TECHNIQUES AND TOOLS FOR QUALITY PRODUCT DESIGN

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Abstract
At present, the importance of accelerating product innovation in the global competition for their quality, functionality and versatility. To increase the quality of development processes and the products themselves, reducing time to market and cost is available to many techniques and tools. Their application is differentiated according to product sectors and business resources. The paper analyses the basic approaches to design tools for product quality. More deals with strategies of lean and agile design. Presents results of experimental research design in automotive production in the project of student car. The conclusion summarizes future trends in product design tools.

Key words: *design for quality, tools for product design, lean design and agile design*

Introduction

In numerous surveys of priorities of innovation are products in the first place. The significance of the intensification of product innovations underscores these factors [12]: constantly accelerating innovation cycles, great potential variability of the products, impact on productivity and product quality, high competition in the market for all kinds of products and complexity and risks of new product development.

Many new products on the market failed for lack of quality. The primary reasons for the existence of low-quality products are: products not correspond to the needs of customers, are outdated, unattractive, fault, evil operators and the second products are material-and energy-intensive and have high labour content, are made obsolete technology and uneconomical.

In the next ten years for example in the automotive industry will precede more changes than occurred in past 50 years. The companies are forced to [8]: innovate the products, technologies and production organization, apply the next generation Lean and Agile Production, and Design, rapid and flexible react on changes and intensive utilization of support knowledge intensive tools.

The important step to get ahead in this competition is designing new products in order to create difference and meeting the customer requirements. Meeting customer requirements has also direct relationship with design quality.

The work analyses the techniques and tools for improving the quality of the product design and presented their own research results in this field.

Overview of approaches to product design and the design for quality

Product design

There are numerous studies on qualitative approaches in the product design.

Common description of new product development' is "*the process that transforms technical ideas or market needs and opportunities into a new product on to the market*".

Product development and management Association /PDMA/ defines 'new product development' as *"the overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialisation of a new product.* [15]

Walsh et al. (1992) describes 'product design and development' as "*the activity that transforms the brief or initial market specification into design concepts and prototypes and then into the detailed drawings, technical specifications and other instructions needed to actually manufacture a new product.* [22]

Business dictionary defines product-design as *the detailed specification of manufactured items parts and their relationships to the whole. A product design needs to take into account how the item will perform its intended functionality in an efficient, safe and reliable manner. The product also needs to be capable of being made economically and to be attractive to targeted consumers.* [14]

For product design there are several known models based on the specification phase of the development process. [2], [3] [23] A typical example is the model used in automotive industry shown in Fig. 1.

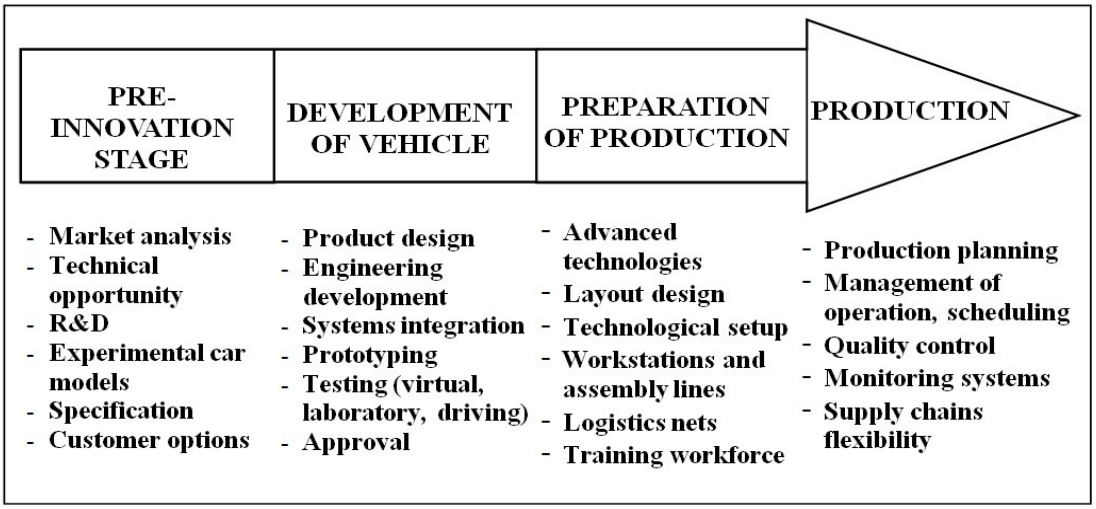

Fig. 1: Model of innovation activities in the automotive industry. Source: Author's papers. [8]

The Design Quality

Roth [18] definition of design quality is '*the processes and activities that need to be carried out to enable the manufacture of a product that fully meets customer requirements*.'

Business dictionary defines quality of design as *level of effectiveness of the design function in determining a product's operational requirements (and their incorporation into design requirements) that can be converted into a finished product in a production process*. [16]

Guide Design for Quality definition is - *DFQ is the disciplined application of engineering tools and concepts with the goal of achieving robust design development and definition in the Pd process. The DFQ process allows the engineer to: identify, plan-for and manage factors that impact system robustness and reliability upfront in the design process.* [1]

Design quality measures vary from organization to organization. They typically involve some measure that attempts to quantify how well the design function achieved certain objectives. These objectives can be product specific or they can be aligned with organizational goals. Examples [4]:

- Carryover parts usage (%),
- Number of variations for similar products (part count),
- Change Management,
- Cost avoidance and cost savings,
- Product Improvement (number of improvements),
- Number of technical changes to the product before and after the start of production.

Design Process Efficiency. Design process measures are metrics intended to quantify the efficiency or cost effectiveness of the design process over all engineering design activities. These are generally referred to as productivity or efficiency measures. The ones quoted by the panel are:

- Productivity = (Sales – Materials)/Engineering Labour,
- Productivity = Engineering cost / Sales (inverse of above),
- Productivity = (number of part numbers going through the PDP process)/(current year engineering expense),
- % Change in productivity,
- Project throughput.

The lean product design

The essence of Lean is to eliminate waste in all aspects of product development and related processes even before getting the product into production. The term is derived from lean manufacturing. The starting point is the customer's requirements and determine the value added. All others need not satisfy the customer and the customer must pay for it is considered waste. This includes: identification of features of the product with the highest added value, delete items without value and engage customers in product development stages [19]:

- Focusing on the initial development phase, which takes into account many variations, as there is room for optimisation.
- Parallel implementation of activities supported by the communication strategy.
- Optimise the development process and eliminating waste.
- Linking specialists from functional departments in multi professional teams.
- Waste reduction options in the draft.

. Examples of waste in product design:

- The proposal was never used, completed or delivered.
- Downtime in search of information, waiting for test results, etc.
- Unnecessary documents and prototypes.
- Insufficient use of product design techniques.
- Lack of risk analysis of manufacturing defects.

The best way to eliminate the losses that don't add value within the process of product design and development is to apply the "lean thinking" philosophy. Since "lean" business cannot produce "bold" products, the Lean Design and Lean Product Development methods get into concern. Chances to dramatic reductions of costs during the product design are:

- Reduction of direct material costs: platform components and material, simplifying of design, reduction of useless waste, samples, prototypes, etc.
- Reduction of direct costs on experiments and testing simplifying of design - design for lean manufacturing and assembly, reduction of part count, adaptation of product tolerances to operational possibilities process standardizing, etc.
- Reduction of operational costs: minimum impact on reconfiguration of manufacturing processes and systems, modular design, standards for modifications according to customer's demands, better utilization of manufacturing capacities and human resources.
- Minimizing development costs: platform of design strategies, lean QFD, Six Sigma, design of experiments, value engineering, and others.
- Acceleration of product development process affects three basic lean principles:
- Concentration of development activities: perform the work tasks in the shortest time possible, and minimum moving of project documentation between individuals and departments. That can be achieved with simultaneous solving and strong IT support.
- Application of knowledge basis from previous experiences portfolio. It means to make use of appropriate expertise, learn more than until now and update the knowledge base with development-relevant data from suppliers, competitors, customers, and partners.

Lean companies [20]:

- Prevent product failures rather than react to them.
- Create the culture to design quality and reliability into their products.
- Use product development teams to ensure that the quality and reliability issues of customers, manufacturing, service, and suppliers are properly represented.
- Open communication channels with customers to obtain timely and detailed product failure data.
- Maintain a well-conceived failure database of product field failure modes supported by failure analysis to root cause.
- Understand in detail the capabilities and limitations of both internal and suppliers' manufacturing operations.

Agile Product Development

The phrase "Agile Product Development" can be interpreted in two ways, both of which are correct and applicable to a wide range of products and industries:
1. An agile product development process that can rapidly introduce a steady succession of incremental product improvements which can be called "new" products — that are really planned "variations on a theme," based on common parts and modular product architecture. This capability results in ultra-fast time-to- market, much faster than possible with independent products that do not benefit from product-family synergies in design and manufacture.
2. Development of agile products that can be manufactured in the following agile environments: Agile Manufacturing, Just-in-Time, Build-to-Order, and Mass Customisation.

The scope of agility – definitions and overview
Emend of speed, flexibility, innovation, quality, proactively and profitability through the integration of reconfigurable resources that must be achieved in synergy. Quickly react to change by re-configuration of products, processes and organization structure. [5], [7].

Factories, based on Agile Manufacturing and customisation, are characterized [6] by: future production sites for a large variety of sophisticated products are offering flexible, short cycle time and variability controlling manufacturing capability. These manufacturing approaches ensure energy-efficient, reliable and cost effective production as well as production set-up/ramp-up with reduced cost and time through lean and simpler ICT. The adaptive (agile) enterprises exploit capabilities to thrive in uncertain and unpredictable business environment. Firms are capable of rapidly responding to changes in customer demand.

The agile manufacturing system should be able to produce a variety of components at low cost and in a short time period. To achieve Agile Manufacturing, company need agile design processes. [7].

Lean product development techniques, many companies have adopted in recent years, minimize waste and boost efficiency, but they also lock in product attributes too early and limit innovation.

Agile product development system is capable of addressing frequent iterations of multiple design options early in the process, based on continuous testing and highly sophisticated customer-driven design changes. This method, which both encourages flexibility and recognizes the unpredictability of the early stages of product development, ensures that the latter part of the cycle is much less uncertain, enabling companies to bring more popular products to market at lower cost, and with fewer delays. [7]

The goal of agile product development is to achieve rapid and frequent iterations with multiple design options up front — driven by continuous testing and granular customer analyses — in order to optimise, balance, and prioritise requirements and identify risks earlier. This early stage of the process has four primary characteristics:
1. Rapid and iterative development model Companies generate multiple concepts, and in a period of weeks, rather than months, test product prototypes with customers.
2. Modular architecture. By breaking a product concept into modules, companies can give sub-teams the responsibility to work out the best set of solutions for the final design and manufacturing of their part of the project, including interfaces, materials, or potential trouble spots.
3. Early risk identification. As cross-functional teams rapidly iterate and synthesize product ideas and concepts, more often than not the deep dive into the design process reveals potential development risks. With this knowledge, teams can prioritise potential risks and incorporate risk reduction plans into the development slate, while scheduling routine test events to verify that risks have been addressed.
4. *Intensive supplier involvement*. Traditionally, companies hold suppliers and the manufacturing function at arm's length until product requirements and concepts have matured. By contrast, the agile front-end approach seeks to gain the input of all - customers, partners, suppliers, and sales and manufacturing teams - to critique designs, offer insights, and broadly minimize risk and maximize efficiency up front so that fewer changes need to be made during production or product launch.

Methods and tools for product innovation

There is a large collection of techniques, methods and tools to support all phases of product innovations. Applications depend on innovation and building innovation potential of the body. Here are the comparison of the preferred methods and tools for product design in engineering with an emphasis on automobile production [2], [10], [12].

Selection tools for conceptual design focuses on the management of:
• Changing customer preferences,
• Incorrect specification of the parameters of the products,
• Different levels of technology maturity,
• Markets, financial uncertainty and the changing legal, political and social environment.

Preferred methods are particularly lean and system engineering. A comprehensive set of techniques for improving product development can be found in specialist publications. Sample selection techniques is in the Table 2. [12]

Table 2.: Selection of techniques for product design

Product planning	Integrated product teams
Design for manufacturability	Project management
Requirements definition	Pipeline management
Solids modelling	Product data management
Configuration management QFD	Early involvement
Analysis & simulation	Early supplier involvement
Empowerment Design re-use	Portfolio Management, CAD, CAE
The Product Development Best Practices	Assessment software and methodology

Other approaches to the selection of techniques for product design:
Software Design Tools: CAD - Computer Aided Design, CAM - Computer Aided Manufacturing, EDA - Electronic Design Automation, DFM - Design For Manufacture, DFT - Design For Test, DFA - Design For Assembly. [17]
Product Design Tools. These would be used predominantly during the design functions, to ensure that the right product is specified and designed and to reduce design time and costs. Within the process of product design, are there used the tools as: Design for manufacturing/assembly (DFM/A), Design for quality (DFQ), Design for Six Sigma (DFSS), Design to cost (DTC), Quality function deployment (QFD), Design failure mode and effect analysis (DFMEA). [18]
In the automotive industry, are widely used methodologies of product quality planning (APQP, VDA 4.3) and the requirements for the approval process to mass production of parts (PPAP, PPF).

Advanced product quality planning (or APQP) is a framework of procedures and techniques used to develop products in industry, particularly the automotive industry. The purpose of APQP is to produce a product quality plan, which will support development of a product that will satisfy the customer. APQP serves as a guide in the development process and also a standard way to share results between suppliers and automotive companies.

Part of the quality control standards in the automotive industry is methodological guide PPAP (Production Part Approval Process) and PPF (Produktionsprozess-und Produktfreigabe) - Unlocking the production process and product. These guides provide a set of requirements for the release of the production process and product to manufacture. Their purpose is to determine whether the supplier properly understand all the customer's requirements and specifications whether the manufacturing process has the potential to produce a product that the requirements will be in the actual production volume and at the agreed production speed consistently met.
The significance of design methods and techniques. In study [3] was made a survey of selected frequency techniques in practice, the automotive industry. The survey results reflected in the 0-3 point scale are follows:

- Design for Manufacture and Assembly 2,4
- Design for Reliability and Durability 2,2
- Design for Six Sigma 1,0
- Value Analysis 0,8
- Design for Service, Repair and Maintenance 0,5
- Design for Green Manufacturing 0,5

Shown differentiated approach to product design tool is caused by authors analyze the various phases of design and various product sectors. The application design tools are needed specialized methodology. In the next part will focus on the results of our research on product design tools to create prototypes of cars.

Case Study: Techniques for Product Design in project of student car

Testing the potential application of techniques for product design was the Faculty of Mechanical Engineering TU Kosice done on a project of student car conducted by the author [9]. The project was to design and construct a fully functional car in real size, which represented the University faculty and students study the production of cars in their acquired skills and knowledge of the issue of product innovations.

The car was taken by its originality, aggressiveness, speed, and innovative features modern and sporty appearance. The project modelled the real process automakers, with the real constraints and didactic intention maximum creative team-based methods learning by doing.

The sequence of phases of the project were as follows: generation of policy options the car, design proposals, graphic and computer design, evaluation, modelling, technical solutions, calculations, experiments, production decisions - subcontracting, original equipment manufacturing, assembly and testing.

The new car was built on the Skoda Fabia platform. Body and interior are completely original components. The new solution is a hinged door opening. Other innovations are the engine and chassis modifications. The new car is shown in Fig. 2.

Figure. 2: Student car ICAR (Faculty of Mechanical Engineering TU)

The project, among other goals / educational, technological, organizational / were investigated options, application potential and the complexity of product design techniques. The results of this research shows the Table 3.

Table 3: Used the techniques and tools for design of student car

Stage of Product Development	Used the techniques and tools for product design
Pre- innovation stage, preparation of a concept car	Innovation intelligence, creative techniques / brainstorming, synectics, morphology, gallery of design models, TRIZ / Sketch, fotomodels, small physical models Benchmarking of innovative ideas
Development stage	Design calculations and solutions CAD, simulation DFM, DFA, DFC Design for Quality Simultaneous and reverse engineering Platform a standardization approach
Phase of realization prototype	Designing products and forms Testing of components Optimising the supply of purchased components Quality Control Testing car

Crosscutting techniques used in all stages of experimental car:

Project management was a crosscutting activity, as part of the student team was not experience of dealing with large and complex projects.
Lean design methods, because in conditions of university research projects are limited financial and technological resources.
Design for quality, because the car represents the quality of student education in innovation and product design techniques. It shows the conditions for their application in automotive research and development.

Conclusion

Generally, all the tools for the product design will be applied in the next decade. Change will be their share. Currently, computer tools for conceptual design and rapid prototyping is the most influential tools used in product design.Simulation products, technologies, manufacturing and assembly processes will be increasingly important and will be partially substituted by prototypes and experiments.

The next most important technologies are design of experiments and competitive benchmarking. They are tools that work in both the physical and the virtual environment.

Design of experiment tools are often used to validate simulation and augment the simulation results in areas of the design that cannot be simulated. These tools will gain in importance as experiments become easier to conduct in simulation, and competitive benchmarking results are more rapidly analysed, disseminated, and integrated into the overall product plan.

Research has confirmed the potential of virtual design tools that reduce the production costs of natural samples and prototypes. Currently, however, can not completely replace experiments.

Challenges for the future quality of the product design:

- System integration product - process - information - knowledge,
- The transfer of innovation from aerospace and military industries to automotive,
- Products for low cost, flexible and reconfigurable manufacturing, products for sustainable production: reducing consumption of materials, energy and waste in product life cycle,
- Electronic data interchange in the design, analysis, manufacturing, testing and operation, allowing an increase in quality, competitiveness and customer orientation, standardization of virtual reality,
- Information security and protection of intellectual property,
- New tools and techniques for analysis, the migration of knowledge, generate innovation, design, testing, simulation and virtual reality.

Innovations in the car next decade will shape these trends:

The development of product design tools will be affected smart consumers. Consumers in the future will be better informed about the quality of products and their use. Transparent information and benchmarking to better decisions about purchasing products.

The trend is interested in intelligent products. If the incentives for innovation today managed by increasing the functionality, quality and effectiveness of products, in the near future products will compete well in intelligence.

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