TECHNICAL PRODUCTS AND THEIR ATTRIBUTES – THEORY AND PRACTICAL APPLICATIONS

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Any technical product – technical system (TS) and its life cycle processes need to meet many requirements. These are not only requirements concerning the TS operation functions, their parameters and connection interfaces, but also high product safety and health protection, good appearance, easy manufacture, transport, maintenance and liquidation, low price, short delivery time, and many others. The paper introduces a system approach based on the "Map" of Engineering Design Science knowledge [Hubka&Eder 1988, Hubka&Eder 1996, Andreasen 2000, Eder&Hosnedl 2008, and many others] the aim of which is to achieve a higher transparency and user friendliness of the outlined and bounded engineering design areas, and shows practical applications, which have quite successfully validated the proposed improvements.

Keywords
Technical Product, Attributes, Characteristics, Properties, Behaviour, Values, Requirements

1. Introduction

Some of the requirements outlined in the abstract concern the TS operation process, some pertain directly to the TS constructional structure, some are more concerned with the TS conformance to other life cycle processes, some have to be fulfilled 'implicitly' within all these processes and some result from previous processes, and so forth. The reason for this diversity is the fact that these requirements have to cover all the important TS 'multiple overlapping' properties related to all the TS life cycle processes. Furthermore, only a minor part of these requirements is available to engineering designers as the explicitly stated requirements. Most of them are generally implied or obligatory, and very often so far unapparent, that, even for very skilled engineering designers and/or researchers, it is very easy not to consider them in time or to omit some relevant points.

2. Technical Systems (TS)/Technical Products

Product can be understood and/or specified [CSN EN ISO 2006, art. 3.4.2] as an output of a (transformation) process, which corresponds to the term Operand of Transformation Process (TrfP) in its Output State [Eder&Hosnedl 2008]. Technical Product is a product with a dominant engineering content which usually serves as TS Operator (i.e. TS means) for a TrfP. Thus Technical Product (which stresses "production view" in the "practice realm") is a synonym for Technical System (which stresses "system view" in the "theory realm").

3. TS Property, Property characteristic, Property characteristic value

3.1 TS Property

In this paper a TS property will be understood as "any attribute or characteristic of a system: performance, form size, colour, stability, life, manufacturability, transportability, suitability for storage, structure, etc. Every Technical System is a carrier of all properties, and their totality represents the value (comments of authors: i.e. total quality) of the system" [Hubka 1980, p. 64]. It is obvious that a TS property is a cumulative criterion, i.e. (not elemental) TS characteristic from a more general nevertheless specific "reasonable" viewpoint. Further synonymous for the phenomenon TS Property can be and are also being used e.g. attribute, characteristic, (design) parameter, (distinguishing) feature, quality, power, performance, etc.. It will be outlined in the presented paper that the consistent use of the term TS property has its advantages in theory, education and practical use.

3.2 TS Property Characteristic

TS property of any kind is characterized by a set of measurable elemental criteria (from 1 to n) which enable any TS Property to be specified, measured, compared and evaluated. The authors of the paper call these criteria TS 'Property Characteristics'. These TS Property Characteristics can be either assigned (established according to experience, intuition, availability, etc.), e.g. TS appearance according to the ratio of main dimensions, compatibility of the used colours, etc. or normatively set (defined by laws, standards, etc., e.g. TS (car) safety according to the strictly defined crash deformation, deceleration, space, etc. characteristics).

3.3 TS Property Characteristic Values

TS Property Characteristic of any kind can be specified and "measured" by its one (direct) or more (indirect/auxiliary/reference i.e. "coordinate") "Dimensions" (in its wider viewpoint, i.e. measurable not only numerically). "Dimensions" of a TS Property Characteristic, can be classified in terms of their measurement scales, e.g. according to [Ackoff 1962] and [Pons 2001] as follows:

– **Quantitative** Scales (and corresponding Dimensions):
= Ratio (numerical)
  – *(e.g. length, weight, duration, absolute temperature)*
= Interval (numerical)
  – *(e.g. relative temperature, relative time)*

– **Qualitative Ordinal** Scales (and corresponding Dimensions):
= Ordinal numerical
  (e.g. Mohs scale of mineral hardness)
= Ordinal (or weak order) textual
  (e.g. "hot, warm", "grades for academic performance"):

– **Qualitative Nominal** Scales (and corresponding Dimensions):
= Nominal numerical
  (e.g. sports player numbers, parts numbers on an assembly drawing)
= Nominal textual
  (e.g. "hammer, pincers, screwdriver"):

However a problem arises how to generally name concrete 'magnitudes' of dimensions corresponding to the shown miscellaneous types of scales. Except for the simplification of statements related to all the mentioned types of TS Property Characteristics, the reason is that it is often impossible to predict/specify the concrete type of scale for many Dimensions. Considering the fact that scales for any type of dimension can be expressed by both textually (linguistically) and numerically (i.e. at least by relevant numerical codes, however very often also by physically reasoned numbers, e.g. by wave lengths of light for colours) or maybe graphically, it is possible to generalise the term 'Value' for all types of the 'magnitudes' of dimensions (similarly, e.g. the term "dimension" is frequently generally used both for numerical and non-numerical magnitudes in real life and even in maths).

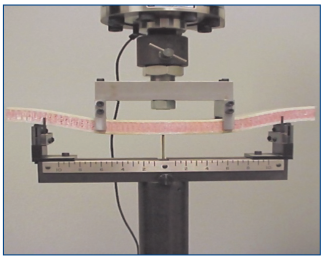
Then any Dimension of any TS 'Property Characteristic' can be specified, measured, compared and evaluated by corresponding (either quantitative or qualitative) values using the established (assigned or normative) scales. Consequently a Value of a TS Property Characteristic state can be specified/measured (directly or indirectly using other TS property characteristics) by comparison using an appropriate scale. More scales can be available for a TS property characteristic!

'Value of a TS Property' is then specified and can be measured, evaluated, etc. by the corresponding set of values of the corresponding TS 'Property Characteristics', i.e. by values of their dimensions.

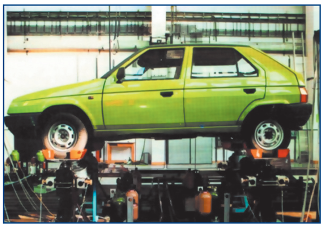
4. TS Behaviour

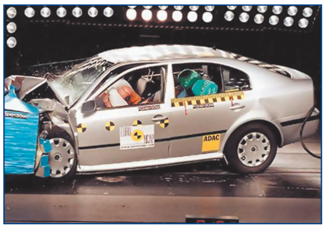
TS Behaviour is a **response of a TS Constructional Structure** on (an external or internal) stimulus. TS behaviour (i.e. response of TS Constructional Structure) is thus specified by **changes of values** (of *dimensions of characteristics*) of **TS Elemental Engineering Design Properties** evoked by an **affecting** (external and/or internal) **stimulus** (i.e. excitement). **TS Behaviour** (response) can be classified according to the changeability of the response and duration of the observation:

– **"Direct" static TS 'behaviour'** (response), e.g. values of a TS static strengths, deformation shifts from static (constant in time) load *(e.g. bending deformation shifts of a loaded beam, plastic deformation shifts caused by Brinell/Vickers/Rockwell/ hardness tests)*.

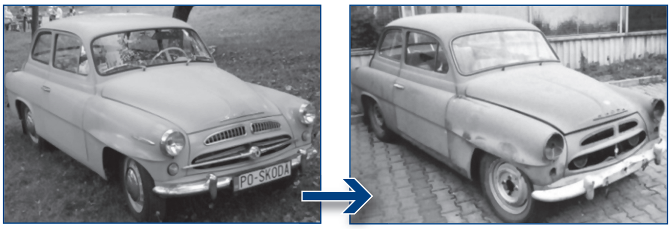


– **"Direct" dynamic (both periodical and un-periodical) TS behaviour** (response), e.g. changeable values of a TS dynamic strength, deformation shifts from dynamic (changeable in time) load *(e.g. dynamic strength of a car loaded by dynamic forces, crash shifts of a car loaded by shock forces):*



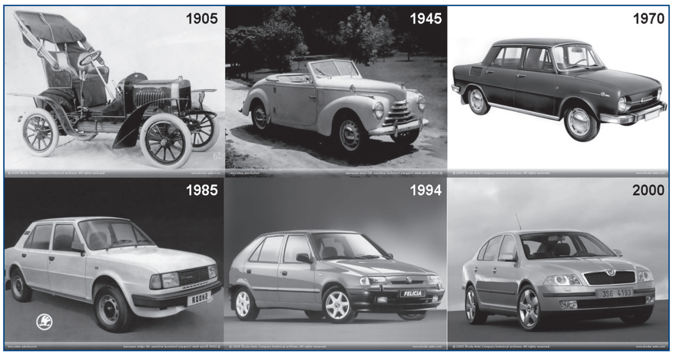


– **"(Existence) life cycle" TS behaviour** (response), e.g. changeable values of a TS dimensions, reliability, appearance, etc. on its static and dynamic "loads" (in its wider sense) during the "existence and liquidation phases" of the TS life cycle:



– **"Historical (generalized) TS behaviour"** (response), e.g. changeable values of TS dimensions, reliability, appearance, etc. on all "loads" (in its wider sense) during historical development of a TS class or family in time *(e.g. a historical series of SKODA cars)*.

TS Behaviour (response) can be either ascertained/predicted using relevant simple or sophisticated computer "Analyses/Simulations for X" AfX/SfX methods or it can be experimentally measured on models of the designed TS, or on an existing TS to determine the behaviour and/or check it. To summarize, we can conclude that TS behaviour also belongs under "the umbrella" of TS properties however the corresponding (immediate, short, or long-term course of) load (in its general sense) have to be simultaneously specified (by its magnitudes within the active environment).



Note: This historical long-term generalised response (to "historical, technical, social, economic, laws, etc. loads") is not usually called TS behaviour but only ***historical development of a TS class/family*** *(generalized properties/property characteristics).*

5. Taxonomy of TS Properties

In the past, it was believed that there were an infinite number of TS Properties, and that they had nothing in common with different products. A consistent, comprehensive system of the TS Properties classification elaborated on the basis of Professor Hubka's and Professor Eder's fundamental works on the Theory of Technical Systems [Hubka&Eder 1988], within the framework of Engineering Design Science [Hubka&Eder 1996], and using the above introduced hierarchical system of TS Property attributes generally depicted in Figure 1. and in a simplified example in Figure 2. is briefly characterized in the following section.

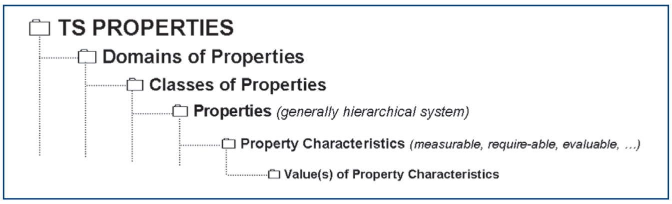


Figure 1. Hierarchical system of attributes of TS Properties

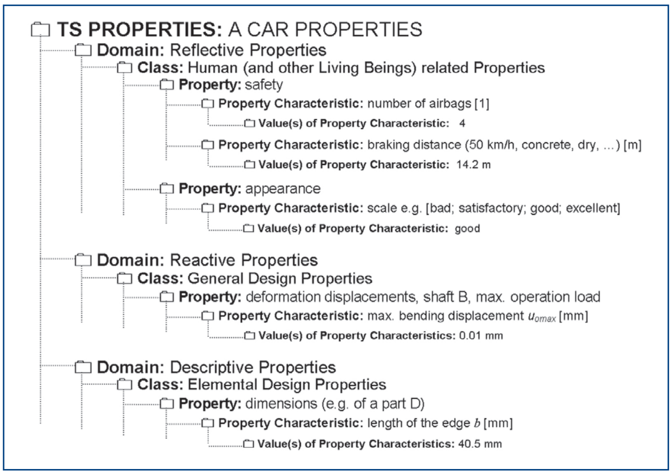


Figure 2. *Hierarchical system of attributes of TS Properties – example(s) for a car*

5.1 Domain and Classes of the Descriptive TS Properties

Domain of TS Properties which characterizes and specifies (i.e. "describes") TS Structure. This domain is axiomatically structured into two classes [Hubka&Eder 1988 => Hosnedl 2007b]:

– *Elemental Engineering Design Properties of TS:*
Class of TS Properties, which fully describes/specifies the TS Constructional Structure.
– *Feature Engineering Design Properties (Characteristics) of TS:*
Class of the TS Properties which describes/specifies the features of TS Constructional Structure and its use in Operation Process.

5.2 Domain and Classes of the Reactive TS Properties

Domain of TS Properties covering General Engineering Design TS Properties [Hubka&Eder 1988] characterizes and specifies topologically internal reactions of the TS Constructional Structure to applied (external and/or internal both immediate, short and long time) effects/stimuli *(see above)*. This domain can be split into respective classes corresponding to the relevant natural science which studies them [Hosnedl 2007b].

5.3 Domain and Classes of the Reflective TS Properties

Domain (of Classes) of TS Properties, which characterizes and specifies topologically external *(see above)* active and/or reactive "reflections" of TS on *(set of values of dimensions of characteristics of)* Descriptive and Reactive Properties of TS Constructional Structure. TS Reflective Properties thus have to mirror TS in its whole Life Cycle. An optimal model of TS/Product Life Cycle (PLC) is thus an advantageous means of achieving their "total" and effective structuring into Classes. Proposals of such a classification have been introduced e.g. in [Hosnedl 2007b], [Eder&Hosnedl 2008], and are still in the process of development.

6. Verification

Our analyses [Hosnedl&Vanek 2006] proved that 10 representative design engineering related publications present from 7 to 28 (on average 16) classes of TS life cycle properties, which include from 16% to 80% of the TS properties covered by the presented system/ 'map'. In addition, on average 29% of these classes are explicitly specified/stressed and 21% are mentioned only generally, while the rest, i.e. on average 50% of classes included in the presented system are not mentioned at all. Another comparison has proved that all these reference publications cover altogether 96% of the properties covered by and specified/stressed in the presented system/'map' of TS property classes and, what is important, do not mention any TS properties, which cannot be included in this system/ 'map'. Besides these achievements it is important that the presented approach is based only on a simple graphical model bounded with other models from the Theory of Technical Systems and is user-friendly as believed explained above.

7. Validation

The presented hierarchical consistent system for specification, measurement, evaluation, and classification of TS Properties has been utilised in a number of our university projects performed for industrial partners.

One of the first larger applications was Information and Evaluation Database Type Sheet System for Regional Rail Vehicles (RRV) [Hosnedl&Heller 2006]. The next quite analogous application was Information and Evaluation Database Type Sheet System for City Tram Vehicles (CTV). The next similar application was Information and Evaluation Database System for Constructional Specimens from conventional (solid) and unconventional (composite) Materials (CSM) [Hosnedl&Srp 2008]. All the mentioned applications have been developed and implemented in MS Excel. The RRV, CTV and CSM property characteristics are arranged in matrix forms respectively, and entered into the first sheets of their MS Excel implementations, further elaborated and displayed as e.g. partially shown for CSM in Figure 3.

Due to the full consistency of the database, the last system has enabled a method to be developed for comparing numerical values of two property characteristics of the same type (e.g. for a bending displacement) for any two specimens independent of their constructional structure, and type of load and border constraint. The first promising results have also been achieved from a method (based on the principle of Case-based reasoning), enabling prediction of an unknown property characteristic value for a (e.g. designed) specimen derived from property characteristic values of the most similar specimens currently stored in the database [Hosnedl 2006].

Further results based on the presented system of structuring TS properties have been achieved in Property Driven Designing of Technical Products. Among others this effective strategy has been successfully utilised in a number of integrated engineering and industrial design students' team projects carried out for a series of industrial companies over the last few years. Students were working each year in several multiple "competing" teams consisting

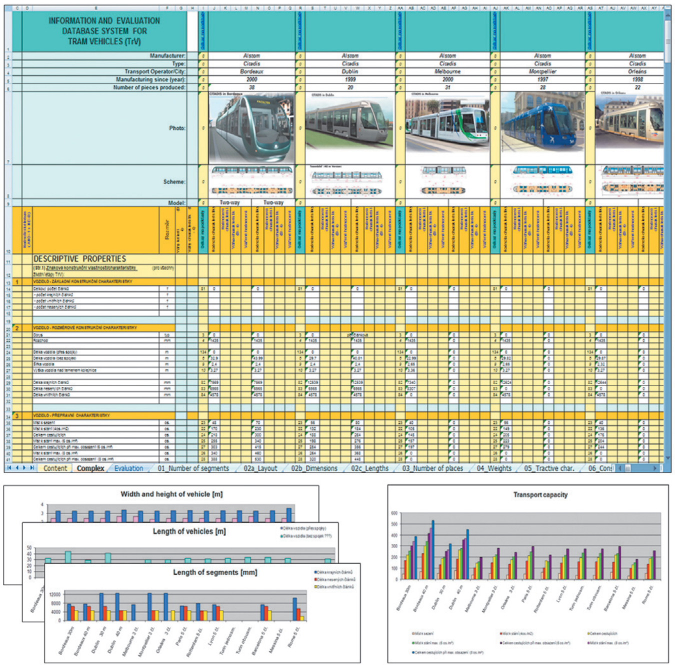


Figure 3. Information and Evaluation MS Excel Database System for City Tram Vehicles (CTV) – section of the recorded values of the CTV property characteristics (top) – examples of the comparative diagrams for the recorded CTV properties (bottom)

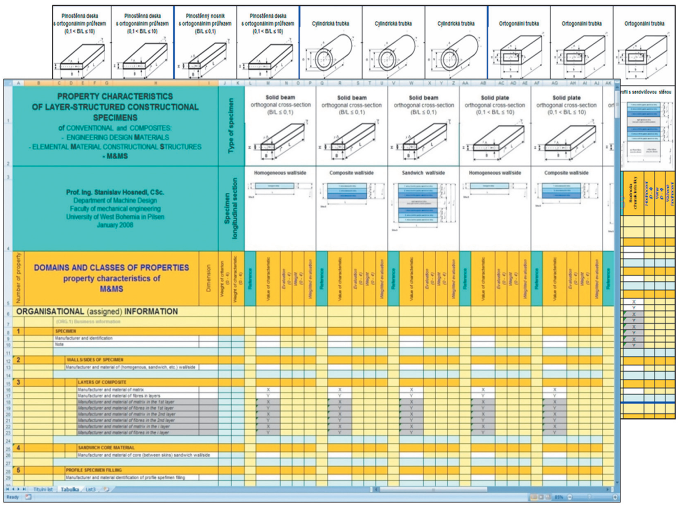


Figure 4. The trial version of the Information and Evaluation MS Excel Database System for Constructional Specimens both from solid and composite Materials (CSM) – section for the recorded values of the CSM property characteristics

of both engineering and industrial design students [Hosnedl&al 2008].

8. Conclusions

The consistent system of TS attributes and their taxonomy presented in this paper helps engineering designers and students to manage their interdisciplinary teamwork more efficiently in a property driven manner thereby achieving the designed product at a higher quality, lower cost and with a shorter delivery time. This increases the design competitiveness of the product and improves its chances of succeeding in the market place. In addition to these benefits, this strategy has also proved to have a high pedagogical value. It brings interdisciplinary team members into teams so they are able to understand the general approach, priorities and aims of the design work. The approach presented here has been successfully verified in comparison with 10 other published analogous systems in the world and validated in a number of very different university database and engineering design applications solved for industrial partners. In particular, the interdisciplinary students' projects have been greatly appreciated not only by the teachers and students involved but also by the participating industrial and research partners.

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