Risk Driven Design of Technical Product

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Abstract: *Technical Products that companies put on the market must be competitive and must find their way to the customer or the customer must find their way to them. In the vast majority, these are new products or innovated existing products that can offer the customer added value compared to the competition and, above all, induce in him the desire to purchase the product and not just include it in the selection of other competitive products. During the development process of these products, it is necessary to take into account the entire life cycle of the product and not only its operational functions and other operational characteristics, which is quite often neglected. There exist a lot of engineering design methodologies, methods and/or tools implemented in guidelines and standards which help engineering designers to innovate products and to reduce constructional, safety, environmental, etc. risks of Designed (future) Technical Products. Their common feature is especially high dependence on specialized experience of their users, time consuming, and their mutual both conceptual and terminological inconsistency resulting in very difficult compatibility with engineering designing itself.*

Keywords*: RISK, INNOVATION, EDSM, THEORY OF TECHNICAL SYSTEMS*

1. Introduction

The issue of innovation is a current global topic and is one of the key factors for a company's success on the market. It must be remembered that if "we (our business) don't do it, someone else will". Product life cycles are constantly shortening, new products must be introduced more and more often. The previously usual "development push (PUSH)" approach is changing to "market pull (PULL)". PULL innovations are those innovations that should be introduced to the market to gain an edge over the competition. A "PULL" innovation can be created by timely and appropriate prediction of properties on an existing (current) Technical Product, and based on this prediction, a qualitatively better product can then be developed. Practice initiates innovation only in relation to operation. Therefore, traditional innovations are mainly focused on improving operational functions.

The Technical Products that companies put on the market must be competitive and must find their way to the customer or the customer must find their way to them. In the vast majority, these are new Products (or innovated existing Technical Products) that can offer the customer added value compared to the competition and, above all, induce in him the desire to purchase the product and not just include it in the selection of other competitive products. During the development process of these products, it is necessary to take into account the entire TS(s) Life Cycle of the Technical Product and not only its operational functions and other operational characteristics, which is quite often neglected.

2. Problem formulation

At the beginning it was necessary to map and analyze at a basic general level the issue of technical product innovations with the aim of identifying options for increasing their effectiveness and, within the limits of possibilities, effectiveness. In the professional literature, one can find a large number of methods whose goal is higher efficiency and quality of the new product development process and improvement of either the entire innovation process or some of its parts (Fig.1). Some methods can be used for the entire process of technical product innovation (from the initial idea to the launch of the product on the market), some can be used only for a part of this process, e.g. the construction process. There is also problem to avoid risk situation(s) of the Technical Product in their Life Cycle (LC) generally.

In the professional literature[8,9], one can find a large number of methods whose goal is higher efficiency and quality of the new Technical Product development process and improvement of either the entire innovation process or some of its parts. Some methods can be used for the entire process of Technical Product innovation (from the initial idea to the launch of the product on the market), some can be used only for a part of this process, e.g. the Design Engineering Process. The goal of our paper is to present methodology which was created as synthesis between innovation methods and methods for risk analyses and elimination as obligatory procedure in several industrial branches when designing Technical Product. Risk analyses are requested often because of certification process mostly by public authority i.e. Chemical industry, nuclear engineering, automotive, healthcare,...

The above and other well-known innovation methods are mainly based on an instructive ("directive") strategy of using knowledge with a significant use of the intuitive strategy, or and the trial-error/success strategy (Fig. 1) [5]:

The instructional strategy is based on guidelines, rules and recommendations leading to the solution of the innovation assignment. These guidelines are based either on standards, company guidelines or are created in the form of methods or methodologies.

Intuitive strategy is based on the use of (irreplaceable, but in any case limited) expertise and experience of innovation solvers.

The trial-and-error/success strategy is applied without the use of rules, experience or methods and is based only on chance (trials).

By using a theoretically based strategy based on the knowledge "map" of Engineering Design Science (EDS) [5], it is possible to implement a "theoretical base" in all mentioned traditional strategies of knowledge support for innovation and use it to make the relevant innovation methods, which are at most at the instructional level, more effective strategy. All of the above-mentioned strategies (i.e. trial-and-error/success, intuitive, instructive) can be incorporated into the strategy of technical systems theories based on EDS, and based on this, they can be optimally combined during the new product development process, which is highly effective.

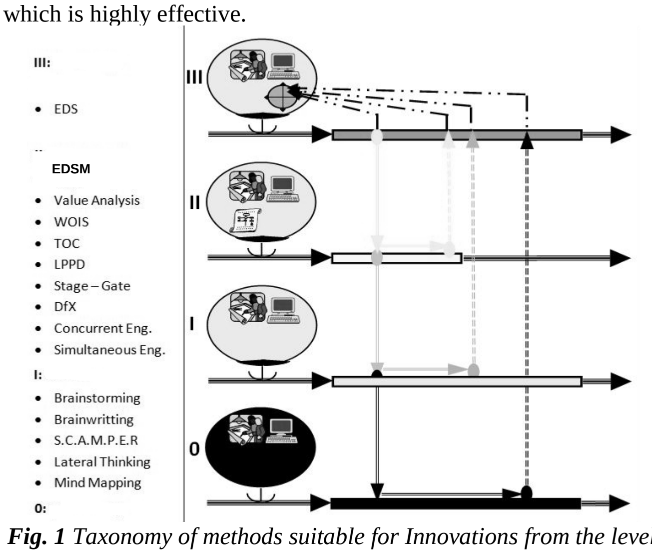

Fig. 1 *Taxonomy of methods suitable for Innovations from the level of its Knowledge support [modified 5 by authors]*

3. Theoretical Background

The basic theoretical structure, which is based on the Theory of Technical Systems to Structures [Hubka & Eder 1988, etc.] is a model of an (artificial) transformation system (TrfS) with a transformation process (TrfP), see Figure 2. This model generally expresses that each activity (e.g. technological operation Tg) is a transformation of a transformed object, marked as OPERAND in a certain input state to OPERAND in a desired state at its output, which is achieved by direct or mediated by the effects of OPERATORS, i.e. the effects of Humans (HuS), Technical Systems (TS), Active and Reactive Environment (AREnv), Information Systems (IS) and Management Systems (MgtS) on the transformed OPERAND.

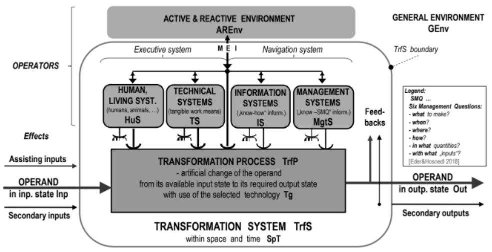

***Fig. 2** General Model of Transformation system with Transformation process* [4]

TS Life Cycle (LC) structuring can be performed according to various aspects (e.g. according to the place of implementation, according to development phases, or cost aspects, sales phases on the market, etc.), but for the needs of designing of TSs their distribution according to dominant transformations - transformation processes (TrfP) [5]. Using the general model of the Transformation system (TrfS) (Fig. 2) with its transformation process (TrfP), a general model of the life cycle of a technical product can be illustrated [2,3,4] The individual stages of the general life cycle of TS are modeled by a serial arrangement of individual stages expressed using these models.

TS life cycle is shown in Fig. 3, is distinguished by index (s) from other technical systems in individual stages. TS (s) is in the initial phase in the form of information (dashed flows), starting with production it is transformed into a material / material form (full flows). TS (s) has mainly the function of an operand, but in the operational /working phase it becomes an operator (with the exception of assisting maintenance and repair processes, when it temporarily becomes an operand). The resulting TS must meet all the requirements for its properties in terms of the entire Technical Product Life Cycle (from planning to disposal) [5].

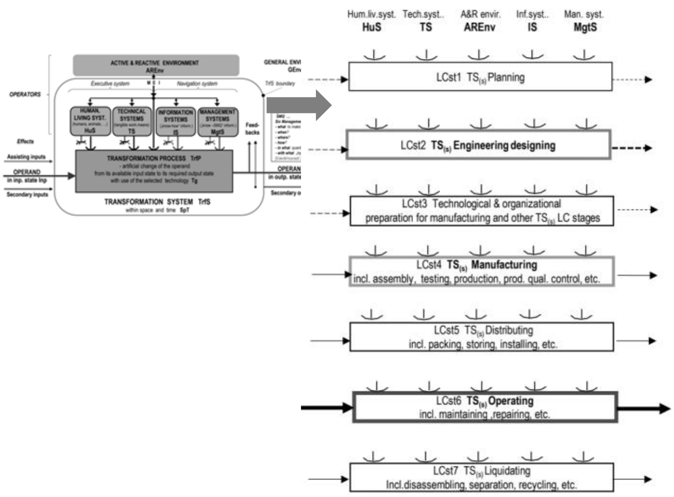

***Fig. 3** TS(s) Life Cycle stages as a sequence of the key transformation processes (TrfP) and respective transformation systems (TrfS) [7] => [2,3,4] => [5,6]*

From analysis of the generalized TS(s) LC model (Fig. 3) with proven systematic structure, it transparently shows that the carrier of R|E/S| in general, could be the following typical Object (sub) systems (ObjS):

- assessed TS (s) (i.e. reliability of TS (s) in its whole LC of TS(s), which is in professional publications, including standards, etc., moreover only with implicit or even explicit focus only on operation TS (s))

- TS (s) & ∑Human/Living Being Systems assessed (i.e. safety of TS (s) for humans and other living beings throughout the LC TS (s)), which is often incorrectly labeled in the professional publications, including standards, "only "as safety against injury / death during the operation of TS (s), moreover only with an implicit or even explicit focus only on the operation of TS (s))

- assessed TS (s) & ∑other TS (i.e. safety of TS (s) for other tangible work equipment in the whole life cycle of TS (s), which is not mentioned in professional publications, etc.)

- assessed TS (s) & ∑Management systems (i.e. safety of TS (s) for management systems in the whole life cycle of TS (s), which is mentioned in professional publications etc., very unsystematically, mostly only with a focus on strategic organization management)

- assessed TS (s) & ∑Environment (i.e. safety of TS (s) for working, natural and space environment in the LC of TS (s), which is mentioned in professional publications, incl. standards, but not systematically)

- assessed TS (s) & ∑Information systems (i.e. security of TS (s) for information systems in LC of TS (s), which is mentioned in professional publications, including standards, very unsystematically, mainly only with a focus on cybersecurity etc.)

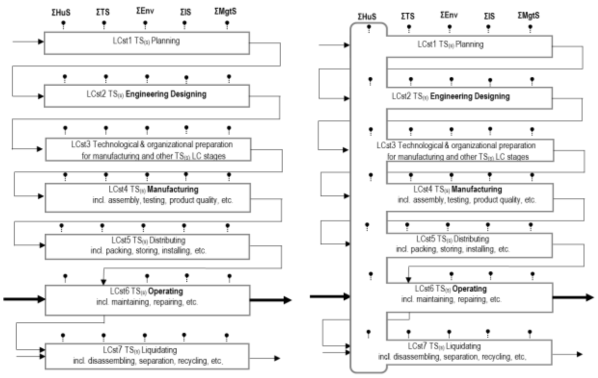

***Fig. 4** EDSM based knowledge "maps" for R|E/S| identification in the LC stages of TS (s) for Object Systems) TS (s) (left), TS (s) & ∑HuS (right) [1]*

4. Conclusion

Technical product innovations are a very current topic, as the success of their solutions determines the success and failure of individual companies. It can be assumed that with the use of knowledge based on the already successfully validated knowledge of Engineering Design Science based on the Theory of Technical Systems (EDSM-TTS) it will be possible to effectively develop and validate improved, possibly and qualitatively new innovative methods for highly creative and at the same time systematic design of innovative technical products with a higher utility value while maintaining optimal proportions: achieved quality - spent costs - spent time.

Further work will mainly be focused on the issue of disruptive innovations, which today represent the current strategy of technical product innovations and their marketing. These innovations focus on solving current problems of existing technical products. The next expected direction of work will therefore also be focused on the rational initiation of these disruptive innovations. In doing so, the use and development of the aforementioned developed software tool is envisaged to support the specification of requirements and to assess their fulfillment (SP&HA). As mentioned, disruptive innovations are mainly focused on eliminating weak points (functions and other properties) of existing technical products, which can be effectively and efficiently detected, analyzed and evaluated with the help of this SW tool.

To improve them, it will be possible to effectively use the existing knowledge and DfX (Design for X) methods, which today already cover a wide range of knowledge for achieving the required specific properties of technical products during their construction. Above mentioned methodology as a support tool for designers and employees of related engineering professions, who can comprehensively or even partially use it as feedback and control of their design activities and use this knowledge in building their own "knowledge map", which each designer creates during their practice was presented. It brings the opportunity for users use it as an effective tool for innovation and building own portfolio of knowledge, for experienced (so-called senior designers) the methodology can offer a different "perspective" on predicting the risks of technical products and confirming or refuting their routine approaches. The above presented methodology allows to perform risk prediction and analysis for object systems TS (s) & ∑HuS, TS (s) & ∑TS, TS (s) & ∑Env, TS (s) & ∑IS and TS (s) & ∑MgtS in all considered stages of the Life cycle of the designed TS or even existing TS[6].

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