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Engineering Design in Integrated Product Development
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DESIGN IN INTEGRATED PRODUCT POLICY

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Abstract: *In the paper the place of design in Integrated Product Policy is indicated. General assumptions connected with product orientation as the actual tendencies are characterized. Additionally different tools to be applied in such a product policy are presented. Some methodological aspects of their applications are discussed. Prospects of Integrated Product Policy are described on the background of design concepts development.*

1. INTRODUCTION

Nowadays, according to the ideas of sustainable development, is a growing need for identifying economically and technically feasible and environmental compatible solutions, which enable us to manage this challenge. From an earlier focus on substances and technology, modern thinking has to move towards greater attention to products themselves, including different dimensions of them. Product life cycle has to be considered by all stakeholders. Particularly, in the product design all the important decisions have to be taken considering its environmental impacts during its entire life cycle. Product management aspects also belong to environmentally sensitive because of their extensive consequences.

For companies that develop product themselves, incorporation of environmental aspects in connection with product development and specification is the only one way to be compatible to the environmental policy and legal regulations. They can be more competitive generally. Experiences of the leading enterprises show that working systematically with environmental aspects during product development can have beneficial side effects in the form of savings, quality improvements, better contact with the market and greater customer satisfaction.

There is a lot of connections with the cost shifts during the product development. For example, the new product can cost more because of new equipment necessary to make this product. However general result can be beneficial, because using and disposing the product can cost less, which could mean bigger sales. This example shows the need of acceptance by the management and a need of clear policy with clear objectives for the goal to achieve.

Generally, the challenge is to combine environmental improvements and better product performance go hand in hand and to create environmental improvements support long-term industrial competitiveness. In consequence, environmental policies should not be focused on large point sources of pollution, such industrial emissions or waste management issues. They need to be complemented by a policy that looks at the whole of a product's life cycle. To be successful, the policy also has to take into account several characteristics of products. Therefore product policy [1]:

– should aim to reduce the environmental impacts of increased quantities of products,
– has to be flexible in order to address many different product variations simultaneously,
– has to use creativity for the benefit of the environment as well as the economy,
– has to take account of the global nature of trade and be in compliance with relevant international agreements,
– needs to ensure that producers and designers become more responsible for ensuring that their products fulfill agreed criteria on health, safety and the environment,
– should ensure that well product design incorporate proper use and disposal, which minimize environmental impacts,
– should contribute to improving information flows along supply-chain.

Presented factors underline the need to introduce a product dimension to environmental policy. It is necessary to look at the product in a holistic way, involve as many actors as possible and leave to them the responsibility for the choices they make. The Integrated Product Policy (IPP) approach seeks to address this challenge in line with not only environmental, but also economic and social objectives.

2. CONSEQUENCES OF PRODUCT ORIENTATION

2.1. General principles of IPP

The Integrated Product Policy is based on five key principles [1]:
– life cycle thinking,
– working with the market,
– stakeholders involvement,
– continuous improvement,
– a variety of policy instruments.

The life cycle of the every product brings together different policy areas such as industry, transport, energy, environment, trade and agriculture. The general aim of IPP is reduction of cumulative environmental impacts of the product. By looking at the whole of a product's life cycle, IPP generates the need to use measures to reduce environmental impacts at the point where they are likely to be most effective in reducing environmental impacts and saving costs for business and society [1].

Activities of different actors who come into contact with the products (i.e. industry, consumer and government) are oriented on different spheres of life cycle, but generate the need of cooperation between different stakeholders. The industry stakeholders look for the integration of environmental aspects in the design phase of product, while consumer want to assess how they can purchase greener products and how they can better use and dispose of them. Government can stimulate environmentally oriented activities by setting economic and legal conditions for entire national economies and by promoting greener products for the markets.

The idea of continuous improvement has general character and is generated by consumer expectation and the market competition. Improvements can be made also to decrease environmental impacts across the product life cycle, whether in design, manufacture, use or disposal. The mature companies put the environmental aims in the development strategy or look for the improvement possibilities because of Total Quality Management practice.

Because of variety of products and different stakeholder involved, IPP should be supported by different instruments. They range from voluntary initiatives to mandatory regulations and from the local to international scale. The best determining factor of tools can be applied is the effectiveness in achieving the desired results with regard to sustainable development [1].

2.2. Activities for IPP

2.2.1. Tools for economic and legal framework

Government intervention can stimulate companies to environmental improvements by different ways. Voluntary regulations connected with market incentives for consumers compose one of the groups of methods. To the second group belongs economic and legal framework which eliminate selected effects in the technology, products and services. The main tools from this group, suitable for the purpose of IPP, are:
– taxes and subsidies (tools for promoting greener products on the base of fiscal measures),
– voluntary agreements and standardization (non-legislative solutions, such as environmental agreement and standardization on environmental protection),
– public procurement legislation (directives and rules setting down the environmentally oriented procedures in the selected branches of the market).

2.2.2. Application of life cycle thinking

Life cycle thinking has to characterize all of actors who come into contact with product. There are two areas of activities particularly important: educational, which causes raising of environmental awareness, and promotion of carefulness of environment on national and regional level. Three sets of actions are indicated as required to develop life cycle thinking in the society:
– making available information and tools (collecting and disseminating life cycle data for design and labeling purposes, promotion of methods such as Life Cycle Assessment, which provide the best framework for assessing the potential environmental impacts of products),
– implementation and re-orientation of Environmental Management Systems (the approach which provide good framework for integrating life cycle thinking and which is re-oriented from the process dimension towards products),
– product design obligations (application of rules oriented on environmental requirements, which stimulate to develop greener products in form of legal base, internal market considerations, international treaty obligations).

2.2.3. Dissemination of information for consumer to decide

To the group of market stakeholders belong consumers – public or individual. They decide whether or not they purchase greener products and how these products will be used. A goal to achieve is to increase the level of consumer awareness necessary for them to play their role part in greening products. Following policy instruments are suitable to fulfillment of such a assumption [1]:

– greening public procurement (determining the extent of greener public procurement, assessing the potential environmental impacts of it, planning programs of greening public procurement, elaborating information measures for public authorities to assist them in greening their purchasing policies),
– greener corporate purchasing (stimulating private sector to demand greener products and certified management systems, and to become environmental reporting more transparent),
– environmental labeling (development of labeling schemes, which support easy product choice, promotion of easily understandable eco-labels),
– programs of sustainable composition and other factors relevant when purchasing products (safety and health aspects, cost, effectiveness and other).

2.3. Directions of IPP development

The need of IPP development requires the synergies between different tools and activities. First of all "IPP thinking" should permeates all aspects of the management of different tools and activities. Additionally it should integrate activities further into other policy areas than environment.

Commission of the European Communities realizes the concept to initiate a number of processes to facilitate coordination and monitor progress. It will develop suitable indicators to measure the environmental improvements inducted by the IPP approach.

On the operational level specific measures are proposed and still develop to monitoring of IPP forming [2]:

– measures aimed at reducing and managing wastes generated by the consumption of products (wastes materials and materials streams which may be recovered and reused or recycled),
– measures targeted at the innovation or more environmentally-sound products (stimulating research and development of technologies and products),
– measures to create markets form more environment friendly products (effectiveness of adoption these products onto the market),
– measures for transmitting information up and down the product chain (transparency about the environmental burdens and full environmental costs of product systems – useful to alter customer behavior across the product system),
– measures which allocate responsibility for managing the environmental burdens of product systems (allocated legal and financial liability concerning to potential and actual burdens).

All presented measures concern different fields, but they have the common feature - they are connected in being aimed at improving the environmental performance of product systems.

3. THE PLACE OF DESIGN IN IPP

The design stage in the life cycle of the product has special role influencing on the final result. Different design strategies may seem to define the goals of a design project. But an effective design relies on a synthesis of multiple strategies for translating requirements into solutions. Appropriate strategies need to satisfy the entire set of design requirements, thus promoting integration of environmental requirements into design. For example, essential product performance must be preserved when design teams choose a strategy for reducing environmental impacts. If performance is so degraded that the product fails in the marketplace, the benefits of environmentally responsible design are only illusory.

General strategies for fulfilling environmental requirements concentrate on [3]:

– product life extension,
– material life extension,
– material selection,
– process management,
– efficient distribution,
– improved management practices.

Typical tendencies assigned to different environmentally oriented decision made during design process are presented below [4]:

- choice of materials:
  - reduce the content of hazardous substances,
  - incorporate recycled and recyclable materials,
  - use more durable materials,
  - use smaller quantities of materials;
- priorities in the processes:
  - reduce wastage,
  - reduce energy consumption,
  - reduce the use of hazardous substances;
- use of the product:
  - ensure energy efficiency,
  - reduce the amount of waste and emissions,
  - minimize the packaging
- reuse and recycling:
  - incorporate reusable or recyclable materials,
  - ensure that the product can be easily separated after use,
  - use as many standardized materials as possible,
  - ensure that each part/component is labeled,
  - reduce the number of components in the product,
  - reduce the number of different materials in the product;
- lifetime of product and components:
  - ensure that components and parts of the products can be used in other products,
  - ensure that the product can be upgraded,
  - ensure that spare parts and accessories are readily available for maintenance and repair,
  - use reconditioned parts from worn-out products;
- disposal:
  - ensure that the parts of the product that can not be reused or recycled can be incinerated with energy recovery,

- ensure that the parts or components the most difficult to disposal can be deposited at a landfill site with the smallest possible impact on the environment.

Diversity of problems, which should be analyzed cause necessity to use complex tools supporting decision process. Such a tool needs to undertake environmental problems connected with the whole life cycle (Fig. 1).

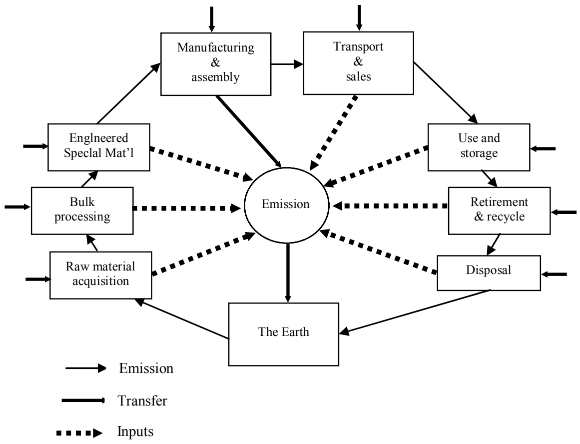

Fig. 1. Environmental problems analyzed during design process [5]

4. THE TOOLS TO BE APPLIED

4.1. General information

In area of environmental aspects, different approaches based on life cycle concept are called also "cradle to grave" analysis and "fence line approach". It is possible to find differences between some of the methods, which belong to this area. For example fence line approach assesses the impacts associated with the product on site and disregards off-site functions. In consequence this approach does not provide essential information needed to assess the total impact, but provides insight into the operations at the site and their impact on the environment. The fence line approach is not a true life cycle analysis but should be considered when determining the exact requirement of analysis [5].

Among the tools (methods) from the family of "cradle to grave" analysis (or broadly expressing chain analysis) one can identified [6]:

- Material Flow Accounting (MFA),
- Life cycle approaches, with Life Cycle Assessment (LCA) as a specific tool,
- Input-Output approaches, with the specific monetary tool – IOA,
- Environmental Impact Assessment (EIA),
- Risk Assessment (RA).

The first three, from the above mentioned, have their focus in the socio-economic system, with larger or smaller extensions into the environment system. The latter two have their focus in the environment only.

Because of the diversity in the area of possible applications Material Flow Accounting and specially Life Cycle Assessment approaches seem to have the biggest perspectives of development. They have one general common feature – environmentally oriented character. In the MFA, transformation of one type of material is analyzed within both the society and environment of the region. In LCA the total inputs (extraction of resources) and outputs (emission of hazardous substances) of one product are analyzed. It means that in MFA analysis one material in the whole society/environment system is considered, and in LCA one subsystem (the product system) for all materials is taken into consideration [6]. It is possible to moderate application of both these tools. The MFA may be extended to groups of materials, and LCA may be extended to broader systems than just one product.

Nowadays LCA is recognized as the most useful method, what is reflected by the significant amount of studies prepared using this methodology and the biggest number of different tools, which can help processes of assessment.

4.2. Life Cycle Assessment method

As it was noticed, LCA method belongs to the group of life cycle approach, which is generally represented by ecobalance designation. Although the scope of the problems considered in the whole Life Cycle Assessment or Life Cycle Analysis is broader than in case of typical ecobalance, all three of these methods are very often treated as equivalent to each other. Such a situation is observed even in the papers addressed to specialists.

The LCA of the object (product, process or activity) is defined as a process aimed at identifying the negative effects of it, quantifying the use of raw materials, energy consumption and emissions, evaluating the impact of these uses made of energy and materials as well as emissions into the environment, and evaluating the relevant improvements in an environmental context [7]. Taking into consideration such a definition one can state, that LCA is designed to support decision making processes particularly in area of environmental aspects, but the true is, that LCA can be supplemented by other assessments which make it possible to take into account other factors, not usually incorporated into the LCA, for example, the economic and organizational aspects.

An example, how various tools and elements may be integrated in a broad process such as product development, is presented on Figure 2.

It is worth noting, that there is no tool that can provide the information required for making the decision. Thus, the additional role of LCA method emerges, which in suitably and complex form can be used to help decision making by meeting requirements of broad aspects, necessary for environmental management:

- human and environmental safety,
- regulatory compliance,
- efficient use of resources and waste management,
- societal expectations and concerns.

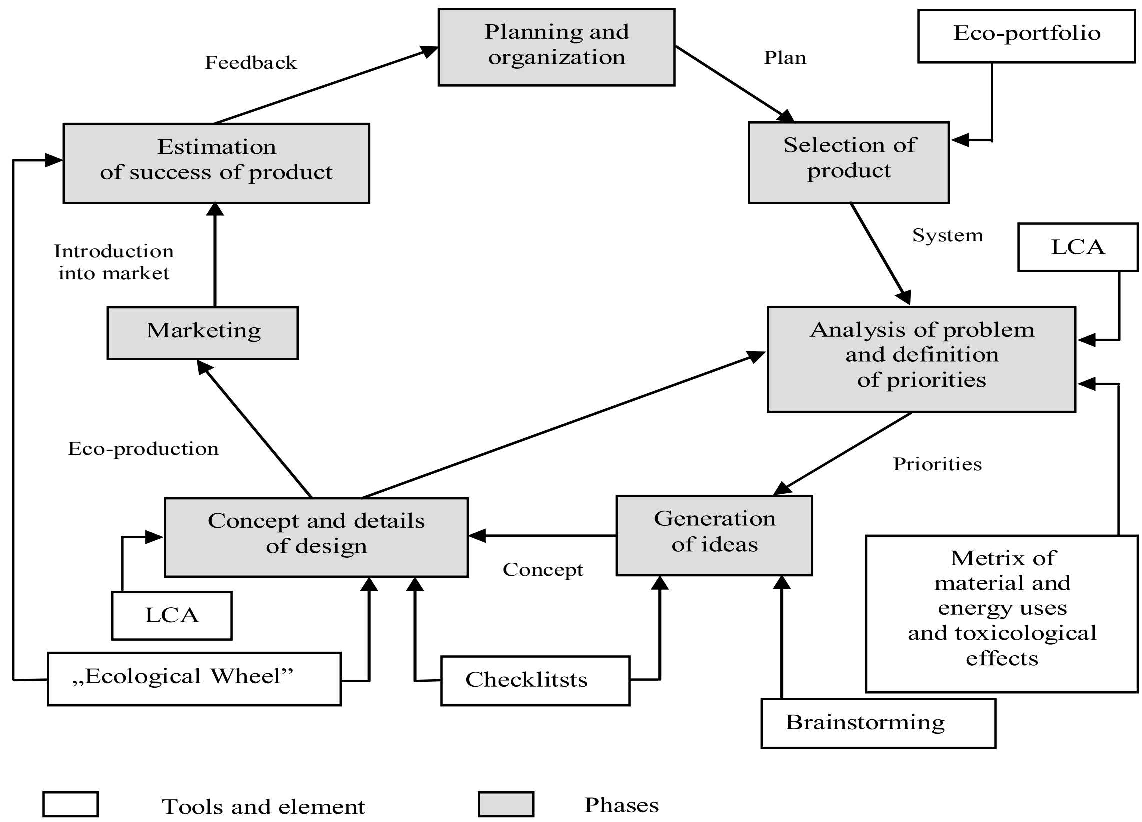

Fig. 2. The place of LCA tools in design and other life cycle phases [8]

Because of universal character particularly in the area of environment, LCA seems to be one of the tools oriented on the sustainable development including Integrated Product Policy which are now on the national and international agendas. They require specially rapid improvements in eco-efficiency, or in the efficiency connected with energy and a wide range of materials taken from nature. Such requirements can be met using LCA, as a tool for indicating weak and strong areas (from environmental point of view), and additionally improvement possibilities.

Nowadays one can state that Life Cycle Assessment is definitely the most recognized and internationally accepted methods for examining environmental performance. Work to develop broad consensus on the conduct of LCA was initiated in 1990 by the Society of Environmental Toxicology and Chemistry (SETAC) and the result in the form of 'Code of Practice' [9] was achieved in 1993.

This was an indication for International Standardization Organization to establish standards on LCA. The general outline on how to perform LCA is given in ISO 14040.

ISO describes LCA as "a technique for assessing the environmental aspects and potential impacts associated with a product, by:

- compiling an inventory of relevant inputs and outputs of a product system,
- evaluating the potential environmental impacts associated with those inputs and outputs,
- interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

LCA studies the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and disposal. The general categories of environmental impacts include resource use, human health, and ecological consequences".

The LCA methodology is composed of following interrelated elements (Figure 3):

- goal and scope definition,
- inventory analysis,
- impact assessment,
- interpretation.

It should be noticed that LCA is not linear process starting with the first and ending with the last phase. Instead it follows an iterative procedure, in which the level of detail is subsequently increased. As an example one can indicate the case when doing the impact assessment it can become clear that certain information is missing which means that the inventory analysis must be improved, or the interpretation of the results might be insufficient to fulfill the needs required by the actual application (which means that the goal and scope definition must be revised).

As it was presented, LCA methodology is a very complex procedure which can involve different aspects (particularly environmental) connected with different objects. Wide variation is also a feature of the application areas of LCA methodology which originally was developed as a decision support tool for distinguishing between products, product systems or services.

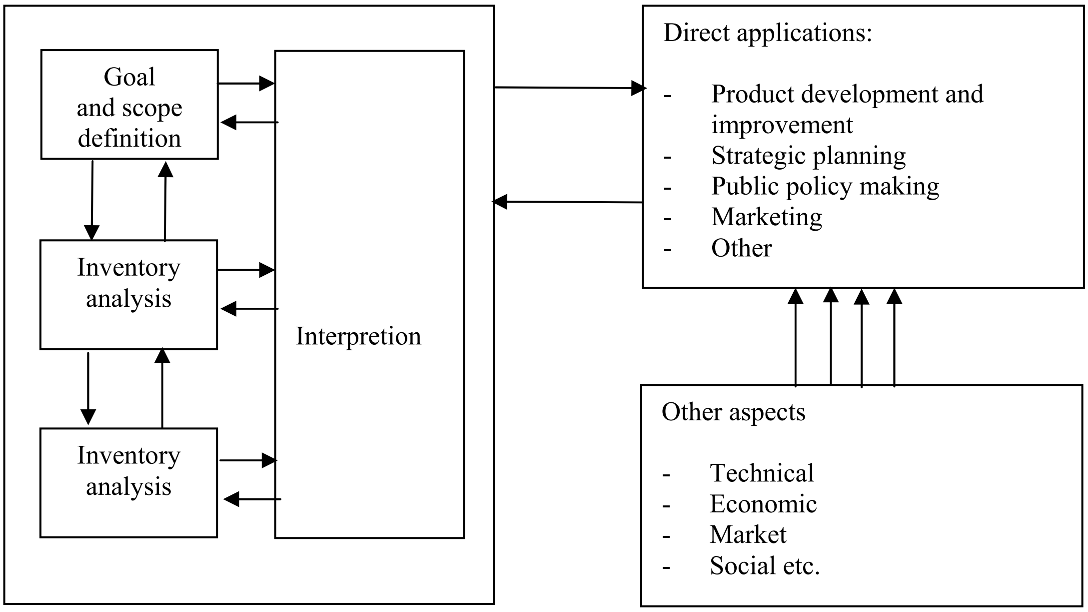

Fig. 3. Phases of LCA

During the evaluation of LCA as a method, the field of its application still becomes broader and broader. In the field of designing process of technical objects goals for LCA are:
– environmental reports (not analyzing the effect of the choice),
– short term system optimization,
– hot spot identification and elimination,
– product system optimization,
– product development,
– product system comparison (analyzing the effect of the choice),
– long-term strategic planning,
– modeling future processes.

Following general applications meet requirements of IPP assumptions:
– internal industrial use in product development and improvement,
– internal strategic planning and policy decision support in industry,
– external industrial use for marketing purposes,
– governmental policy making in the areas of eco-labelling, green procurement and waste management opportunities.

4.3. Life Cycle Management

Life Cycle Management (LCM) concentrates on decision processes that influence system cost and usefulness. Environmental aspects are not always put into this practice, but it is easy to observe such tendencies. Mentioned earlier decisions must be based particularly on full consideration of business functional requirements, economic and technical feasibility in order to produce an effective system. The main objectives of the LCM practice comprise:
– delivering quality systems which meet customer expectations, including cost estimation,
– delivering systems that work effectively and efficiently within the current and planned technology infrastructure,
– delivering systems that are cost-effective to enhance and maintain,
– developing quality systems using an identifiable, measurable and repeatable processes,
– establishing an management structure with appropriate levels of authority,
– identifying and assigning the roles and responsibilities of all affected actors including functional and technical managers,
– ensuring that information system or infrastructure system requirements are well defined and subsequently satisfied [10].

LCM includes six phases, during which information or infrastructure system are created or modified. They are characterized below [10]:
- initiation phase; the purposes of this phase are:
  - identification and validation an opportunities to improve business results, environmental view and others,
  - identification of significant assumptions and constraints on solutions,
  - choice of exploration concepts and methods to satisfy the need;
- concept phase; this phase is to determine whether an acceptable and cost-effective approach and technology solutions can be found to address the business and environment need; the purposes of this phase are:
  - identification of system interfaces and functional requirements to satisfy the business and environment need,
  - establishing system boundaries, identification of goals, objectives, success factors and performance measures,

  - cost and benefits evaluation of alternative approaches to satisfy functional requirements,
  - risk assessing and developing process models, data models and concept of operations;
- detailed analysis and design phase; the purposes of this phase are:
  - further definition of requirements,
  - complement and selection of components, including reuse components,
  - business process reengineering as a support tool,
  - developing of detailed data and process models,
  - refining design to support the functional and technical requirements,
  - identifying and mitigating risk, and coordinating with the business area;
- development phase; the purposes of this phase are:
  - designing, developing, integrating and testing information or infrastructure system,
  - updating and finalizing plans to deploy information or infrastructure system,
  - complement business and other aspects transition planning, and initiation transition activities;
- deployment phase; the purposes of this phase are to ensure that:
  - information or infrastructure system is implemented,
  - people involved in the LCM practice are trained,
  - end users and supporting organizations accept the system;
- operations phase; in this phase following activities are dominating:
  - operation of the system,
  - testing that the system can process sensitive information,
  - data base assessment,
  - conducting periodic assessment of the system efficiency,
  - determining conditions to modernize, replace or retire the system.

To implement LCM as an efficient tool in practice it is necessary to build complex information or infrastructure system. It is a combination of functional users, information technology, business processes, application procedures, documentation, networking, information dissemination. Such a solution requires considerable costs and significant number of people engaged. The most sensitive areas and processes during LCM implementation are: requirements management, data management, quality assurance, configuration management.

The general objective of life cycle management is optimized quality of the product, which consists of four dominant parameters [11]:
– functionality,
– costs,
– ecology,
– human conditions.

Each of these parameters consists of a set of technical performance parameters. Their continuous improvement can be a consequence of the more general practice – total quality management.

4.4. Total Quality Management

As it was mentioned earlier, Total Quality Management (TQM) implementation is a chance for companies for putting the environmental aims high in the development strategy and finding the improvement possibilities. The reason why, we find in the complex definition of TQM, which is the way of organization management, characterized by:
– system approach,
– orientation on strategic goals,
– ability to continuous and for ever improvement,
– active team activity of the whole staff, with full engagement of top management

which leads to fulfill the needs of consumer in a given moment and in a future, with the minimum costs, done by using through the people quantitative methods to:
– assessment and rationalization of all important processes in the organization,
– improvement of deliveries (materials and services) supplied to the organization,

and which is cultural change of management style of organization [12].

Generally, TQM, if introduced and managed correctly, will:
– eliminate wastes,
– cut inventories,
– enhance profitability and
– improve customer satisfaction [13].

For the environmentally conscious companies almost all above mentioned factors could be applied for achieving also environmental aims. Word "also" means that the fighting for higher quality means very often gaining the satisfaction of single environmentally conscious consumers or fulfilling the environmental regulations standing on the guard of sound environment for everybody.

5. CONCLUSIONS

It is still lack of information on how to make the technical objects more environment friendly. In general, designers, especially in developed countries start to understand the relationship between a product and an environment. The product designing is therefore aiming at:
– reducing the total material content,
– preferring the materials, which can be recycled,
– minimizing the use of energy-intensive materials,
– decreasing the energy consumption in use phase etc.

Different initiatives and activities are undertaken to support creation of more and more environment friendly products. Among them Integrated Product Policy seems to be the most complex concept, which can cover different aspects of product's life cycle (environmental, financial and quality). IPP is the useful approach both for people from companies and for customers. Governments can create their relations with companies on the base of IPP ideas and the requirements of customers can be formed in agreement with its assumptions.

IPP do not have to generate additional costs in the product life. Although changes in technology or processes organization can cause rising price of the product, general result can be beneficial because of limitation of the costs connected with disposal or environment damage repair.

To be IPP tools efficient in practice they need a lot of information about different types of interactions in the product surrounding – environmental, technology, costs , quality and other. Practitioners have to disseminate such information and to build complex information systems integrated with the IPP tools.

To sum up the general view of the IPP approach one can conclude that the IPP is mainly product-oriented, because the object of analysis is defined in terms of environmental, economical and quality consequences of product. Additionally IPP can be treated as an integrative instrument, covering all life-cycle stages and a lot of types of impacts. Potential results of IPP dissemination are very promising. They are oriented on:

– creation and development of many new enterprises, mainly small and medium,
– significant improvements on customer goods market,
– destruction of the state giants, i.e. large and inefficient state-owned companies,
– increasing companies competition with their technologies, standards, culture, etc,
– development and strict execution of ecological law.

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