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PRODUCT DEVELOPMENT APPROACHES IN INDUSTRY 4.0

The concept of Product Development based on the needs, wants, and wishes of customers has found popularity since the focus was shifted from direct production and to the causes of consumption, the manifestation of utility, and the marginal utility of the product, and, eventually, customization in "Product Development 4.0" related to the vision of Industry 4.0. A unique approach in the research of this phenomenon spread in the 19th century during the period of the School of Marginalism establishment [1]. The concept of the product life cycle was proposed at a later stage, from the mid-20th century. Transnational entrepreneurial structures have also entered the stage - including capital expansion and increasing foreign direct investment. Following Vernon, this process causes the product life cycle to increase its duration due to the appearance of its international phases [2]. However, it should be noted that due to the global industrial changes, the economic cycles of production gradually shorten. As a result of these challenges the international product life cycle began to tend towards the decrease of its duration. In the 21st century we have new product development methods based on customization. It is of interest to study the product life cycle in Industry 4.0 where the product development process is based on the needs, wants and wishes of customers. It is especially important for the companies functioning under monopolistic competition and monopsony.

Due to the transnational entrepreneurial structures' policy on foreign direct investment for host countries, their economies had business prospects for rapid development. The efforts of the governments of the host countries boiled down to attracting foreign direct investment, which ensured emergent and rapid development of host countries' economies. In this way, emergent national economies which attracted FDI transformed into competitors for the home countries. These and other factors have contributed to the policy of reshoring as the process of returning the manufacturing of goods back to the company's original country. This situation creates challenges and opportunities for many enterprises and factories. Under Industry 4.0 conditions with a vision of "mass customization" the product's life cycle is perhaps even shorter. Thus, in the first stage (product development and trial production with consumer response tracking), small-scale production using 3D-printing may take place [1]. This type of trial production may enable low cost and efficient supply of a certain amount of goods, limited by the demand of each specific consumer. Therefore, (almost) any product feature can be adapted to the unique needs of a particular consumer -at an affordable cost. As noted in [3], "Life will be more sustainable and comfortable as only desired products and services will be provided as required".

In the future transition to Industry 4.0 factories will be challenged to operate more quickly, flexibly and cost-effectively [4]. The lead times will become significantly shorter with the increase in product variability, thus, small quantities should be produced economically. In order to be competitive the product should have high value, in other words, meet the needs of the customers, which is to perform necessary functions with certain quality parameters, at the lowest possible expenditure required to create it [5]. Moreover, modern demands related to sustainable product and process design lead to a need to find a balance between economic and environmental benefits [6]. From this point of view the product should be repairable, recyclable, its manufacturing should be resource efficient and should not affect the environment and ecosystem. According to the concurrent engineering concept, the new product is designed and developed simultaneously with the development of processes required for its manufacturing. Other functions, like quality engineering, field service, materials engineering etc., can be included with a final goal of decreasing the lead time and cost while fully maintaining or improving the functional characteristics and quality of the product. In recent decades a plethora of techniques were developed to reach this goal.

Nowadays these techniques share the heading "Design for Excellence" or "Design for X", where X can be replaced with the intended area of interest, like one of the life cycle processes or a certain product characteristic. The highest effect is achieved when Design for X principles are applied at the earliest stages of product development; however they can also be successfully utilized for redesigning existing products, as indeed a great share of engineering industry products are created by improving on previous designs. This approach is reasonable, as it allows for exploring the positive experience of design and production over the years. But it also has weaknesses, e.g. the presence in the products of a large number of "outdated" design solutions, which do not consider modern materials, processes and equipment as well as environmental aspects and sustainability. Moreover, some parts may be superfluous, because at a certain stage of the design or process improvement, they have lost their original, functional purpose.

Design for X approaches allow the usage of expert knowledge in processes to provide the designers with guidelines on how to develop a product which can be cost-effectively manufactured and assembled, disassembled and repaired, and which is safe, of the required quality, etc. Let us consider at which stages of the product development process these approaches can be implemented. In a market-driven process, commonly called demand pull, the product development process starts with the description and analysis of existing or emerging customer needs. Then, marketing specifications have to be transformed into performance and technical specifications. At this stage the product value should be considered in terms of future functions and their expected cost [7]. At the concept generation and selection, variants of product realizations are generated and assessed in terms of their ability to satisfy requirements, as well as their possible costs and risks. Quality function deployment techniques can be used to ensure that targets set for the engineering characteristics of a product will satisfy customer needs, wishes and requirements. Value engineering and value analysis methodology can be used in order to understand product functions decomposition and control costs through the development process.

At this early stage, a preliminary technology plan, a supplier strategy and a manufacturing cost estimation could be made. Simultaneously, Design for X techniques could be applied according to the concurrent engineering concept, for example the Design for Assembly methodology which considers, among other issues, whether reducing the part count may have influence on the product architecture [7], intended processes and suppliers. Additionally, sustainability and environmental aspects (Design for Sustainability) could be considered - for instance, during material selection, issues on recyclability and re-use, or during process selection, decisions on energy efficiency, minimization of emissions, waste, and scrap [6]. After the concept is selected, the target specifications, cost, design, manufacturing and assembly processes, schedule and resources can be formulated [7]. Simultaneously with the product design, the assembly processes and manufacturing processes can be planned. Thus process requirements, limitations and possible risks can be considered at early stages to prevent costly changes that might occur later during manufacturing. This approach is commonly called DFM/A - design for manufacturing and assembly [8]. During design and process planning it is also important to consider issues of Design for Disassembly with possible targets of improved serviceability and repair opportunities as well as reuse and recycling [6].

Considering future challenges related to reduced lead times, increased product variability, and reaching sustainable development goals, the significance of decisions made during product development cannot be overestimated. The concurrent engineering concept, which includes a set of Design for X techniques is, despite the fact that it is not new, becoming more and more relevant for reaching the targets of minimizing costs, environmental impact as well as improving future product operation, use, reuse and disposal. Customization in product development, manufacturing and promotion enables companies to adapt their product life cycle model. This is especially important for meeting the actual needs, wants and wishes of customers in Industry 5.0 (Society 5.0). A prospective direction for further research is the peculiarities of entrepreneurial structures which are catalysts for innovative development in a new era of humanity.

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