TECHNICAL PRODUCTS AND THEIR ATTRIBUTES – THEORY AND PRACTICAL APPLICATIONS

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1. Introduction

Any technical product - technical object system (TS) and its life cycle processes need to meet many requirements. These are not only requirements concerning the TS operational/transformation 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. Some of these requirements concern the TS operational process (the TS operational/ transformation functions and their parameters, etc.). Some pertain directly to the TS constructional structure (locations, forms and dimensions of connection interfaces, etc.). Some are more concerned with the TS conformance to other life cycle processes (easy manufacture, transport, operation, maintenance, liquidation, etc.). Some have to be fulfilled 'implicitly' within all these processes (high product safety, health protection, environmental compatibility, etc.) and some result from previous processes (low price, short delivery time, etc.). The reason for this diversity is the fact that these requirements have to cover all the important (partial, subtotal and total) 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. The paper will introduce 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 user friendliness of the outlined and bounded engineering design areas, and shows a number of practical applications, which have quite successfully validated the proposed improvements.

2 Technical Systems (TS) / Technical Products

"Technical system (TS) is a category of an artificial deterministic system that performs the necessary effects for transformation of the operands" [Hubka 1980, p. 81], i.e. of the transformed material, energy, information and/or living beings [Eder&Hosnedl 2008]. **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 Technical System/Product 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 both in theory and in practical use.

3.2 TS Property Characteristic

TS property of any kind is characterized by a set of measurable (not necessarily according to a numerical scale) elemental criteria (from 1 to n) which enable any TS Property to be specified, measured, and evaluated. The authors of the paper call these criteria **TS** '**Property Characteristics**' and have very good experience with its use in many theoretical and practical fields of design engineering, some of which will be introduced in the presentation at the workshop. 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).

3.2 TS Property Characteristic Values

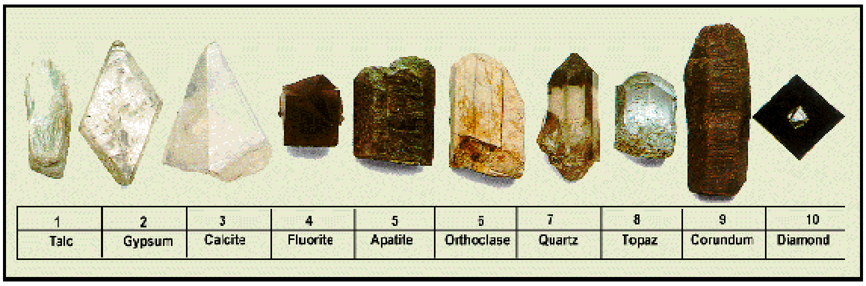
TS **Property Characteristic** of any time can be specified and "measured" by its one (direct) or more (indirect/auxiliary/reference i.e. "coordinate") **"Dimensions"** (in its wider viewpoint, i.e. measurable not only numerically) i.e. **"Variables". "Dimensions"/"Variables" of a TS Property Characteristic,** 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/Variables)**:**

= Ratio (numerical) (*e.g. length, weight, duration, absolute temperature):*

= Interval (numerical) *(e.g. relative temperature, relative time):*

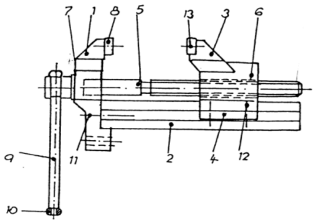
- **Qualitative Ordinal** Scales (and corresponding Dimensions/Variables)**:**
  = **Ordinal numerical** *(e.g. Mohs scale of mineral hardness):*



  = **Ordinal** (or weak order) **textual** *(e.g. "hot, warm", "grades for academic performance"):*

ECTS Scale	Definition
A	Excellent – outstanding performance with only minor errors
B	Very good – above the average standard but with some errors
C	Good – generally good work with a number of notable errors
D	Satisfactory – fair but with significant shortcomings
E	Sufficient – passable performance, meeting the minimum criteria
FX	Fail – some more work required before the credit can be awarded
F	Fail – considerable further work is required

- **Qualitative Nominal** Scales (and corresponding Dimensions/Variables)**:**
  = **Nominal numerical** *(e.g. sports player numbers, parts numbers on an assembly drawing):*



COMPONENT	
1	Fixed jaw
2	Base
3	Movable jaw
4	Guide plate
5	Motion screw spindle
6	Nut insert
7	Keeper plate
8	Jaw plate (hardened)
9	Handle
10	Handle knob
11	Screw
12	Screw
13	Screw

  = **Nominal textual** *(e.g. "hammer, pincers, screwdriver"):*



However a problem arises how to generally name concrete 'magnitudes' of dimensions/variables 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/Variables (see below). Concrete 'magnitudes' of Dimensions/Variables corresponding to **'Quantitative scales'** and maybe of the **'Qualitative ordinal numerical scales'** can be called **'parameters'** as usual. However, it is not suitable at all to call 'parameters' the 'magnitudes' of the dimensions/variables corresponding to the remaining types of the (not numerical) scales. However, considering the fact that scales for any type of dimension/variable 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/variables (similarly, e.g. the term "dimension" is frequently generally used both for numerical and non-numerical variables in real life and even in maths).

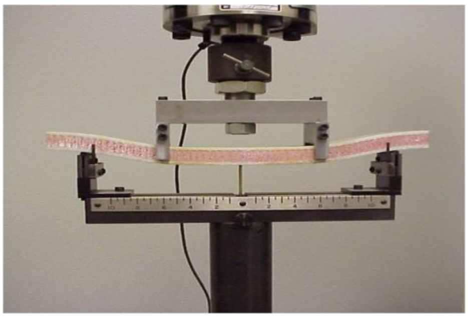
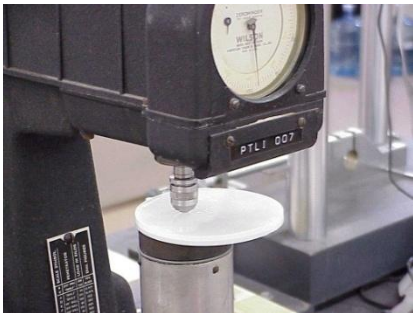
Then any **Dimension/Variable** of any **TS** '**Property Characteristic**' can be **specified, measured, compared and evaluated** by corresponding (either **quantitative** or **qualitative**) **values** using the established (assigned or normative) **scales.** Consequently a **Value** of a **TS Property 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 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/variables**.

4 TS Behaviour

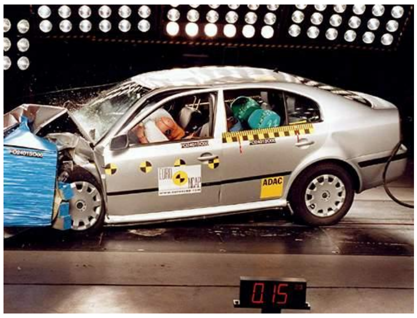
TS Behaviour is a **response of a TS Constructional Structure** on (an external or internal) stimulus. TS behaviour (i.e. response of TS Constructional Structure) is thus specified by **changes of values** (of *dimensions/"dependent variables" of characteristics) of* **TS Elemental Engineering Design 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):*

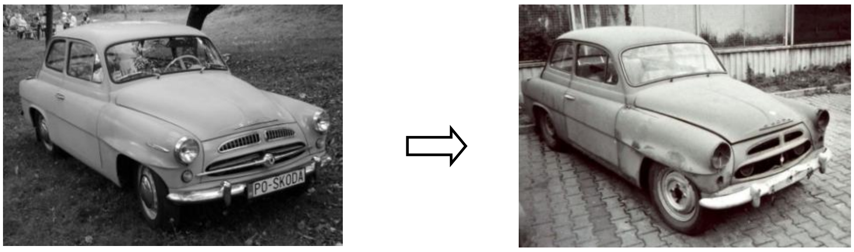
*NOTE: This immediate static response is not usually called TS behaviour but only a '**TS static response**',*

- **"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):*

*NOTE: This immediate dynamic response is usually understood as **TS behaviour** in its narrower sense.*

- **"(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:



*NOTE: This life cycle response is not usually called TS behaviour but only **changes/ageing of TS (properties) in its 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 [wwwSkoda 2000]):*

*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).*

TS Behaviour (response) can be either (more or less precisely) 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 space and time). Load magnitudes can be specified analogously as in the case of TS Properties by values of the set of the respective Load Property Characteristics. TS Properties are understood in this wider sense in the following section.

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.

- **TS PROPERTIES**
  - **Domains of Properties**
    - **Classes of Properties**
      - **Properties** *(generally hierarchical system)*
        - **Property Characteristics** *(measurable, require-able, evaluable, …)*
          - **Value(s) of Property Characteristics**

Figure 1. Hierarchical system of attributes of TS Properties

- **TS PROPERTIES:** SKODA-OCTAVIA PROPERTIES
  - **Domain:** Reflective Properties
    - **Class:** Human (and other Living Beings) related Properties
      - **Property:** safety
        - **Property Characteristic:** number of airbags [1]
          - **Value(s) of Property Characteristic:** 4
        - **Property Characteristic:** braking distance (50 km/h, concrete, dry, …) [m]
          - **Value(s) of Property Characteristic:** 14.2 m
      - **Property:** appearance
        - **Property Characteristic:** scale e.g. [bad; satisfactory; good; excellent]
          - **Value(s) of Property Characteristic:** good
  - **Domain:** Reactive Properties
    - **Class:** Mechanical Properties
      - **Property:** deformation displacements, shaft B, max. operation load
        - **Property Characteristic:** max. bending displacement u_{omax} [mm]
          - **Value(s) of Property Characteristics:** 0.01 mm
  - **Domain:** Descriptive Properties
    - **Class:** Elemental Design Properties
      - **Property:** dimensions (e.g. of a part D)
        - **Property Characteristic:** length of the edge *b* [mm]
          - **Value(s) of Property Characteristics:** 40.5 mm

Figure 2. Hierarchical syst. 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 *(see above)* 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/states of dimensions/variables 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 (e.g. 'TS safety', which is often intuitively bounded only with the usage process, or 'TS ecology' which is often bounded only with usage and/or liquidation processes, etc., and not with other TS Life Cycle phases), 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 (where 78% is explicitly specified/stressed only) 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 (compared to the difficult to remember 6 enumeration based and 4 procedural schema based approaches in the mentioned reference publications) and is user-friendly as explained above.

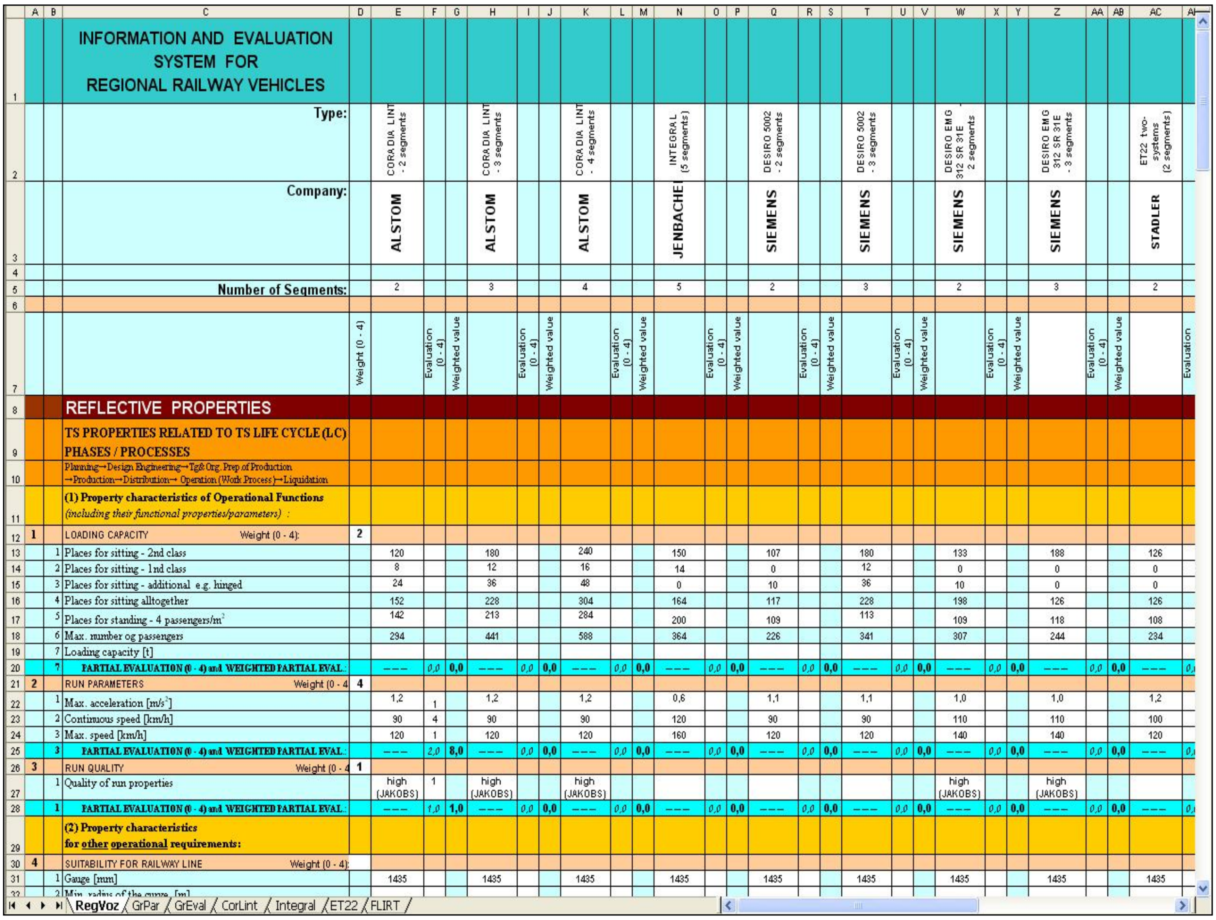
7 Validation

The presented hierarchical consistent system for specification, measurement, evaluation, and classification of TS Properties has been utilised in a number of 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], developed and implemented in MS Excel. It currently covers 179 comparable characteristics (values for 81 characteristics can be retrieved or derived according to [RRV 2005]) for each of 49 variants of 20 RRV types of 10 leading European competitors of Czech producers. The 136 characteristics of reflective and reactive properties are split into 30 properties structured into 12 classes derived from transformation systems corresponding to 7 crucial processes of product life phases according to [Hosnedl 2004], and 1 class of reactive properties. The 43 remaining characteristics of descriptive properties are split into 2 axiomatically defined classes [Hubka&Eder 1996]. The RRV property characteristics are arranged in matrix form, and entered into the first sheet of MS Excel, further elaborated and displayed (Figure 3).

The next quite analogous application was **Information and Evaluation Database Type Sheet System for City Tram Vehicles (CTV)**, also developed and implemented in MS Excel. It currently covers 260 comparable characteristics (values for 110 characteristics can be retrieved or derived according to [CTV 2007]) for each of 80 variants of 68 CTV types of 5 leading European competitors of Czech producers.

The 149 characteristics of reflective and reactive properties are split into 12 classes derived from transformation systems corresponding to 7 crucial processes of product life phases according to [Hosnedl 2007b], and 1 class of reactive properties. The 111 remaining characteristics of descriptive properties are split into 2 axiomatically defined classes [Hubka&Eder 1996]. The CTV property characteristics are arranged in matrix form, and entered into the first sheet of MS Excel, further elaborated and displayed (Figure 4).



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1			INFORMATION AND EVALUATION SYSTEM FOR REGIONAL RAILWAY VEHICLES																											
2			Type:		CORADIA LINT - 2 segments			CORADIA LINT - 3 segments			CORADIA LINT - 4 segments			INTEGRAL (5 segments)			DESIRO 5002 - 2 segments			DESIRO 5002 - 3 segments			DESIRO EMG 312 SR 31E 2 segments			DESIRO EMG 312 SR 31E - 3 segments			ET22 two-systems (2 segments)	
3			Company:		ALSTOM			ALSTOM			ALSTOM			JENBACHE			SIEMENS			SIEMENS			SIEMENS			SIEMENS			STADLER	
4																														
5			Number of Segments:		2			3			4			5			2			3			2			3			2	
6																														
7				Weight (0 - 4)		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation (0 - 4)	Weighted value		Evaluation
8			REFLECTIVE PROPERTIES																											
9			TS PROPERTIES RELATED TO TS LIFE CYCLE (LC) PHASES / PROCESSES																											
10			Planning→Design Engineering→Tg& Org. Prep. of Production →Production→Distribution→ Operation (Work Process)→Liquidation																											
11			(1) Property characteristics of Operational Functions *(including their functional properties/parameters)* :																											
12	1		LOADING CAPACITY Weight (0 - 4):	2																										
13		1	Places for sitting - 2nd class		120			180			240			150			107			180			133			188			126	
14		2	Places for sitting - 1nd class		8			12			16			14			0			12			0			0			0	
15		3	Places for sitting - additional e.g. hinged		24			36			48			0			10			36			10			0			0	
16		4	Places for sitting alltogether		152			228			304			164			117			228			198			126			126	
17		5	Places for standing - 4 passengers/m^2		142			213			284			200			109			113			109			118			108	
18		6	Max. number og passengers		294			441			588			364			226			341			307			244			234	
19		7	Loading capacity [t]																											
20		7	PARTIAL EVALUATION (0 - 4) and WEIGHTED PARTIAL EVAL.:		---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,
21	2		RUN PARAMETERS Weight (0 - 4	4																										
22		1	Max. acceleration [m/s^2]		1,2	1		1,2			1,2			0,6			1,1			1,1			1,0			1,0			1,2	
23		2	Continuous speed [km/h]		90	4		90			90			120			90			90			110			110			100	
24		3	Max. speed [km/h]		120	1		120			120			160			120			120			140			140			120	
25		3	PARTIAL EVALUATION (0 - 4) and WEIGHTED PARTIAL EVAL.:		---	2,0	8,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,
26	3		RUN QUALITY Weight (0 - 4	1																										
27		1	Quality of run properties		high (JAKOBS)	1		high (JAKOBS)			high (JAKOBS)												high (JAKOBS)			high (JAKOBS)				
28		1	PARTIAL EVALUATION (0 - 4) and WEIGHTED PARTIAL EVAL.:		---	1,0	1,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,0	0,0	---	0,
29			(2) Property characteristics for other operational requirements:																											
30	4		SUITABILITY FOR RAILWAY LINE Weight (0 - 4):																											
31		1	Gauge [mm]		1435			1435			1435			1435			1435			1435			1435			1435			1435	
32		2	Min. radius of the curve [m]																											

RegVoz / GrPar / GrEval / CorLint / Integral / ET22 / FLIRT

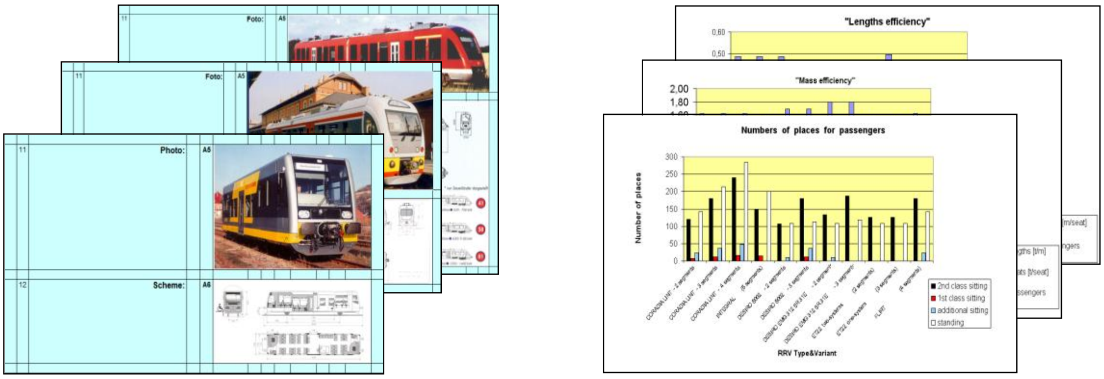


Figure 3. Inform. and Eval. MS Excel Database System for Regional Railway Vehicles (RRV)
- section of the recorded values of the RRV property characteristics (top)
- sections of the RRV Type sheets (bottom left)
- examples of the comparative diagrams for the recorded RRV properties (bottom right)

The next similar application was **Information and Evaluation Database System for Constructional Specimens from conventional (solid) and unconventional (composite) Materials (CSM)** [Hosnedl & Srp 2008], also developed and implemented in MS Excel. It currently covers 268 comparable characteristics for each of 34 considered variants of 4 considered CSM types. The 114 characteristics of reflective and reactive properties are split into 19 classes derived from transformation systems corresponding to 7 crucial processes of product life phases according to [Hosnedl 2007b], and 17 classes of reactive properties.

The 154 remaining characteristics of descriptive properties are split into 2 axiomatically defined classes [Hubka & Eder 1996] and their 7 subclasses. The CSM property characteristics are arranged in matrix form, and entered into the first sheet of MS Excel, further elaborated and displayed (Figure 5).

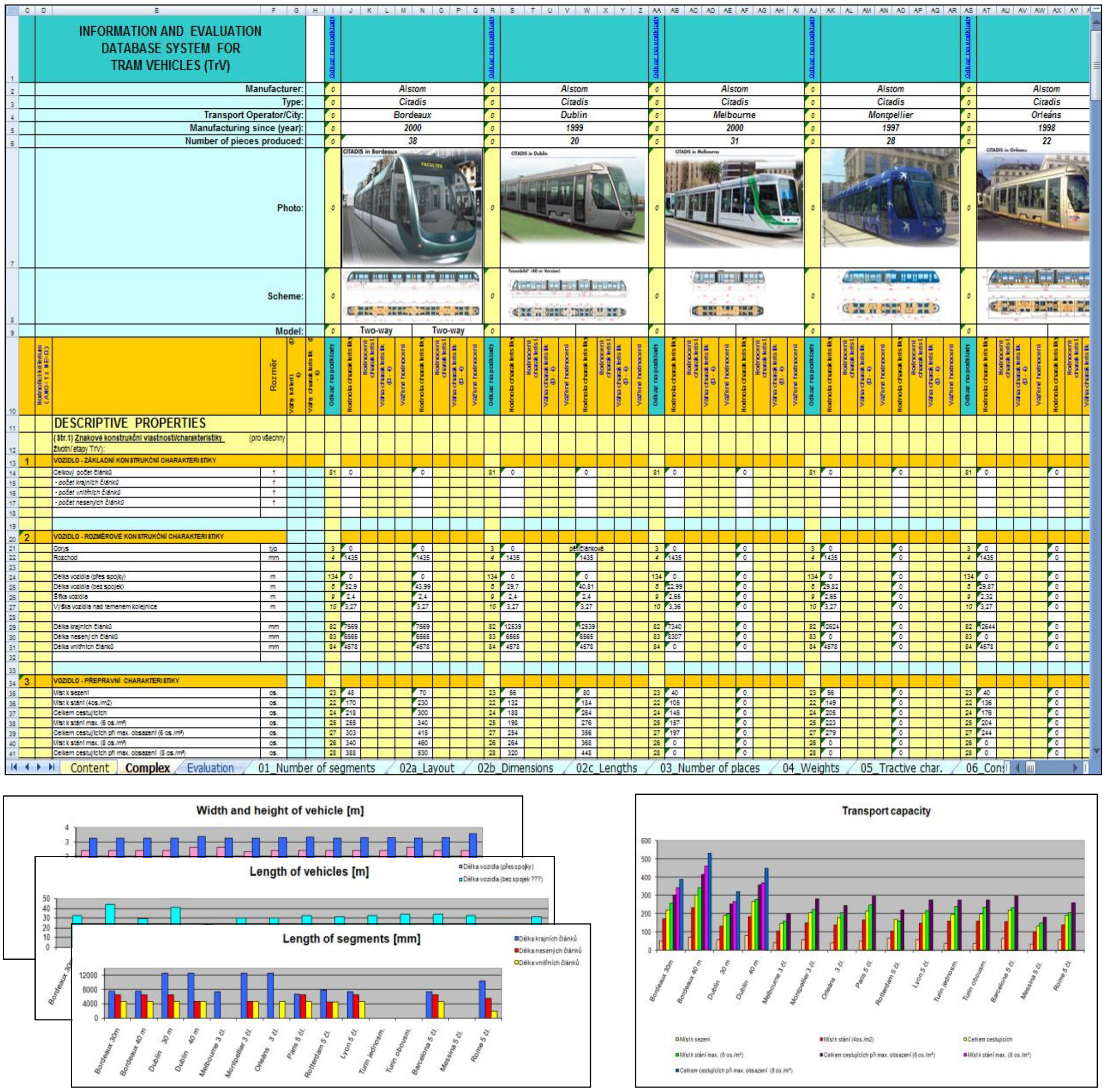


Figure 4. Information and Evaluation MS Excel Database System for City Tram Vehicles (CTV)
- section of the recorded values of the CTV property characteristics (top)
- examples of the comparative diagrams for the recorded CTV properties (bottom)

Due to the full consistency of the database, the 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. Positive results have also been achieved from a method (based on the principle of Case-based reasoning), enabling prediction/estimation 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 2006b].

Further results based on the presented system of structuring TS properties have been achieved in **property driven designing of technical products**. This philosophy has been utilised in a number of 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 of both engineering and industrial design students. The following topics were or are undertaken in the following academic years [Hosnedl&al 2008].

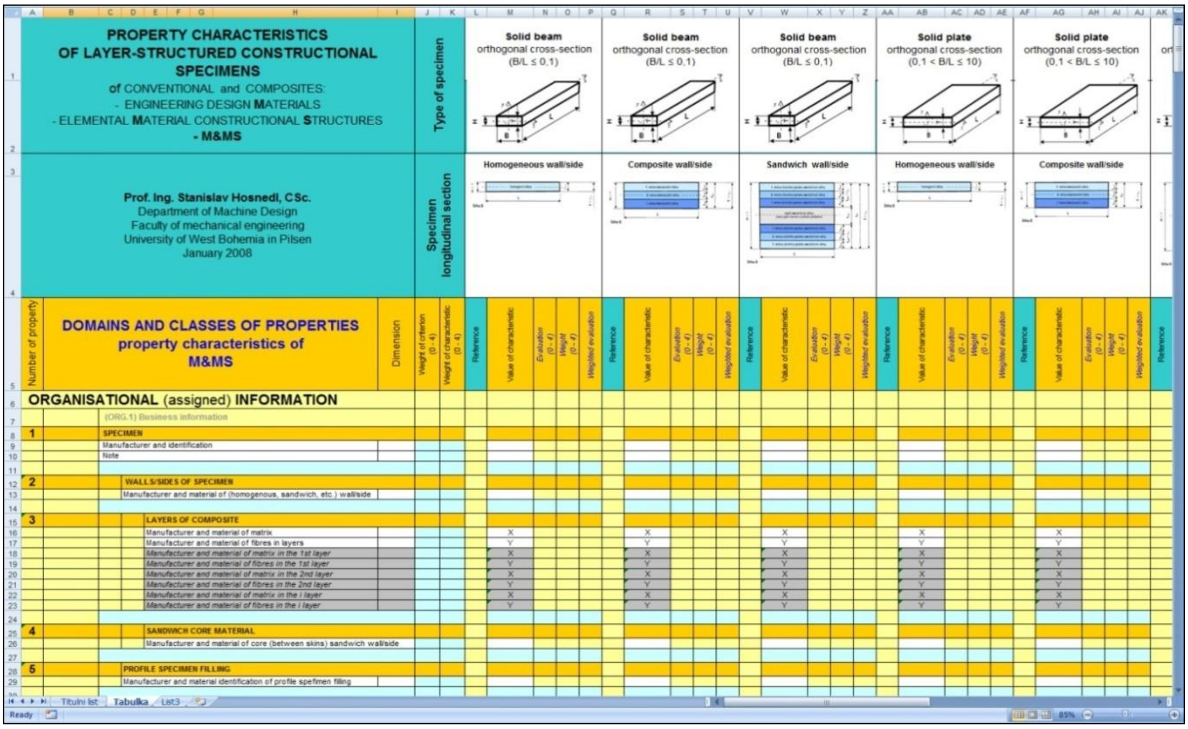


Figure 5. The trial version of the Information and Evaluation MS Excel Database System for Constructional Specimens both from solid and composite Materials (CSM) - section for the recorded values of the CSM property characteristics

2004/2005: Front seat with an active headrest for private cars of a higher class. GRAMMER, Tachov/Amberg, CZ/G
2005/2006: Locks for a luggage space of private cars of a higher class (VALUE ENGINEERING, Pilsen, CZ/G)
2006/2007: Dentist's working place for the 3rd millennium, CHIRANA DENTAL Piestany, Slovakia. Assembly line for gluing hinges on mirror doors for bathroom cabinets. FLABEG, Domazlice, CZ/G. Parking facilities for Coupe Vehicles in the project ComplexTrans. SKODA, Pilsen, CZ
2007/2008: Covers for working space of boring and milling machines TOS Varnsdorf. ASTOS, As. Emergency bed for very seriously ill patients. Linet, Zelevcice (Figure 6).- Luggage space for estate cars. Skoda Auto, Mlada Boleslav
2008/2009: Covers for working space of boring and milling machines TOS Varnsdorf, ASTOS, As. Hospital bed for children. Linet, Zelevcice. Interior of a car for disabled. Auto Project Centrum (Gordon), Pilsen

8 Conclusions

The consistent system of TS attributes and their taxonomy presented in this paper helps engineering designers 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.

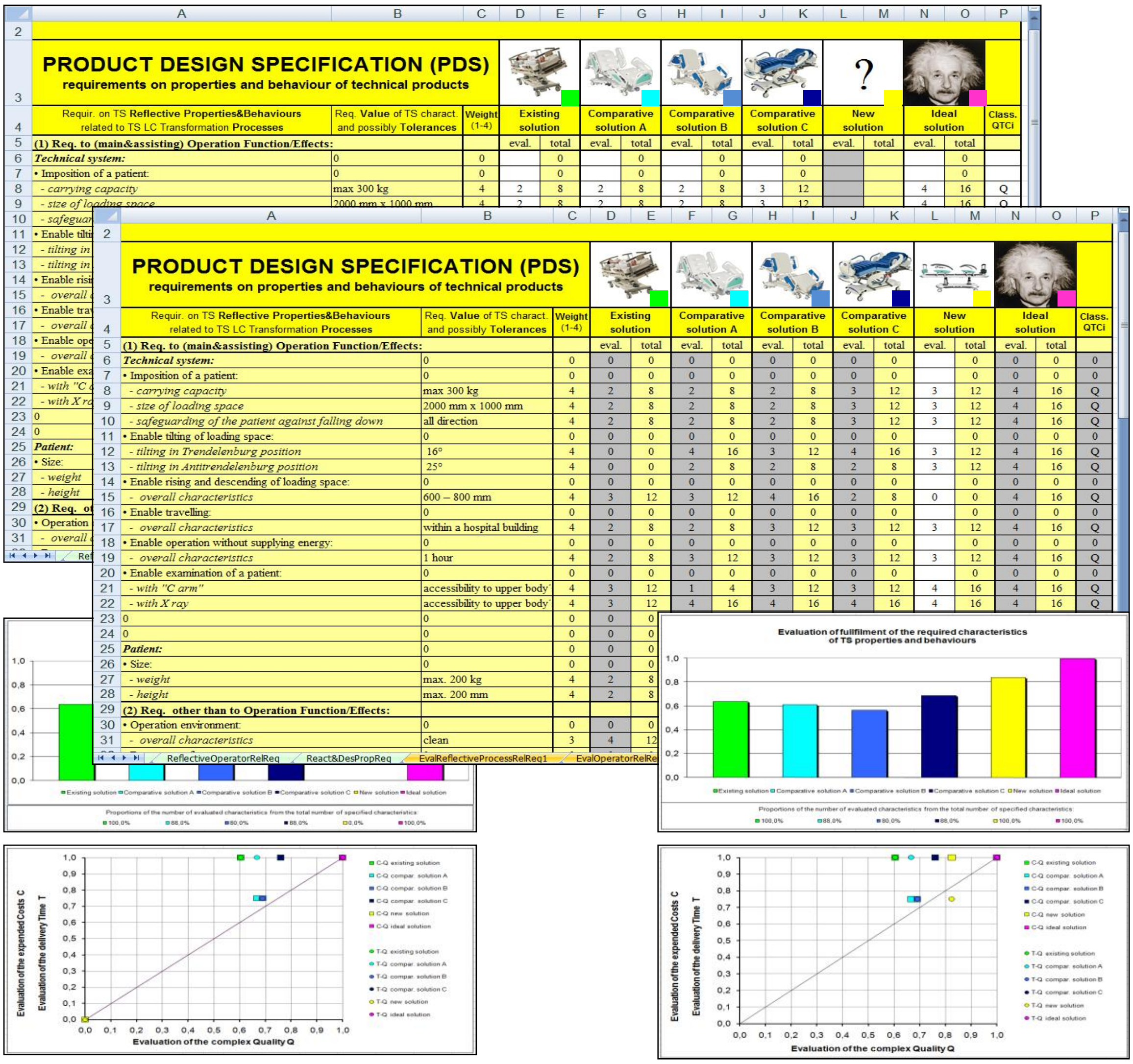


Figure 6. Specification of Requirements (Product Design Specification -PDS) on TS properties with reference evaluation of the fulfilment of the required TS property characteristics for the existing, comparative (competitive), ideal (back left), and newly designed (front right) TS - example of the section for the recorded values of the hospital bed property characteristics

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