INTERNATIONAL JOURNAL OF INTERDISCIPLINARITY IN THEORY AND PRACTICE

ITPB - NR.: 13, YEAR: 2017 – (ISSN 2344 - 2409)

PREPARING OF QUALITY PRODUCTION WITH REGARD TO RECYCLING-ORIENTED DESIGN

Alena Pauliková[1] – Marek Jemala[2] - Martin Vysocký[3]

Abstract: *After finishing of a life cycle, every product should be eliminated in such way to decrease waste loading. Recycling of unnecessary customer products is one of the most important tasks for sustainable development. However product recycling leads to several kinds of problems. „New-created„ products, obtained with recycling technologies, have to fulfil qualitative requirements given by a comparison with qualities of basic materials. The main goal of this article is to outline several important aspects of ecological construction, production, and management of industrial products, and at the end of the article is the partial analysis of waste generation by regions, proportion of waste recycling, and development of the number of manufacturing companies in the Slovak Republic.*

Keywords: Quality, recycling, design, waste, raw material.

1 INTRODUCTION

A process (within Pre-production stages management), which is intended to design new or innovative products, machinery or tools, is called construction. Creating a new product design, system, or technology, in our country, is more associated with visualizing and materializing a new product proposal. Construction can be associated with several technical disciplines (electrical engineering, computer science, architecture, optics, material engineering etc.), while a designer must have an adequate synopsis of the related safety-, health-, and environmental legislation, regulations, and standards. A new product design can be preceded by marketing research, technical-economic plans, and calculations, drawing up project documentation, etc. A designer largely determines a shape, dimensions, materials, functions and parameters of a new product, which must be effective, safe, environment-friendly and convenient to use.

2 ENTRY TO ISSUES OF CONSTRUCTION AND DESIGN OF INDUSTRIAL PRODUCTS

Investment in information technology (IT) was the most dynamic component of investment in the late 1990s and early 2000s. This investment enabled new technologies to enter the production process, to expand and renew the capital stock, and to sustain economic growth. It becomes a very difficult task for the policy makers of an organization to decide about the investments in IT. There can be two possibilities.

A part of the construction- and design work is to prepare a construction documentation, including, in particular, manufacturing drawings, BOM (Bill of materials) – design, description of technical parameters, test code, instructions for use and maintenance, BOM – components, test results, documentation for the production. Etc. (Rybanský - Drahňovský, 2009) Many software solutions (Adobe Photoshop and 3D; SolidWorks; Alias, etc.) enable to generate (together with a new product design) information necessary for the preparation of this documentation. Although, a crucial role in this process must have a man, especially in terms of products and technologies that have a direct impact on people and the environment. A part of the design process is archiving of documents related to the new product. This documentation often helps to find the causes of problems as to the negative effects of products that cannot be estimated in the long term.

The design works in industrial enterprises are often divided into so-called a functional design and a production design. The output of *functional design* is a prototype of a new product that is how the new product will function. In this phase of construction are taken into account, in particular, the following criteria: reliability, maintainability, usability, as well as safety and environment-friendliness. *Production design* completes the prototype to the product ready for serial or other production (Dupaľ - Leščišin - Stern, 2008). At this stage, there is mainly taken into account the appropriate manufacturability, in terms of technologic and economic parameters of the manufacturing process. Products that are too difficult to manufacture can be inefficient for a company and may have shortcomings in terms of quality and environmental parameters.

In view of the prevailing trends in a design of industrial products, in terms of environmental aspects of production, it may be mentioned, for example, so-called *Design simplification*, which aims to reduce a number of products groups, subgroups, parts and components so that it is easier and quicker to manufacture the product and at lower costs. The standardization of various parts of a product enables a rapid change and expands the product range, but also has cost and quality advantages. Standardly produced product parts that have also appropriate environmental parameters enable the company to improve its environmental aspects of the whole production as well as in terms of the changing assortment or production technology. This approach, however, should never lead to simplifying the requirements for safety, environmental and wholesome parameters of new products. It is not just about immediate effects of a new product/technology use, but also about long-term endogenous effects. Many businesses prefer so-called *Design for manufacturing*. This product design also has ecological purposes and is aimed at the fast and economical production. Specific software (DFMPro; DFMA; SolidWorks 3D CAD, etc.) for this type of design allows in particular to:

- Minimize the number of new product parts and thus also assembly processes.
- Minimize production time, a number of rejects and work in progress.
- Use of standardized components, a modular design, and technology.
- Use certified environment-friendly materials and construction.
- Increase the innovativeness of production, flexibility of technologies, and thus the competitiveness of the company, etc. (Russell - Taylor, 2009).

Nowadays, these links are practically impossible to implement without information technology (IT), in terms of a design, testing, implementation of new products or the rationalization of production. CAD/CAM and other IT systems can not only integrate these processes but also significantly improve, accelerate and cheapen pre-production stages. On the other side, the complexity of these systems, with the assistance of expert systems, envisages a more stable/complex conception of production and good market analyses as to the supply process. (Heyde - Lauden - Sabisch, 1990) The modular structure of IT in support of the process preparation may to some extent facilitate the pre-production processes, particularly if the company operates in a more turbulent market environment. CAD / CAE / CAM / CPD / 3D PDF[1] systems, however, are justified especially if pre-production/design processes have a higher repeatability and pretension, crucially determine the time and costs of the product development, and are an effective long-term business investment. However, many times happens that a company uses only 5-10% of the capacity of these IT. The goal is, therefore, the creation of integrated systems supporting preparation of production that enable automation of these processes, automate planning and a process design, organization and implementation of a new production. This integration allows the company to leverage the IT fully. In many industrial enterprises, particularly in terms of advanced technologies – these processes take place continuously, which requires adequate personnel and financial capacities as well.

Construction of a new product practically predetermines its quality, environment- friendliness, and cost. An inappropriate design, in terms of a poor scheme, excessive construction or high costs may make the company loses its customers. An efficient design of products should, therefore, meet the following requirements:

- Product design, materials, functions, and parameters should meet the requirements of customers, i.e. user parameters of quality.
- Design process of a new product should be fast enough so as the company can benefit from a suitable market opportunity, but not so fast that it fails to comply with quality parameters.
- Lower design costs may imply a greater competitiveness, but also a lower quality of the product.
- Design of a product and technology should be linked to a large extent, to avoid an unnecessary downtime during the start-up of the new production.
- Product construction should be designed so that it can be produced only with minimal changes after the tests of a prototype.
- Product design should also take into account the maximum recycling of used materials, etc.

Constructional preparation of production, a design of prototypes, and testing of a prototype are essential parts of the pre-production processes, but also of the acquisition of intellectual property rights associated with the new product. Design preparation of serial production is performed if the prototype passed the initial tests. This process includes a list of subcontracted parts/BOM, distribution schemes, or other specifications for serial production etc. Often, a company cooperates with various external partners in these processes. These may be research and design laboratories of various institutions and universities, but also private design- and consulting companies (Porsche Design, Wilddesign, LKK Design, etc.). In preparation for the new production is appropriate to formulate a strategy that will optimise spent investments to protect the key business know-how and ensuring a long-term socio-ecological acceptability of the production.

---

[1] *CAD (Computer-Aided Design) enables the creation, modification, and the analysis of a new product (e.g. 3D PDF). A technical analysis by means of CAD is called CAE (Computer-Aided Engineering). These processes make it possible to simulate the operations of a new product before the prototype fabrication. 3D printing then speeds up a functional prototype design. CAM (Computer-aided manufacturing) allows an automatic conversion of the virtual design to procedural instructions for production. CPD (Collaborative Product Design) means a joint collaboration of several designers on the design processes within the software program. (Russell - Taylor, 2009) This program also enables external companies to participate in the design of a new product that improves the synergies and time parameters of the pre-production stages. (Russell – Taylor, 2009)*

3 ENVIRONMENTALLY FRIENDLY DESIGN

Everyone case of material recycling is a specific task, which is complicated enough. Some of the components and materials cannot be recycled anywise. Although the technical progress achieved in recycling of the used products, together with economic efficiency of the whole recycling process, are the main criteria, the "environmental" design also plays a very important role. From this reason it is possible to say that recycling of the products partly depends on the product construction, whereas in the branch of engineering it concerns mainly various kinds of the machine components and materials.

Optimisation of the recycling systems, taking into consideration the economic, quality and environmental criteria, includes a requirement to modify design of the products with regard to the whole product life cycle as well as to eliminate the environmental impacts and to reduce exploitation of the primary natural resources.

Adjustments relating to the production design must be performed considering the constructional limitations, which are given by the various requirements. In Figure 1 there are illustrated the possible properties of the product, which are required individually for every given product.

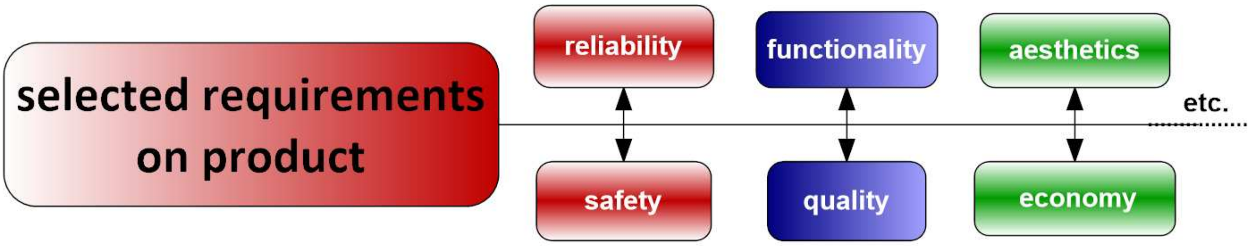

Fig. 1 Some of the selected requirements relevant for the product

3.1 Basic rules valid for constructional preparing of environmentally friendly production

The environmentally conscious designers should apply the following 10 "golden" rules during design process of the recycling friendly products:

1. to design the products with respect to the eco-trends, which are required by the customers,
2. to consider all the recycling aspects of the products already in the product projection phase,
3. to take into consideration maximal saving of the material, which has to be expended on the product,
4. to prefer the recyclable or reusable materials, i.e. materials with a possibility of their recycling as well as materials with a high level of the recycling compatibility,
5. to shape the individual parts and their assemblies using the high-precise engineering technologies already during production,
6. to avoid an early wear of the products by means of the proper design solutions (for example to apply suitable damping elements),
7. to apply the environmentally friendly technological procedures,
8. to utilize the energy-saving processes,
9. to simplify and to make easier procedure of the product disassembly,
10. to ensure a reusing possibility for the constructional components during utilization, repairs and maintenance of the product, etc.

3.2 Reusing of compatible and recyclable materials

The fourth rule within the given "golden Decalogue" is connected with the ninth rule directly during performing of the measures relating to the materials recycling. If the construction of the product contains the permanent joints of the individual components, without any possibility to change them, so the environmentally welcomed solution is application of the combinable materials that are tolerant with regard to their recycling. Thus, the constructional preparing includes utilization of the catalogues and databases containing the individual waste material groups.

The material catalogues as well as the databases are summarized mainly for the engineering constructional materials, namely for the ferrous and non-ferrous metals, plastics, glass and other materials categorized according to the branch of industry.

If it is not possible to create such suitable combination, which contains only the tolerant materials, then a better solution is design of the product using the components or groups of the components that will be easy detachable after termination of their durability, i.e. to apply the ninth rule of the environmentally conscious designer.

There is expected from a designer such arrangement of the components made from the valuable materials so that they will be accessible in the given construction, easy demountable and marked according to their recycling characteristics and suitability for recycling. The components manufactured from the materials, which are creating the hazardous wastage after ending of the product technical life, must be exactly determined already during the phase of their constructional preparing.

There was developed a methodology specified for indexing or evaluation of the materials according to the extent of their reusability, i.e. with regard to the level of recyclability. This methodology is based on a compatibility of the original materials with the waste materials, i.e. with the recycled materials or with the stuff produced just from these recycled materials.

3.3 Example of reusable product – stop shelter of urban public transportation

The stop shelters of the Urban Public Transportation (UPT) are usually produced from the aluminium alloys, steel or wood. Nowadays, the modern trends applied in design of the UPT-stop shelters represent the elegant and practical shelters manufactured from the steel profiles.

Walls and roof of these modern stop shelters are transparent. The roof panel is a polycarbonate voided-slab either clear, opalescent, lightproof or in colour modified. The roof beam also serves as a rainwater down-comer.

The glass walls with the unified dimensions are made from the hardened safety glass. Thickness of this glass is 10 mm and the glass mechanical strength is five-times higher than a strength of the standard glass with the same thickness.

The shelter can be suitably equipped with a wooden bench and handrail, plastic or aluminium timetable panel or advertising panel, plastic wastebasket and with other components necessary for the given UPT-stop (Mantič, 2016).

Tab. 1 summarizes the chosen materials, which are used for the given product, according to the valid technical standards and with their marking. The stop shelter itself is illustrated in *Fig.2*.

Tab. 1 Chosen materials applied for design of the shelter

Shelter assembly component and applied	ISO standard and marking
Self-supporting steel column construction with the roof beam – deep-drawing steel	STN 41 1321
Roof voided-slabs – plastics: polycarbonate (PC) materials suitable for shaping and extruding	Adapted international document: STN EN ISO 7391-1: 2006
Glass tables (sideboards and back wall) – hardened safety glass	STN EN 572-2;STN EN 12150-1; STN 70 1550

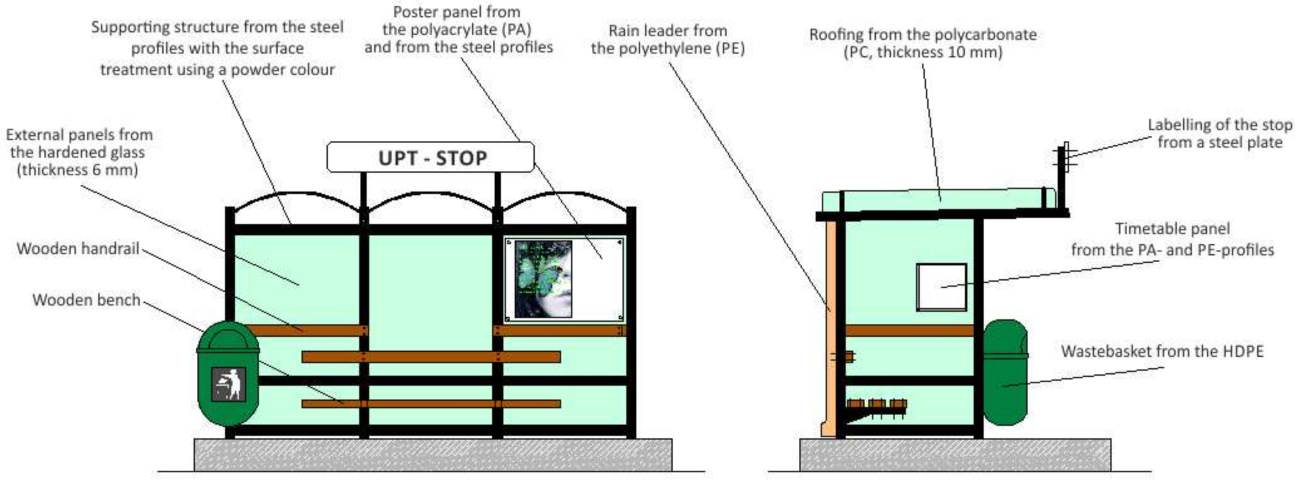

Fig. 2 Stop shelter of urban public transportation

3.4 Compatibility matrixes for the individual materials

Methodology of compatibility contains a classification of the materials according to the rate of their recyclability. The recycled materials are situated in the first line of the matrix and the original materials are arranged in the first column of the matrix. Degree of compatibility between the individual couples of the materials is situated in the intersection of the corresponding line and the column, whereas it is given in a percentage ratio of the recycling fruitfulness according to the compatibility between the concerned materials. *Tab.2* presents an example of the recycling compatibility matrix for the steels; *Tab. 3* is example of the recycling compatibility matrix for the plastics and *Tab.4* is for the glass.

Tab. 2 Example of the recycling compatibility matrix for the steels

Original steels \ Recycled steels	Deep-drawing steel	Unalloyed steel	Free-cutting steel	Cr low alloyed steel	Cr high alloyed steel
Deep-drawing steel	I.	I.	I.	I.	I.
Unalloyed steel	-	I.	I.	I.	I.
Free-cutting steel	-	-	I.	III.	III.
Cr low alloyed steel	-	-	-	I.	II.
Cr high alloyed steel	-	-	-	-	I.

Tab. 3 Example of the recycling compatibility matrix for the plastics

Original plastics \ Recycled plastics	PBT	PP	PVC	PC	PS
PBT – Polybutylene terephthalate	I.	V.	V.	II.	V.
PP – Polypropylene	V.	I.	V.	V.	V.
PVC – Polyvinyl chloride	V.	V.	I.	III.	V.
PC – Polycarbonate	I.	IV.	III.	I.	IV.
PS – Polystyrene	V.	V.	V.	V.	I.

There are known several classification scales created for determination of the compatibility. The individual classification scales are varying according to their classification sensitivity, physical units used for definition of the material properties relating to the material compatibilities as well as with regard to the number and kind of the analysed materials. *Fig.3* illustrates a simple five-stage classification of the material compatibility.

Tab. 4 Example of the recycling compatibility matrix for the glass

Original glass \ Recycled glass	Bullet-proof glass	Spy glass	Sound insulating glass	Safety glass	Radiation-proof glass
Bullet-proof glass	I.	III.	V.	II.	III.
Spy glass	III.	I.	II.	III.	V.
Sound insulating glass	V.	II.	I.	III.	III.
Safety glass	II.	III.	III.	I.	V.
Radiation-proof glass	III.	V.	III.	V.	I.

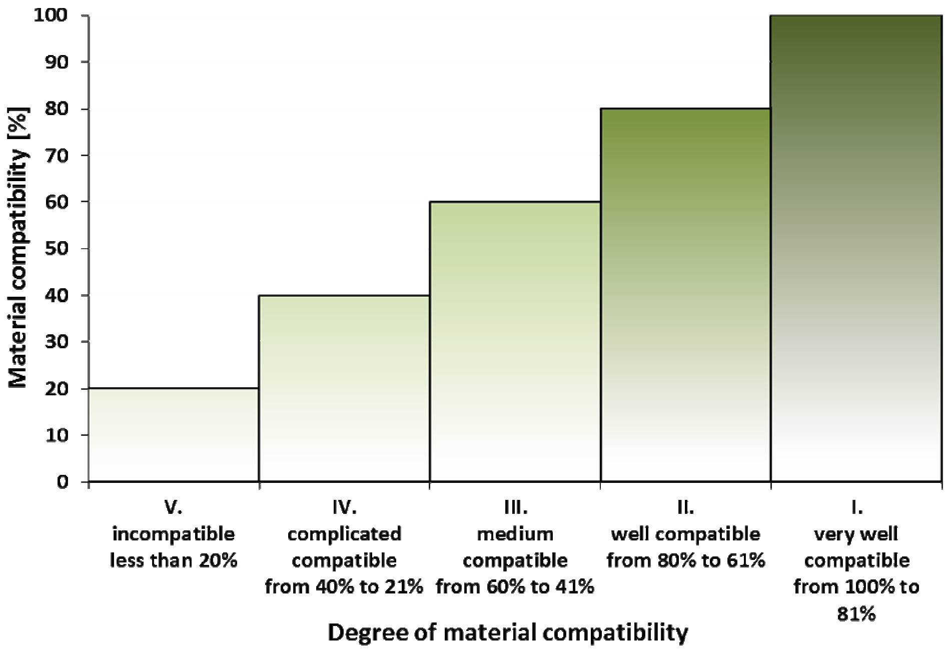

Fig. 3 Classification scale for the compatibility of materials

4 OTHER SOLUTIONS

The last performed analyses concerning the waste economy emphasize a necessity of stricter design recycling requirements, because the natural resources of the raw materials are limited. The simplest recycling solution would be a design of the product using only one kind of material, like were manufacturing our ancestors in the past. Application of the various materials and their variable mutual combinations are significantly complicating the following recycling process. Just from this reason the recycling process requires performing of a demanding separation, cleaning and homogenising of the waste materials. If it is impossible to use only one kind of the material in order to design the given product, then it is necessary to reduce the material diversity at least. It is still needed to determine the materials and their combinations that are utilized in one product with regard to their functioning during the life cycle and mainly according to their recycling compatibility.

5 MICROANALYSIS OF WASTE PRODUCTION IN THE SLOVAK REPUBLIC BY REGIONS, PROPORTION OF WASTE RECOVERY AND DEVELOPMENT OF NUMBER OF MANUFACTURING COMPANIES

Based on the statistics of the information portal of the Ministry of Environment (SR), there can be partially identified several trends in terms of the total waste production in Slovakia by regions, the proportion of waste recovery and the development of the number of manufacturing companies. During the reporting period (2012÷2013), the *Trenčín Region* had the largest share of waste production/generation in the SR, approximately 21.7%. The share of manufacturing companies in the region, however, was only 12.5 to 12.6% and the share of the population only 10.9%.[2]This development may indicate a greater burden on the environment in the region, but also the inadequate environmental policy (mainly of industrial enterprises). Among the most important companies in the Trenčín region can be included: Continental Matador Rubber, Puchov; Unipharma, Bojnice; Yura Corporation Slovakia, Lednické Rovne, etc. Matador, for example, has introduced the certified environmental management system according to ISO 14001:2004, the company has also decided to apply for the EMAS registration.[3]Environmental Management System (EMS) was implemented with a greater or lesser effect in many industrial companies operating in Slovakia. The EMS significance lies in the fact that it allows preventively avoid environmental problems in an enterprise and identify opportunities to continuously improve the environmental parameters of production also in terms of product design processes.

Among the largest "producers" of waste in the SR, one may also place the Banská Bystrica region (BBR) and the Košice region (KR) with the shares on the waste generation in the SR: 19.7% and 15.5% in 2013. For example, the BBR is the least densely populated region in the SR. The industry in the region is not evenly distributed. In the north of the region is the higher concentration of industrial companies in particular – the metallurgical, engineering, automotive, timber, pharmaceutical, and printing industries. In the southern part of the region prevails the food industry and agriculture. The KR is the second largest region regarding the export performance production and the GDP per capita. There mainly dominates metallurgy, which accounts for around 60% of the region's industrial production and approximately 50% of its exports.(SARIO, 2017) In terms of the number of companies in both regions, this figure was about the same from 9.9 to 10%, within the SR. In terms of population, in the Košice region live approximately 14.7% of people and in the Banská Bystrica region lives about 12% of the population within Slovakia (according to the data from 2015). Among (perhaps) the most important companies in the BBK region belong Slovalco, Žiar nad Hronom; Continental Automotive Systems Slovakia, Zvolen; Ironworks Podbrezová etc. The US Steel Kosice (possible future He Steel Group); VSE Holding, Košice; Magneti Marelli Slovakia, Kechnec, etc. belong to the most important companies in the KR. For example, U. S. Steel Košice regularly makes substantial investments in upgrading its own production facilities and environmental systems. The company has been gradually implementing the Environmental Management System (ISO EN 14001) across all its processes as well as in terms of the design process so as to implement the system of continuous improvements in all its business activities. (USSKE, 2017) Such a business-wide environmental management system can deliver better synergies in terms of public health and environmental aspects in a given region.

In terms of changes in the amount of waste generated in the period 2012÷2013, there mainly dominated the Banská Bystrica region (+ 101.3%), but also the Trnava region (+ 18.3%), within the SR. The Prešov region produced the least waste in this period within Slovakia, only about 4.8 to 6.8%, while the share of manufacturing companies was approximately 12.3 to 12.4%. The food, chemical, engineering, and textile industries mostly contributed to the production and exports in the Prešov region. Except for the chemical industry, these sectors are evenly distributed throughout the county. (SARIO, 2017) Among the most significant companies are currently Tesla Stropkov and Whirlpool Poprad. Regarding Tesla Stropkov, the company has received the certification according to EN ISO 9001, ISO/ TS 16949, EN ISO 14001. According to the company, these standards are again applied throughout the business cycle, consisting of marketing, development, design, tool production, core production (plastic, metal, assembly, piezo-ceramic), logistics, sales, and services. The quality control department has the key task to ensure the control at all levels (from the initial technical inspection to the final technical control), testing and validation of products (within the in-house laboratories, as well as with the external laboratories). (Tesla, 2017) This approach may be a positive example for other industrial companies, including the design processes. In terms of the population, in the Prešov region lives around 15.1% of the population, which ranks the region among the largest in Slovakia.

If we look at the waste recovery in different regions of Slovakia, then there dominate the Trenčín

[2] *We are taking into account also the population, since households are significant emitters of waste.*

[3] *EMAS - Environment Management Audit System*

and Žilina regions. The biggest change recorded in the monitored period again the Trenčín region (+ 34.3%). Already in 2009, the company – ERSON Recycling Trenčín in cooperation with the Ministry of Environment has received about EUR 7.7 million, within the European OP Environment and the state budget, for the development of waste management. The company has successfully built the recycling center for approximately EUR 12.8 million. (SME, 2016)In the Žilina region is also, in accordance with the regional waste management program, one of the main goals– the recycling of waste, but also the waste prevention. This program defines the role of municipal authorities and indirectly also companies, in the given region, to protect the environment. The region has already implemented several international projects focused on environmental protection (Strategy for development and building of integrated transport system ŽSK Žilina Municipality; By effective cleaning of roads to improve the environment, etc.).

The Prešov region is the county with the lowest generation of waste, but also the smallest share on the waste recycling in Slovakia. Regarding the foreign investment and projects in the region to promote environment-friendly products, technologies, and services, these are insufficient in the Prešov region in the long term. The main reason for this may be in the lower attractiveness, the lower economic potential and the lack of qualified workforce in the region. Here is the role municipal bodies, in cooperation with the government to create opportunities for the economic growth, employment, and systemic programs in industrial and environmental areas. The question of foreign investments to support the environment-friendly industrial production is also the matter of high responsibility, expertise, and culture of the relevant executive authorities in the region.

The most manufacturing companies in the Slovak Republic is in the Bratislava region (BR) and in the Nitra region. The least enterprises in Slovakia is located in the Košice region. Regarding the turnover of these enterprises, there again dominate the Bratislava and Žilina regions. The BR, in terms of waste generation, accounted for approximately 10.4 to 12.3% within Slovakia in the monitored period. While, the share of manufacturing companies was up from 19 to 19.2%. This development may indicate a more effective system of environmental management of enterprises in the Bratislava region, as well as the industrial production, which produces less waste. Approximately 53 to 53.5% of the generated waste was also recycled in the region. As regards to the financial indicators, the BR accounts for about 35.3 to 36.5% of sales of manufacturing companies in Slovakia (which is the most), as well as the largest amount of foreign investment. Increased financial resources also enable businesses to invest more in environment-friendly industrial production, but it may not be the rule. Many companies have invested more in quantitative parameters of production, which can only be effective in the short term. Among the most important companies in the BR belong: Volkswagen SK, Slovnaft, and Slovenské elektrárne. For example, the environmental protection at Volkswagen SKis the subject of the separate department that coordinates activities in the field of air protection, water protection and waste management. The environmental management program involves all employees of VW SK, including the non-production staff and also the research and development. (VW SK, 2017)

The share of construction work is higher in the industry of automotive production/mechanical engineering, compared to the petrochemical and power industries. In the area of design and technological preparation of production of these international companies operating in Slovakia, however, mainly dominate the parent companies. This means that the planning of preventive environmental management is largely set abroad, so many environmental Slovak enterprises are more focused on post-production activities – the capture and recycling of waste. These developments may indicate a certain lag in the long term, even when it comes to the protection of the environment and human health in Slovakia.

During the reporting period, the largest amount of waste per capita was produced by the Trenčín region, i.e. 3.18 tons, and 3.58 tons. In the second place was the Žilina region (2012) with 2.05 tons and the Banská Bystrica (BB) region (2013) with 2.94 tons per capita. The biggest increase was recorded just in the BB region and in the second place was the Trnava region. If we look at the investment activity in the BB region (to December 31, 2012), then the Department for Investment Projects had 72 investment projects in progress with the total volume of EUR 1.64 billion, of which 57 projects were in the stage called "live", their total volume reached EUR 1.26 billion. As mentioned, in this region are investments mainly allocated in the wood and furniture industry (German and Austrian companies), chemical industry (Petrochema Dubová – Fuchs Oil Corp. SK) and among the newer investment, it is the German tire production – CONTINENTAL in Zvolen. The BB region is among the regions with the highest unemployment and uneven industrial structure even in terms of the investment in environmental protection. (Sario, 2012; Sario 2015) For example, as part of the company Fuchs SK, continuous improvement of chemical products, especially in terms of their environmental aspects, is the main goal of the environmental corporate policy. For example, in the manufacture of coolant-lubricant compositions (water immiscible) were emissions lowered by over 80%by reducing the oil mist. (Fuchs SK, 2017). Such ecological solutions and standards create the basis for the economy of "clean" solutions, but it is necessary to start them as soon as possible in pre-production stages, particularly as regards to the technical preparation of production.

The least waste per capita was produced by the Prešov region, i.e. 0.72 tons, and 0.57 tons (2012 to 2013). The Prešov region recorded also the largest decrease in waste generation per capita, i.e. -20.3%. This region also reached the lowest GDP per capita EUR 7975.8, - and EUR 8042.1, - as well as the lowest average annual salary EUR 7704, - and EUR 7884, - in 2012-2013. On the contrary, the highest GDP per capita was recorded in the Bratislava region EUR 32603, - and EUR 33802.8, - (2012-2013), and there was also the highest annual average salary EUR 14700, - and EUR 15276, - (2012-2013). Economically more developed regions achieve in these indicators multiple differences compared to the poorer regions in Slovakia, which may be reflected in the promotion of environmental protection. There may be identified some correlation between an economic success of a region and a higher environmental burden on the environment. But, this does not apply fully in our conditions, because, for example, the Trenčín region had the high waste production per capita, but the GDP per capita and the average salary were below the Slovak average. In this study, however, we partly identified that the increase in GDP can mean a greater environmental burden. This is again a task for environmental management for more sustainable production. But, it is a problem also of an overall business efficiency, and also of innovation activities and responsibility towards a greener way of design, production, and doing business.

On the macroeconomic level are the longer-term trends to replace the main economic indicator – GDP, with the newer Index of Sustainable Economic Welfare (ISEW), which measures not only economic costs/investments but these are compared with expenditures/investments to protect the environment and sustainability of business. (Lawn, 2003) However, these processes must be initiated in pre-production stages when deciding on a design of a product, type of material, production technology, and spendings on recycling of materials and energy. Investments mainly to capture waste and emissions may not mean a significant impact on the environmental protection in Slovakia (Tab. 5, Tab. 6, Tab. 7).

Tab. 5 Comparison of waste production and recovery with number of production companies in Slovakia
Source: Own table based on statistics of [ŠÚ SR, 2017; Enviroportál, 2017]

Regions:	Waste production (in thous. ton)		Change (%)	Waste recovery(in thous. ton)		Change (%)	Number of production companies		Change (%)
	2012	2013		2012	2013		2012	2013	
Banskobystrický	953.8	1919.6	101.3	457	462.8	1.3	1545	1593	3.1
Bratislavský	1071.1	1004.1	-6.3	568	537.1	-5.4	2905	3100	6.7
Košický	1393.3	1514.9	8.7	366	488.4	33.4	1557	1617	3.9
Nitriansky	637.1	567.4	-10.9	285.1	247.3	-13.3	1950	2113	8.4
Prešovský	591.6	471.6	-20.3	303.7	189.6	-37.6	1897	1982	4.5
Trenčiansky	1877.3	2114.8	12.7	837.7	1124.9	34.3	1927	2015	4.6
Trnavský	728.9	862.5	18.3	351.4	416.1	18.4	1745	1860	6.6
Žilinský	1415	1304.4	-7.8	707.2	694.7	-1.8	1769	1880	6.3
SUM	**8668.1**	**9759.3**	**12.6**	**3876.1**	**4160.9**	**7.3**	**15295**	**16160**	**5.7**

Tab. 6 Comparison of waste production with turnover of enterprises and population in Slovakia
Source: Own table based on statistics of ŠÚ SR, 2017; Enviroportál, 2017; ŠÚ SR, 2015]

Regions:	Waste production (in thous. ton)		Change (%)	Turnover (in EUR 100 thous.)		Change (%)	Population in Slovakia
	2012	2013		2012	2013		2015
Banskobystrický	953.8	1919.6	101.3	4084	3850.6	-5.7	653024
Bratislavský	1071.1	1004.1	-6.3	30153.6	29164.6	-3.3	633288
Košický	1393.3	1514.9	8.7	7639.5	7034.1	-7.9	796650
Nitriansky	637.1	567.4	-10.9	6162.6	6528.3	5.9	682527
Prešovský	591.6	471.6	-20.3	3269.2	3197.7	-2.2	820697
Trenčiansky	1877.3	2114.8	12.7	8146.1	8848.1	8.6	589935
Trnavský	728.9	862.5	18.3	11490.3	11400	-0.8	559697
Žilinský	1415	1304.4	-7.8	11571.9	12535.5	8.3	690434
SUM	**8668.1**	**9759.3**	**12.6**	**82517.2**	**82558.9**	**0.1**	**5426252**

Tab. 7: Comparison of waste production with GDP per capita and average salary in Slovakia
Source: Own table based on statistics of [ŠÚ SR, 2017; Enviroportál, 2017; ŠÚ SR, 2015]

Regions:	Waste production per capita (in ton)		Change (%)	GDP per capita (in EUR)		Change (%)	Average salary per year (in EUR)		Change (%)
	2012	2013		2012	2013		2012	2013	
Banskobystrický	1.46	2.94	101.3	9549.90	9925.40	3.9	8940	9048	1.2
Bratislavský	1.69	1.59	-6.3	32603.00	33802.80	3.7	14700	15276	3.9
Košický	1.75	1.90	8.7	10513.20	10693.90	1.7	10440	10524	0.8
Nitriansky	0.93	0.83	-10.9	12036.70	12012.20	-0.2	9000	9108	1.2
Prešovský	0.72	0.57	-20.3	7975.80	8042.10	0.8	7704	7884	2.3
Trenčiansky	3.18	3.58	12.7	11865.80	11901.00	0.3	9348	10188	9.0
Trnavský	1.30	1.54	18.3	15040.60	15072.20	0.2	10800	10860	0.6
Žilinský	2.05	1.89	-7.8	11587.80	11671.20	0.7	10140	10344	2.0
MEAN	1.60	1.80	12.6	13448.06	13702.20	1.9	10308	10668	3.5

6 CONCLUSIONS

Many practical examples indicate that in today's conditions of globalization of industrial production and the 4.0 Industry trends is very important to link interactively individual pre-production processes, but especially the design and technological preparation of production. The designers must strive to make a product effective to manufacture and safe to use. The effort is not only to minimize a number of structural parts of the product and to use safe materials and practices but also to design the product structure so as to allow the quick and ecologic installation of each separate structural unit. In many industrial companies, construction works affect up to 80% of the total cost of the new product. While many leading industrial companies recycle around 85% or more of the materials used. Therefore, the design of more environment-friendly products and technology also has many economic advantages. The role of design and production technology is not only to propose and implement environment-friendly materials and methods of production but mainly the prevention of unnecessary waste and emissions production.

These processes are often a precondition for the innovative business development in many areas. In some areas (Chernobyl, Agbogbloshie, Citarum River, etc.), however, it is no longer possible to expand the industrial production, due to the excessive burdens on the environment and very negative impacts on society. Therefore, in this process should take a necessary preventive, legislative, control and corrective role – the state and its institutions. Adequate environmental strategies, policies, and programs must therefore adequately define requirements for the environment-friendly production of industrial goods. Environmentally acceptable construction (Design for Environment) is expected to prepare products in terms of materials, production and uses with a maximum protection of the environment (Russell - Taylor, 2009). Environmentally labelled products (e.g. Green Dot, ISO 14 000) create often a necessary precondition for competitiveness of a firm in terms of a customer demand, as well as foreign funds, bank loans, low rates on insurance, government grants etc. Production efficiency, recyclability and a minimal burden on the environment must, therefore, be the main criteria for the environmentally acceptable design of new products.

Acknowledgment: *This paper was written with the financial support of the granting agency KEGA of The Ministry of Education, Science, Research and Sport of the Slovak Republic as a part of the project No. 074TUKE-4/2015 - An innovative approach to legislative coordination of environmental protection through the visualization on the basis of the phenomenon Small World Networks.*

REFERENCES

[1] Dupaľ, A. – Leščišin, M. – Stern, J. (2008): Manažment výroby. SPRINT–Bratislava, ISBN 8089355006.

[2] Enviroportál (2017): Produkcia odpadu a nakladanie s odpadom v SR, [on-line], <http://cms.enviroportal.sk/odpady/verejne-informacie.php?rok=B-2013&kr=v&kat%5B%5D=v>, February 2017.

[3] Fuchs SK (2017): Ekológia, [on-line], <http://www.fuchs.sk/o-nas/ekologia>, April 2017.

[4] Heyde, W. – Lauden, G. – Sabisch, H. (1990): Komplexná príprava výroby. ALFA – Bratislava, ISBN 80-05-00658-6.

[5] Lawn, P. A. (2003): A theoretical foundation to support the Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI), and other related indexes, Ecological Economics, Vol. 44,No. 1, pp. 105-118, ISSN: 0921-8009.

[6] Mantič, M. – Kuľka, J. – Faltinová, E. – Kopas, M. (2016): Autonomous online system for evaluating steel structure durability - 2016. In: Diagnostyka. Vol. 17, no. 3 (2016), p. 15-20. - ISSN 1641-6414

[7] Russell, R. S. – Taylor, W. B. (2009): Operations Management. John Wiley and Sons (Asia) Pte Ltd., ISBN: 978-0470-23379-5.

[8] Rybanský, R. – Drahňovský, J. (2009): Manažment výroby I. MTF STU – Trnava, ISBN 978-80-8096-084-1.

[9] SARIO (2012): Výročná správa, [on-line], <http://www.sario.sk/sites/default/files/content/files/sario-vyrocna-sprava-2012_0.pdf>, April 2017.

[10] SARIO (2015): Výročná správa, [on-line], <http://www.sario.sk/sites/default/files/data/sario-vyrocnasprava-2015.pdf>, April 2017.

[11] SARIO (2017): Regionálne analýzy, [on-line], <http://www.sario.sk/sk/obchodujte-so-slovenskom/regionalne-analyzy>, February 2017.

[12] SME (2017): Schránke z Cypru išli eurofondy za predražené stroje na recykláciu, [on-line], <https://ekonomika.sme.sk/c/20070323/schranke-z-cypru-isli-eurofondy-za-predrazene-stroje-na-recyklaciu.html>, February 2017.

[13] STN 41 1321 - Oceľ 11 321 (17. 8. 1987)

[14] STN EN ISO 7391-1 Plasty. Polykarbonátové (PC) materiály na tvárnenie a vytláčanie. Časť 1: Systém označovania a základy na špecifikáciu (1. 7. 2006)

[15] STN EN 572-2 Sklo v stavebníctve. Základné výrobky zo sodnovápenatokremičitého skla. Časť 2: Floatové sklo (1. 1. 2013)

[16] STN EN 12150-1 Sklo v stavebníctve. Tepelne tvrdené sodnovápenatokremičité bezpečnostné sklo. Časť 1: Definície a opis (1. 1. 2016)

[17] STN 70 1550 Bezpečnostné sklo tvrdené. Sklo na zasklievanie dopravných prostriedkov. Spoločné ustanovenia (14. 3. 1988)

[18] ŠÚ SR, (2015): Population and migration, [on-line], <https://slovak.statistics.sk/wps/portal/ext/themes/demography/population/indicators/>, February 2017.

[19] ŠÚ SR (2017): Regional statistics, [on-line], <https://slovak.statistics.sk>, February 2017.

[20] TESLA (2017): Certifikáty, [on-line], <http://www.tesla.sk/sk/-certifikaty-na-stiahnutie>, February 2017.

[21] USSKE (2017): Životné prostredie, [on-line], <http://www.usske.sk/sk/o-nas/zivotne-prostredie/uvod>, February 2017.

[22] VW SK (2017): Životné prostredie vo VW SK, [on-line], <http://sk.volkswagen.sk/sk/Podnik/ochrana_zivotneho_prostredia.html>, February 2017.

AUTHORS ADDRESSES

[1] doc. Ing. Alena Pauliková, PhD.

Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Industrial Engineering and Management, the Slovak Republic

E-mail: alena.paulikova@gmail.com

[2] doc. Ing. Marek Jemala, PhD.

Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Industrial Engineering and Management, the Slovak Republic

E-mail: marek.jemala@stuba.sk

[3] Ing. Martin Vysocký, PhD.

Inter-Informatics a.s., Praha Libeň, The Czech Republic