyer.

A basic diagram of the proposed CAD software is shown in Figure 5. It consists of two basic parts: (1) The Customer Interface, and (2) The CAD System that does the analysis, checks conflicts, and visualizes the interior with the modules that the customer selected.

The design process is done in iterations in which the customer's approval is in the loop.

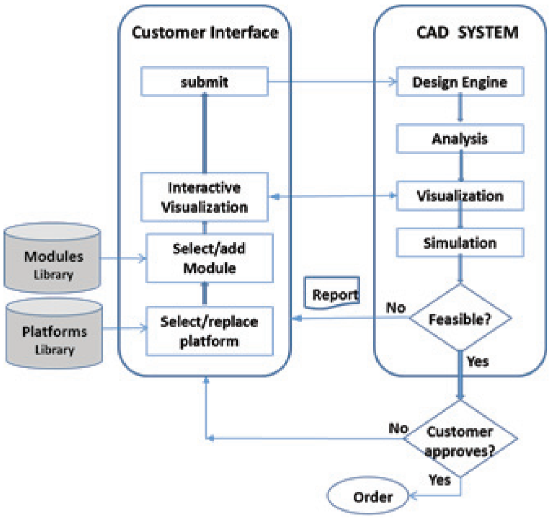

Fig. 5. Diagram for CAD software for OAP

The aim of the software in Figure 5 is to enable non-professional customers to propose product designs for OAPs for which a library of platforms and a library of modules for each platform are available. The customers do so by selecting a platform, and then adding modules. For this aim to be realized, the system must include CAD capabilities provided by the product manufacturer. The CAD system is web-based or easily downloaded to the customer's PC, free of charge.

The procedure and the related components are shown in Figure 5. The customer selects a platform and then adds modules, as desired, from the Module Library. When the design is ready, the customer submits the selection to the CAD system, which builds a model that represents the customer's selection. The model is analyzed from various perspectives, such as its impact on the platform. In cases that include moving parts, simulation is used to detect collisions or to demonstrate operations.

The results are visually depicted, and transferred back to the user. Virtual and augmented reality technologies can be used to enable the user to view the product image [14]. If the model proposed by the customer fails to pass the analysis stage, a problem report is generated and sent to the user. The user can then change the arrangement or modify the selection by using the interactive visualization module in the interface. After the changes are made, the user resubmits the design proposal. Once the proposed structure and arrangement successfully pass the analysis stage, the system waits for user confirmation. At this stage the user can either accept and order the open product or manipulate it even further and resubmit an alternative proposal. The process is iterative and ends only when the customer is satisfied.

Figure 6 shows the CAD software for the particular case of design of automobile interior [7]. First the buyer selects the car platform, and its interior space is displayed (retrieved from a database). Using the CAD system, the buyer can position and orient any chosen interior module (stored in a database) within the car's interior space and place it in the preferred location. The buyer can drag and drop the selected modules into available locations. The buyer can also rearrange the modules in the car interior.

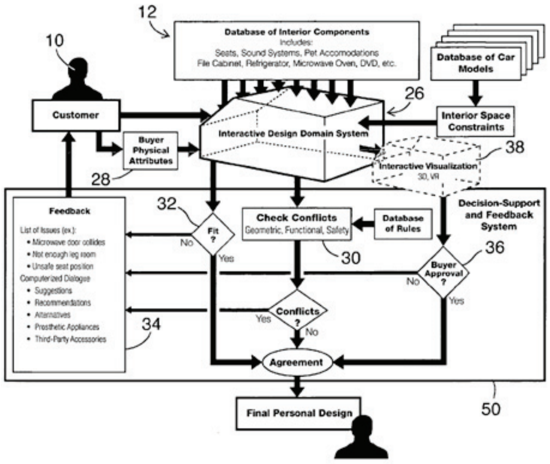

Fig. 6. Details of the CAD software with buyer-in-the-loop design

5. Challenges in Marketing Individual Products

Many factors influence a customer's choice to buy a particular product, among them personal, psychological, and social aspects. Usually consumers evaluate alternatives in terms of the functional and psychological benefits that they offer. In the mass-individualization paradigm comparing product alternatives will become a challenge. First, comparing products will also depends on the number of modules and their functions offered for competing open platforms. Then, the complexity of the design process by the consumers presents new challenges. Reuven Katz, a professor for product design, summarized the challenge by asking the first author of this paper: "Do you expect that my banker will become a car designer?"

Psychological Aspects: We may anticipate that buyer's psychological concerns will be associated at the personal design stage of the Mass Individualization paradigm. One of the main challenges in design of open-platform products using a CAD system is to determine how to know when the buyer is satisfied with the product s/he designs. A major related question is: Do buyers have the ability to create their desired results that will give them the level of product personalization and satisfaction that they anticipated? Is the final design worth going through this complex design process? This process is contradictory to the marketing philosophy of "shifting the consumer orientation toward simplicity" [15]. Therefore, the Decision-Support and Feedback System in Figure 6 is of extreme importance for the Mass Individualization paradigm becoming a reality.

The Paradox of Choice: Many of us believe that added consumer choices makes us better off because many choices mean that the consumers get exactly what they want. But too many choices can also overwhelm and confuse potential buyers so they decided not to buy at all. We don't know how the public will accept this new paradigm.

This last statement is especially true because open-platform products will be designed with consumer involvement, where the level of consumer involvement may determine consumer's buying behavior. Consumer behavior involves the buyer's psychological processes in identifying the needs and implementing plans to solve these needs [16].

Product Cost: The OEM has to manufacture a product with an open platform. Although the OEM saves money by not delivering the passenger seat and the back seat, the OEM has to build an open-platform product, which perhaps may increase the product cost for the manufacturer.

Nevertheless, despite these challenges the open-platform interior design paradigm will enable the auto industry to move toward a new paradigm – products tailored exactly to customer needs, budget, and preferences. This is an important benefit to society, and also a new potential market expansion for car manufacturers. This paradigm will also facilitate production of open-ended products that can be reconfigured by users (probably, with the aid of professionals) to adapt them to their changing needs [17]. The economy will expand with the establishments of many new companies designing and producing innovative modules as well as a completely new industry of reconfigurable vehicle interiors. This expansion will create many new local jobs that cannot be outsourced and affected by globalization. This yields a new sustainable manufacturing industry.

6. Paradigm Transitions In The Last 100 Years

As we said above, a new paradigm of open products has emerged with the introduction of smartphones and their Apps, which are modules that adapt the product to consumer's personal desires and needs. Because the software architecture of smartphones is partially open, many small entrepreneurs are able to develop Apps that can be easily integrated into customers' phones.

Mass customization changed customer manufacturer interactions in selecting product modules, so that consumers can choose the module combination they most prefer [18]. Ultimately, however, consumers may still not obtain the product functionalities they desire. Hence, the existing modes of interactions are not sufficient.

Professor Tseng claimed few years ago that mass customization is usually targeted toward meeting explicit requirements of defined market segments, and there is a need to develop "mass personalization" that aims at satisfying individual needs [19]. Mass personalization was also suggested in an earlier keynote paper [6]. Open-platform products make the mass personalization goal attainable by offering the opportunity to design cost-effective personal products by selecting the most desired modules from a large available variety.

A research study has shown that a paradigm change in manufacturing is always triggered either (a) by changes in market conditions or (b) by society's desire for product offerings [20]. For example, Mass-Customization was generated by society's desire to have a variety of similar products to choose from. In the case of open products, the social drive is the desire to fit products exactly to consumer needs without compromising on personalization of the product, but while keeping it at an affordable cost.

Figure 7 summarizes the transitions among three major manufacturing paradigms in the last 100 years. As said above, each paradigm shift was initiated by the changing needs of customers and/or by changes in the market conditions, but was always enabled by new technologies [21]. The figure illustrates how the market influences the invention of new types of manufacturing systems, and how the public's desire for greater product variety drives the product architecture and the business model that manufacturing enterprises implement.

The beginning of the mass-production paradigm is marked by Henry Ford's invention of the moving assembly line in Dearborn, Michigan in 1913, one hundred years ago. This invention enabled a dramatic price reduction for automobiles, making automobiles affordable for everyone. However, product variety was very minimal. Because of this limited variety, product architecture could be unified (not modular). A smaller number of modules reduced the product costs, because there was no need to spend money on connecting modules. The dedicated machining line (DML) was also invented at that time to produce the main powertrain components for automobiles – engines and transmissions. The DML perfectly fits the goal of mass production – high production rate at low cost. The business model is a push-type model – automobiles are built in factories and "pushed" to a parking lot, and customers will always come and buy the products.

When competition for similar products began, people started to look for a variety of product offerings to enable them buy a product that fit their needs and purchasing power. Offering product variety at low cost became possible with the invention of CNC [22], which is the vital element of flexible manufacturing systems (FMS) that became available around 1980. So, society's desire for larger variety in the offered products, combined with the ability of CNC and FMS to produce product variety at low cost, enabled the mass-customization paradigm. To offer product variety at low cost, the product must have modular architecture. The modular architecture and the FMS are the two enablers of mass customization.

In the mid-1990's manufacturers started to offer multiple options for some products, such as personal computers and automobiles. The manufacturers design many potential product options, and each customer can select a set of options that fits his/her needs. The customers then pay for the product, and only then is the specific product made, so that the business model becomes a pull-type model.

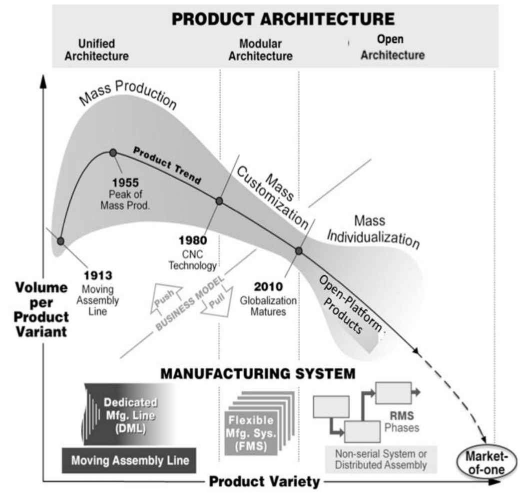

Fig. 7. Transition of manufacturing paradigms in the last 100 years; volume of each product variant is going down, and with open-products may reach a Market-of-One*

7. The Mass-Individualization Paradigm

The content of this paper suggests that we are now witnessing the emergence of a new manufacturing paradigm of Open-Products, or open-architecture products [23]. Open products enable the production of a huge quantity of individual products where each product precisely fits to the individual who purchased it. And the product can be rapidly produced at low cost. We call this paradigm the mass-individualization paradigm.

In the mass-individualization paradigm the manufacturer designs an open product platform and defines the interfaces for potential modules. Interfaces may be mechanical, electrical, and information/software. Many companies may produce modules, not necessarily just the platform manufacturer. Then the customers are involved in the design of their final products by selecting the combination of modules they like.

Obviously, because the module design is opened to the wild imagination of many innovators, the offer of modules is huge, and product variety is increased tremendously. Therefore, the probability of having two identical products with exactly the same combination of exactly the same modules becomes very small. With large module offering eventually we may even reach a Market-Of-One, in which each product is unique, as was the case in the Craft-Production paradigm, but with one big difference – the cost of OA products is tremendously lower, and is similar to that of Mass-Customization products.

Another advantage is that mass-individualization can address the needs of numerous world regions. In each region customers can select the modules that are tailored to address their specific individual and regional needs, such as climate, cultural needs, government regulations, as well as local their purchasing power. The new design challenge for manufacturers, then, is to design platforms that have the potential to fit the culture of many world regions.

A specific manufacturing system based on a technology enabler was invented for each paradigm. For example, the mini-computer was the enabler that made possible the invention and operation of the FMS, which, in turn, allowed the creation of the mass-customization paradigm.

The mass-individualization paradigm is more complex than previous paradigms. This huge complexity occurs because modules are produced by a large number of vendors that are spread across remote locations, and the number of product variants that may be manufactured is enormous. The enabler that can handle this level of complexity is cyberspace, which now has reached maturity. Cyberspace can connect module producers with buyers and OEMs that build the product platforms.

The mass-individualization paradigm may change the structure of the traditional auto industry. Of course the essential car components and basic features (engine, transmission, steering, etc.) will continued to be produced by the automakers. But the automakers will have to devote a major part of their activity to cyberspace issues by establishing module libraries and closer relationships with customers. Traditional automobile assembly [24] will also be different. Perhaps final assembly of internal modules will be done at automobile dealerships.

We further believe that module trading on the Internet will become significant. Customers will sell and buy used modules, the same way that people today buy and sell used cars. Products with modular structure whose module interfaces are simple and known are easy to disassemble facilitating reuse and resale of modules and thereby promoting sustainable practices.

8. Conclusions

The introduction of products with open-platform software is a promising start. Next, we anticipate the introduction of products with open-platform hardware. Such a paradigm change is applicable to many consumer products, ranging from automobiles and appliances, to wheelchairs, rehabilitation equipment and hospital beds, and to machine tools [25] and other manufacturing equipment. This paradigm shift, however, requires that the manufacturers of these products begin designing their products with an open platform that allows adding hardware modules designed by numerous module inventors. These inventors will be able to advertise their modules via the Internet as well as via social networks, such as Facebook and Linkedin. The inventor-buyer interaction will eventually result in a rich database of modules for every open product, enabling each customer to have his/her individual product.

The authors suggest coining the term "Mass Individualization" to describe the new paradigm, similar to the paradigm of Mass Customization. With the transition from customized products to individual products, the role of the customer will change dramatically — from merely selecting

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* Adapted from Y. Koren, "The Global Manufacturing Revolution," Wiley 2010 [21]

options designed by manufacturers to actual involvement in the design itself. Customers will be involved in designing products or product modules as they intend to use them, whether to conform to their bodies or to fulfill their wishes and dreams.

Mass-individual products have the potential to become a large share of the economy in Europe, North America, Japan and other countries. Many new small companies will be established to produce the modules needed for consumer products that will be redesigned with open platforms for mass-individualization. Module manufacturing will become a new, large industry that will create many new jobs, which will revitalize and expand the manufacturing sector of the economy. This in turn will provide a boost for the middle class and create huge benefits for society.

We strongly believe that the significance of the Mass Individualization paradigm will not only change the business and manufacturing models, but also will facilitate mass-innovations. This new paradigm will enable many customers and consumers to become innovators and small business investors/owners. The dividing line between business owners and customers will not be as clear as it is today. Because of individuals' involvement in third party manufacturers, customers may become a module manufactures and also its owners.

9. References

[1] http://en.wikipedia.org/wiki/Mobile_app

[2] http://europa.eu/rapid/press-release_IP-14-145_en.htm, February 13, 2014

[3] Muligan M, Card D (2014) Sizing the EU App Economy. Gigaom Research.

[4] Koren Y (2005) Reconfigurable Manufacturing and Beyond. The summary of keynote Speech of CIRP05 3rd International Conference on Reconfigurable Manufacturing, Ann Arbor, Michigan, USA.

[5] Koren Y, Barhak J (2007) Automobile Interior Personalization-Trends and Analysis. Proceedings, MCPC 2007 World Conference on Mass Customization & Personalization: 7-9.

[6] Koren Y, Ni J (2009) Personalized Production Paradigm. University of Michigan, umich.edu. A keynote paper presented at the European Union Manufuture Summit, Gothenburg, Sweden, November 2009.

[7] Koren Y, Barhak J, Pasek Z, (2006) Method and Apparatus for Re-Configurable Vehicle Interior Design and Business Transaction. US Patent Application 11/326,069. Google Patents.

[8] Paralikas J, Fysikopoulos A, Pandremen J, Chryssolouris G (2011) Product Modularity and Assembly Systems: An Automotive Case Study. CIRP Annals-Manufacturing Technology 60(1): 165-168.

[9] Kimura F, Kato S, Hata T, Masuda T (2001) Product Modularization for Parts Reuse in Inverse Manufacturing. CIRP Annals-Manufacturing Technology 50 (1): 89-92.

[10] Gu P, Hashemian M, Nee A (2004) Adaptable Design. CIRP Annals-Manufacturing Technology 53(2): 539-557.

[11] Zhang J, Chen Y, Xue D, Gu P (2014) Robust Design of Configurations and Parameters of Adaptable Products. Frontiers of Mechanical Engineering. Springer.

[12] Xue D, Hua G, Mehrad V, Gu P (2012) Optimal Adaptable Design for Creating the Changeable Product Based on Changeable Requirements Considering the Whole Product Life-Cycle. Journal of Manufacturing Systems 31(1): 59.

[13] Orion Caravans. Http://Www.Orioncaravans.Com.Au/.

[14] Lu YSC, Shpitalni M, Gadh R (1999) Virtual and Augmented Reality Technologies for Product Realization. CIRP Annals-Manufacturing Technology 48 (2): 471-495.

[15] Spenner P, Freeman K (2012) To Keep Your Custmers Keep It Simple. Harvard Business Review May: 108-114.

[16] http://www.consumerpsychologist.com/.

[17] Hu C, Peng Q, Gu P (2014) Adaptable Interface Design for Open-Architecture Products. Computer-Aided Design and Applications. 12 (2): 156-165.

[18] Daaboul J, Da Cunha C, Bernard A, Laroche F (2011) Design for Mass Customization: Product Variety Vs. Process Variety. CIRP Annals-Manufacturing Technology 60(1): 169-174.

[19] Tseng M, Jiao R, Wang C (2010) Design for Mass Personalization. CIRP Annals-Manufacturing Technology 59(1): 175-178.

[20] Jovane F, Koren Y, Boer C (2003) Present and Future of Flexible Automation: Towards New Paradigms. CIRP Annals-Manufacturing Technology 52(2): 543-560.

[21] Koren Y (2010) The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems. Wiley.

[22] Koren Y (1983) Computer Control of Manufacturing Systems. McGraw-Hill, New York.

[23] Koren Y, Hu SJ, Gu P, Shpitalni M (2013) Open-Architecture Products. CIRP Annals-Manufacturing Technology 62 (2): 719-729.

[24] Hu SJ, Ko J, Weyand L, ElMaraghy hA, Lien TK, Koren Y, Bley H, Chryssolouris G, Nasr N, Shpitalni M (2011) Assembly System Design And Operations For Product Variety. CIRP Annals-Manufacturing Technology 60 (2): 715-733.

[25] Spicer P, Yip-Hoi D, Koren Y (2005) Scalable Reconfigurable Equipment Design Principles. International journal of production research 43 (22): 4839-4852.