THEORY BASED MANAGEMENT AND SOFTWARE SUPPORT OF PROPERTY DRIVEN DESIGNING OF TECHNICAL PRODUCTS

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There exist a lot of engineering design methodologies, methods and/or tools which help engineering designers and/or engineering design managers to increase design quality and competitiveness of the designed technical products. The presented paper reports on the contribution to it by a developed methodology and its SW support for design specification of both Product-Business and Product-Design requirements posed on a designed Technical Product seen as generalized abstract Technical System (TS) during its whole life cycle. These input data are then processed by continuous evaluation of their predicted properties and by early prediction of inherent strengths and weaknesses of the designed alternatives of TS including indication of potential risks. All this is accompanied by comparative evaluation of the designed TS competitiveness related to a starting 'mother' product and/or technical solution, and selected competitive products. Calculated results are represented in the form of detailed and clear summary diagrams.

Keywords:
technical product, life cycle, design specification, property classes, evaluation, quality, competitiveness, risks.

1. Introduction

The aim of engineering design methodologies and/or tools is to help engineering designers and/or engineering design managers to increase design quality and competitiveness of designed technical products which are seen as Technical Systems (TS) in this paper. TS quality and competitiveness obviously also depend on early identification of inherent strengths and weaknesses and risks and their consequent elimination.

The outputs of the engineering design process obviously influence not only 'visible' functions and shapes of designed technical products but they also have a fundamental significance on their usable properties, safety, use of materials, manufacturing, maintenance, transport and other life cycle costs, delivery time and many other product properties. Thus engineering design is the key stage of the life cycle of technical products

Our research in the area of Theory of Technical Systems (TTS) together with fruitful cooperation with our research and industrial partners 'navigated' us towards changing the traditional paradigm regarding product engineering design specification.

We have qualitatively increased its traditional role from a 'passive push' tool to an 'active pull' explicit ('leading') and implicit ('embedded') management tool for a continuous property driven and evaluated engineering design process. This enhanced concept has been utilized and validated in a number of interdisciplinary engineering and industrial design projects, mostly of an educational nature, but also real projects which were performed in cooperation with leading Czech companies, and also some industrial companies abroad.

The presented paper includes the theoretical background and a substantially innovated software management and engineering design tool for support of Engineering Design Specification and Evaluation of the designed TS, including indication of the TS strengths and weaknesses and risks, which has been implemented in MS Excel .

The theoretical background stems from long lasting cooperation with Professors V. Hubka, W.E. Eder, H. Birkhofer and other members of the former WDK Society and its successor the Design Society (from 2000) [Birkhofer 2011]. The last comprehensive version of our approach was published in [Eder 2008] and [Eder 2010]. Some of the latest improvements, focusing mostly on the explicit and implicit management of design engineering activities are presented in this paper.

2. TS Properties

2.1 Technical Product as a Technical System

'Technical system (TS) is a category of an artificial deterministic system that performs the necessary effects for transformation of the operands' [Hubka 1988] i.e. of the transformed material, energy, information and/or living beings. In another words it is a technical product viewed as a system.

Technical Product is a product with a dominant engineering content which usually serves as TS Operator (i.e. TS means) for a Transformation Process. Thus **Technical Product** (which stresses 'production view' in the 'practice realm') can be understood as a synonym for **Technical System** (which stresses 'system view' in the 'theory and methodology realms').

To specify, measure, compare and evaluate the designed and existing TS, we have developed and implemented the following general hierarchically consistent system for TS properties and their indicators, including the corresponding consistent taxonomy [Hosnedl 2010].

2.2. TS Properties, their Indicators and Values

In this paper a **TS property** is 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]. It is obvious that a TS property is a cumulative criterion, i.e. (not trivial) a TS characteristic from a more general, but nevertheless specific 'reasonable' viewpoint, which must be further specified. Further synonyms 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 that the consistent use of the term TS Property has its advantages in both engineering design theory and methodology as well as its practical use including 'leading' and 'embedded' management of designing.

TS property of any kind can be indicated (i.e. 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, compared and evaluated. The author of the paper call these criteria TS 'Property Indicators' and have very good experience with its use in many theoretical and practical fields of design engineering, [Hosnedl 2008]. These **TS Property Indicators** 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 colours used, etc., or normatively set (defined by laws, standards, etc., e.g. TS (car) safety according to strictly defined indicators such as crash deformation, deceleration, space, etc.).

TS Property Indicators of any kind can be specified, 'measured' and thus compared and evaluated by their one (direct) or more (indirect) 'Dimensions' (in its wider viewpoint, i.e. measurable not only numerically). 'Dimensions' of a TS Property Indicator, can be classified in terms of their measurement scales incl. corresponding dimensions. However, the problem arises of how to generally name concrete 'magnitudes' of dimensions corresponding to these miscellaneous scales. Except for the s implification of statements related to all the mentioned types of TS Property Indicators, the reason is that it is often impossible to predict/specify a concrete type of scale for many dimensions.

Considering the fact that scales for any type of dimension can be expressed both textually (linguistically) and numerically (i.e. at least by relevant numerical codes, but very often also by physically reasoned numbers, e.g. by wavelengths of light for colours) or perhaps graphically, it is possible to generalize 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 nonnumerical magnitudes in real life and even in mathematics.

Then any dimension of any TS 'Property Indicators' 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 Indicator's state can be specified/measured (directly or indirectly using other TS Property Indicators) by comparison using an appropriate scale. Of course more than one scale may be available for a particular TS property Indicator. 'Value of a TS Property' can then be thus specified, measured, compared and evaluated, etc. by the corresponding set of values of the corresponding TS 'Property Indicators', i.e. by values of their dimensions.

2.3. TS Behaviour as a TS Property

TS Behaviour is a **response of a TS Constructional Structure** to an external or internal stimulus. TS behaviour (i.e. response of a TS Constructional Structure) is thus specified by **changes of values** (of dimensions of TS property indicators) 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:

3. Taxonomy of TS Properties

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, within the framework of Engineering Design Science [Hubka 1988], [Hubka 1996] and using the hierarchical system for TS Properties specification introduced above and generally depicted in Fig. 1 and in a simplified example in Fig. 2 is briefly characterized in the following subsections.

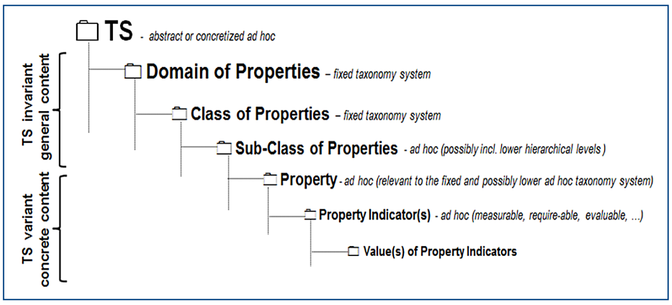


Figure 1. *Taxonomy system for TS Properties - Domains, Classes, Sub-Classes, Properties, and their Property Indicators incl. their Values*

3.1 Domain and Classes of Descriptive TS Properties:

It is domain which characterizes and specifies (i.e. 'describes) TS Structure. This domain can be axiomatically structured into **two classes** [Hubka 1988], [Hubka 1996], [Eder 2008]:

- **Elemental Engineering Design Properties of TS:** fully defining the TS Constructional Structure.
- **Feature Engineering Design Properties of TS:** describing features of TS Constructional Structure and its use in Operation Process.

3.2 Domain and Classes of Reactive TS Properties:

It is domain covering **General Engineering Design TS Properties** which characterize and specify topologically internal reactions of the TS Constructional Structure on affecting (external and/or internal immediate, short and long term) effects/stimuli. This domain can

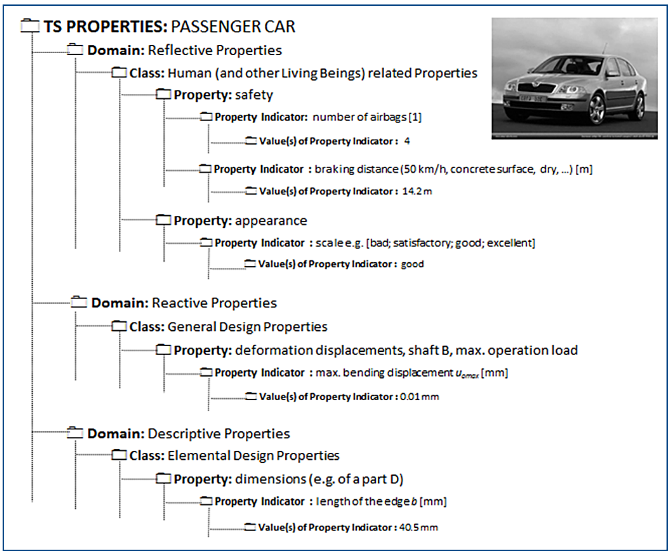


Figure 2. *An example of application of the developed general hierarchical system for specification, measurement, comparison and evaluation of any TS Property*

be split into **classes corresponding to** the respective **science and professional areas** which study and professionally treat them [Hosnedl 2010].

3.3 Domain and Classes of Reflective TS Properties:

It is domain which characterizes and specifies logically external active and/or reactive 'reflections' of TS Descriptive and Reactive Properties of TS Constructional Structure. TS Reflective Properties mirror TS in its whole Life Cycle. Separation of the respective TS life cycle stages could be made according to different standpoints e.g. place of realization, finance provider, etc.; however from the viewpoints of design engineering and development of TS it has been found and proved that it is optimal to structure them according to the dominant life cycle transformation processes (TrfP) [Hubka 1988].

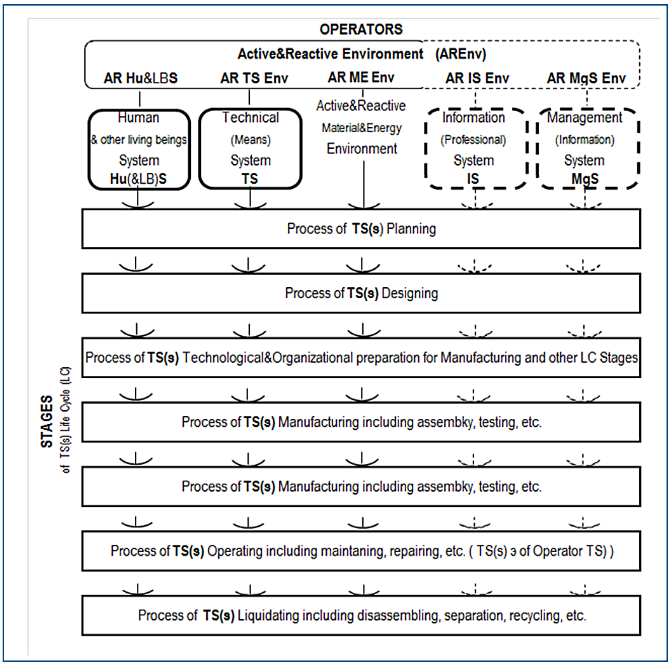


Figure 3. *Simplified Life Cycle model for a TS(s) consisted of the respective models of concretised Transformation Systems with their Transformation Processes and Operators*

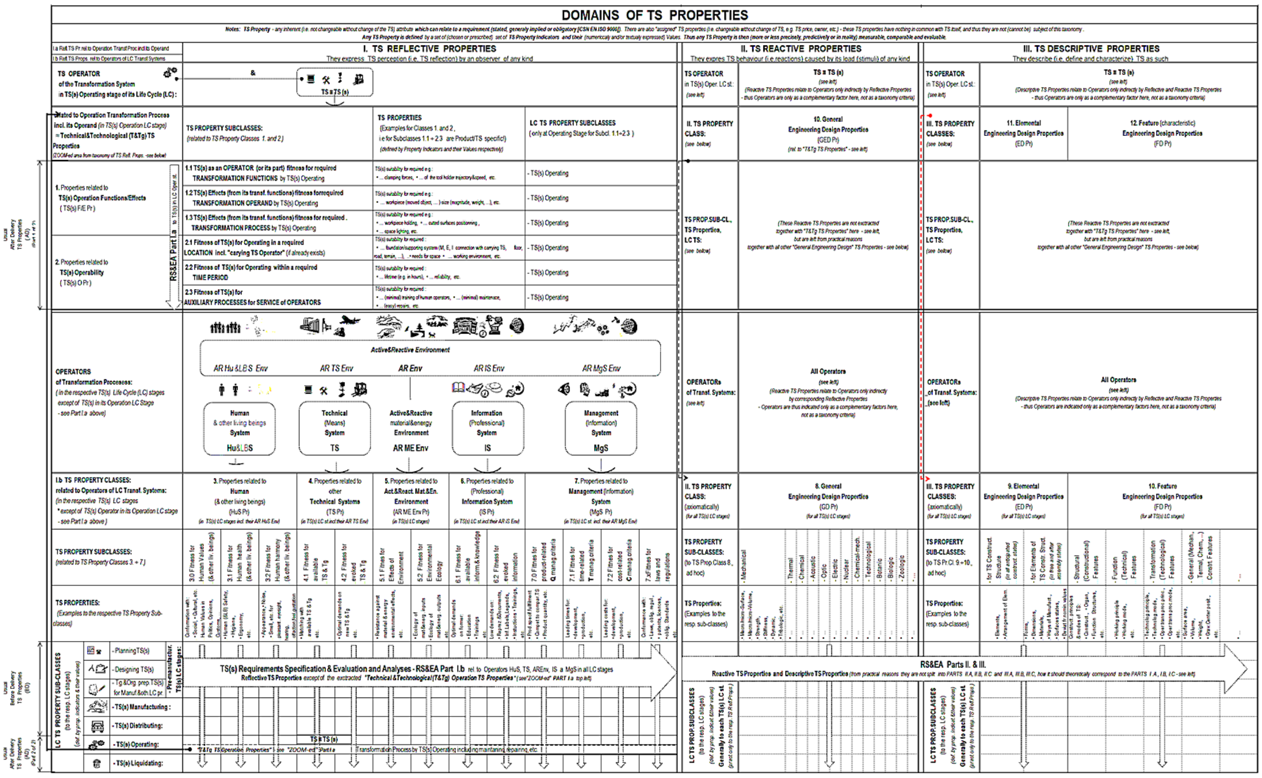


***Figure 4.** Essential framework for taxonomy of TS properties*

By using the General Model of the Transformation System (TrfS) with its Transformation Process (TrfP) [Hubka 1988], [Eder 2008], [Hosnedl 2010] it is possible to depict a clear General Model of TS Life Cycle [Hosnedl 2010] as outlined in Fig. 3. Such a model has been found to be an advantageous means of achieving 'total' and effective structuring of TS Reflective Property Classes. Resulting TS invariant taxonomy system for TS Properties of any Technical Product is depicted in Fig. 4.

4. TS Quality and Competitiveness

Quality is defined according to CSN EN ISO 9000 as a level of fulfilling requirements by a set of inherent characteristics. We understand TS Quality more generally in concordance with the philosophical category (in contradiction to Quantity one) as a set of required inherent TS properties which represent a view (i.e. criteria for evaluation) of a TS evaluator. Thus TS Quality is defined by posed and judged requirements on inherent TS properties.

Different kinds of TS quality (and corresponding values of TS Quality) can thus be distinguished, e.g.:

Specified set of properties in TS Life Cycle
⇒ Sort of TS Quality, related e.g.:

- only to production ⇒ 'Production' Q
- only to end user(s) ⇒ 'User (small q)' Q
- to total life cycle ⇒ 'Total Life Cycle' Q
- to selected delivery criteria ⇒ 'Judged' Q

Relationships of evaluations of the judged 'delivery' Quality Q, Time T, and Cost C in triads (Fig. 5) corresponding to compared Technical Products/ Systems (TS) can then serve for prediction of their mutual competitiveness. It can be predicted either as Product-Design or Product-Business depending on the scope of criteria of the evaluated 'delivery' Q, T, and C. Product-Design Q, T and C relate only to those TS requirements which are abstracted from a concrete real market and business criteria, while Product-Business ones include it (e.g. territorial value of a company trademark and company tradition, intended profit, sale and service infrastructure, etc.)

For better evaluation, each generally inclined triad (corresponding to one of the compared technical products) can be converted into two points in two 2D, possibly overlapping, diagrams as shown in Fig. 10.

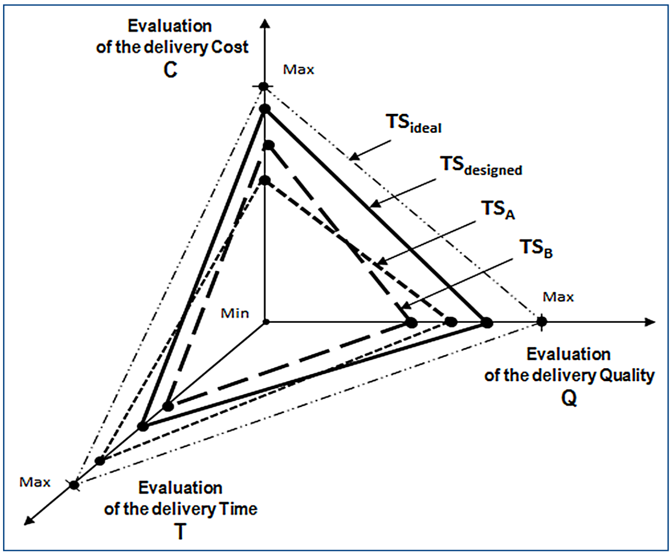


***Fig. 5.** Triad for evaluation of TS competitiveness*

5. Methodology of Property driven Management and its SW support

As introduced above, the software tool SP&HA implemented in MS Excel has been developed to support engineering design specification and continuous evaluation of designed technical products based on the above outlined theory. Orientation in its extensive content (having about 100 columns and 1100 lines on its input / output working sheet) is facilitated by hypertext buttons which enable the user to reach the required SW sheet in a user friendly manner, and especially the required class or subclass of

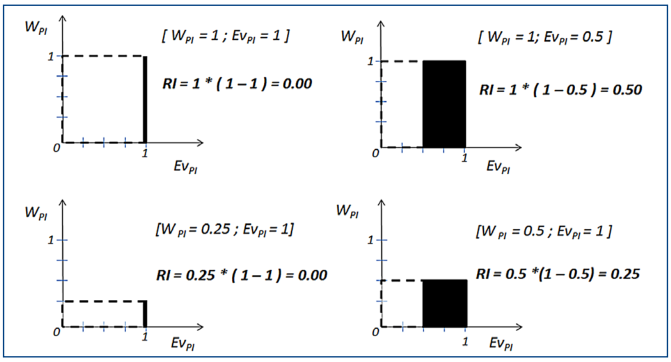


Figure 6. *Examples of Risk Indicator values*

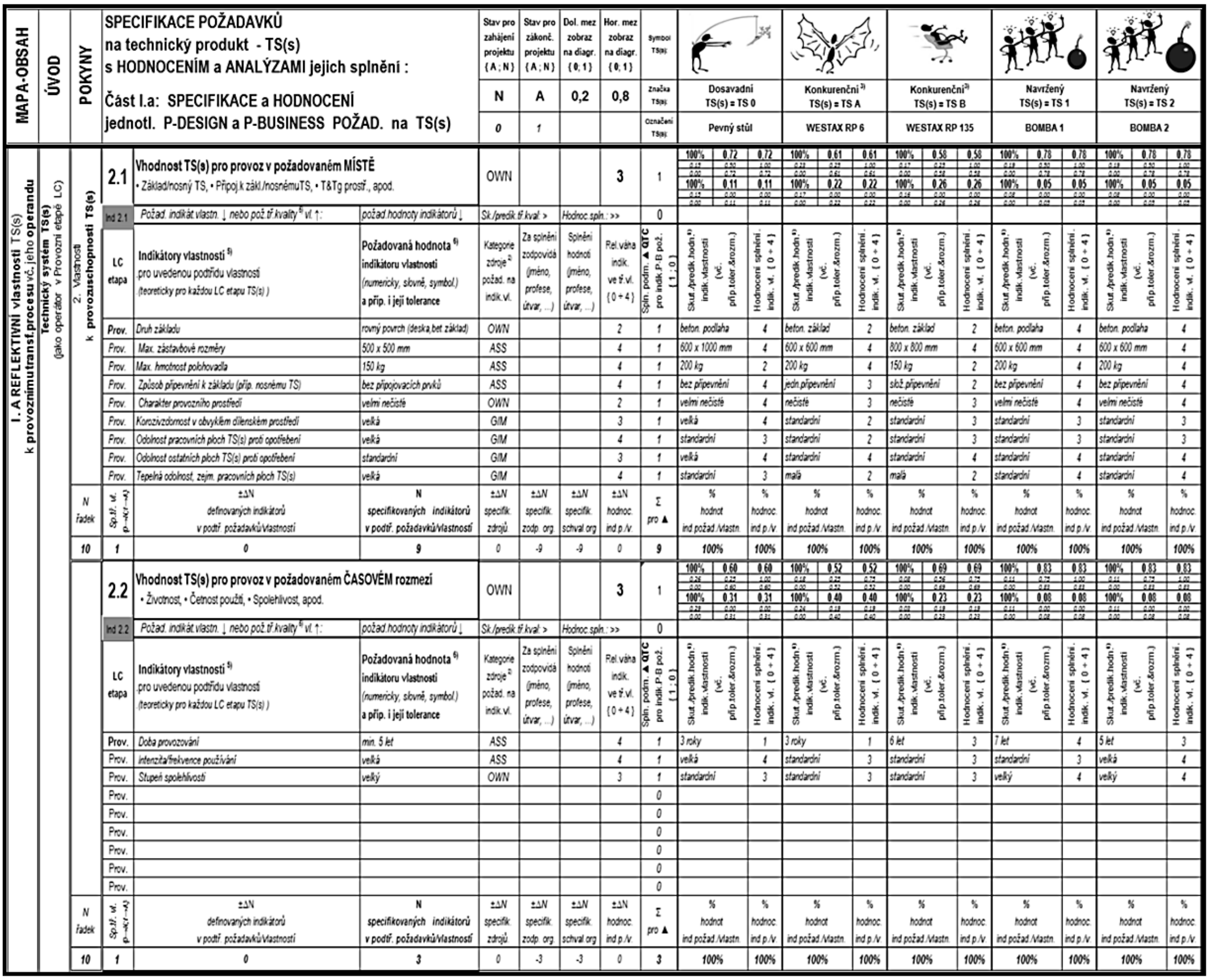
requirements on TS properties or the corresponding diagrams in the input/output working sheet.

In the introductory phase of the engineering design process it is necessary to specify requirements which the designed Technical Product – TS(s) should meet during its whole Life Cycle. However these cannot be only requirements assigned by the end user(s). Each TS has to satisfy not only assigned and other stated requirements, but also a number of other obligatory and generally implied requirements CSN EN ISO 9000 and/or even own requirements which are not currently 'externally' required but which can e.g. potentially increase TS 'attractiveness and thus competitiveness on the market.

To rationalise this time consuming task software SP&HA enables an optional simplified input of a joint requirement on any (maybe temporary) less important (sub)Class of TS Properties without detailed specification of its Property Indicators (e.g. often related to each stage of the TS Life Cycle). Unused lines can be hidden and vice versa with use of roll-up functions operated by user friendly buttons (e.g. Ind.2.1 and Ind.2.2 in Fig. 7). Each specified requirement (either detailed or joint) can be then completed by its source, bodies responsible for its fulfilment and evaluation, and its importance – weight {from 0 to 4}.

At the end of this step clearly organised Product-Business and Product-Design Specification documents usually called Lists of Requirements are obtained (Fig. 7, left). In the following step all available real Values of the specified Property Indicators for an existing former company product (if any, marked here TS0) and for specified competitive products (two defaults marked TSA and TSB) are completed and the respective fulfilments are evaluated {from 0 to 4} (Fig. 7, middle right).

Based on evaluation of fulfilment of the specified requirements, inherent TS Risk Indicators (RI) are determined using the formula:



SPECIFIKACE POŽADAVKŮ na technický produkt - TS(s) s HODNOCENÍM a ANALÝZAMI jejich splnění :
Část I.a: SPECIFIKACE a HODNOCENÍ jednotl. P-DESIGN a P-BUSINESS POŽAD. na TS(s)

MAPA-OBSAH | ÚVOD | POKYNY
I. A REFLEKTIVNÍ vlastnosti TS(s) k provoznímu transf. procesu vč. jeho operandu — Technický systém TS(s) (jako operátor v Provozní etapě LC) — 2. Vlastnosti k provozuschopnosti TS(s)

			Stav pro zahájení projektu {A;N}	Stav pro zákonč. projektu {A;N}	Dol. mez zobraz na diagr. {0;1}	Hor. mez zobraz na diagr. {0;1}	Symbol TS(s):										
			N	A	0,2	0,8	Značka TS(s):	Dosavadni TS(s) = TS 0		Konkurenčni[3] TS(s) = TS A		Konkurenčni[3] TS(s) = TS B		Navržený TS(s) = TS 1		Navržený TS(s) = TS 2	
			0	1			Označení TS(s):	Pevný stůl		WESTAX RP 6		WESTAX RP 135		BOMBA 1		BOMBA 2	
2.1	Vhodnost TS(s) pro provoz v požadovaném MÍSTĚ • Základ/nosný TS, • Připoj.k zákl./nosnémuTS, • T&Tg prostř., apod.		OWN			3	1	100% 0,72 / 100% 0,11	0,72 / 0,11	100% 0,61 / 100% 0,22	0,61 / 0,22	100% 0,58 / 100% 0,26	0,58 / 0,26	100% 0,78 / 100% 0,05	0,78 / 0,05	100% 0,78 / 100% 0,05	0,78 / 0,05
Ind 2.1	Požad. indikát.vlastn. ↓ nebo pož.tř.kvality[6] vl. ↑:	požad.hodnoty indikátorů ↓	Sk./predik.tř.kval: >		Hodnoc.spln.: >>		0										
LC etapa	Indikátory vlastností[5] pro uvedenou podtřídu vlastností (teoreticky pro každou LC etapu TS(s))	Požadovaná hodnota[6] indikátoru vlastnosti (numericky, slovně, symbol.) a příp. i její tolerance	Kategorie zdroje[2] požad. na indik.vl.	Za splnění zodpovídá (jméno, profese, útvar, ...)	Splnění hodnotí (jméno, profese, útvar, ...)	Rel.váha indik. ve tř.vl. {0÷4}	Spln. podm. ▲ QTC pro indik.P-B pož. {1;0}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}
Prov.	Druh základu	rovný povrch (deska,bet.základ)	OWN			2	1	beton. podlaha	4	beton. základ	2	beton. základ	2	beton. podlaha	4	beton. podlaha	4
Prov.	Max. zástavbové rozměry	500 x 500 mm	ASS			4	1	600 x 1000 mm	4	600 x 600 mm	4	800 x 800 mm	4	600 x 600 mm	4	600 x 600 mm	4
Prov.	Max. hmotnost polohovadla	150 kg	ASS			4	1	200 kg	2	200 kg	4	150 kg	2	200 kg	4	200 kg	4
Prov.	Způsob připevnění k základu (příp. nosnému TS)	bez připojovacích prvků	ASS			4	1	bez připevnění	4	jedn.připevnění	3	slož.připevnění	2	bez připevnění	4	bez připevnění	4
Prov.	Charakter provozního prostředí	velmi nečisté	OWN			2	1	velmi nečisté	4	nečisté	3	nečisté	3	velmi nečisté	4	velmi nečisté	4
Prov.	Korozivzdornost v obvyklém dílenském prostředí	velká	GIM			3	1	velká	4	standardní	2	standardní	3	standardní	3	standardní	3
Prov.	Odolnost pracovních ploch TS(s) proti opotřebení	velká	GIM			4	1	standardní	3	standardní	2	standardní	3	standardní	3	standardní	3
Prov.	Odolnost ostatních ploch TS(s) proti opotřebení	standardní	GIM			3	1	velká	4	standardní	4	standardní	4	standardní	4	standardní	4
Prov.	Tepelná odolnost, zejm. pracovních ploch TS(s)	velká	GIM			4	1	standardní	3	malá	2	malá	2	standardní	4	standardní	4
N řadek / Sp.tř. vl.	±ΔN definovaných indikátorů v podtř. požadavků/vlastností	N specifikovaných indikátorů v podtř. požadavků/vlastností	±ΔN specifik. zdrojů	±ΔN specifik. zodp. org.	±ΔN specifik. schval.org	±ΔN hodnoc. ind.p./v.	Σ pro ▲	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.
10 / 1	0	9	0	-9	-9	0	9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2.2	Vhodnost TS(s) pro provoz v požadovaném ČASOVÉM rozmezí • Životnost, • Četnost použití, • Spolehlivost, apod.		OWN			3	1	100% 0,60 / 100% 0,31	0,60 / 0,31	100% 0,52 / 100% 0,40	0,52 / 0,40	100% 0,69 / 100% 0,23	0,69 / 0,23	100% 0,83 / 100% 0,08	0,83 / 0,08	100% 0,83 / 100% 0,08	0,83 / 0,08
Ind 2.2	Požad. indikát.vlastn. ↓ nebo pož.tř.kvality[6] vl. ↑:	požad.hodnoty indikátorů ↓	Sk./predik.tř.kval: >		Hodnoc.spln.: >>		0										
LC etapa	Indikátory vlastností[5] pro uvedenou podtřídu vlastností (teoreticky pro každou LC etapu TS(s))	Požadovaná hodnota[6] indikátoru vlastnosti (numericky, slovně, symbol.) a příp. i její tolerance	Kategorie zdroje[2] požad. na indik.vl.	Za splnění zodpovídá (jméno, profese, útvar, ...)	Splnění hodnotí (jméno, profese, útvar, ...)	Rel.váha indik. ve tř.vl. {0÷4}	Spln. podm. ▲ QTC pro indik.P-B pož. {1;0}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}	Skut./predik.hodn.[8] indik.vlastnosti (vč. příp.toler.&rozm.)	Hodnocení splnění indik. vl. {0÷4}
Prov.	Doba provozování	min. 5 let	ASS			4	1	3 roky	1	3 roky	1	6 let	3	7 let	4	5 let	3
Prov.	intenzita/frekvence používání	velká	ASS			4	1	velká	4	standardní	3	standardní	3	standardní	3	velká	4
Prov.	Stupeň spolehlivosti	velký	OWN			3	1	standardní	3	standardní	3	standardní	3	velký	4	velký	4
Prov.							0										
Prov.							0										
Prov.							0										
Prov.							0										
Prov.							0										
Prov.							0										
N řadek / Sp.tř. vl.	±ΔN definovaných indikátorů v podtř. požadavků/vlastností	N specifikovaných indikátorů v podtř. požadavků/vlastností	±ΔN specifik. zdrojů	±ΔN specifik. zodp. org.	±ΔN specifik. schval.org	±ΔN hodnoc. ind.p./v.	Σ pro ▲	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.	% hodnot ind.požad./vlastn.	% hodnoc. ind.p./v.
10 / 1	0	3	0	-3	-3	0	3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure 7. *Section of a SW SP&HA form with TS Product-Design specification (left) and its evaluation (right) The following data processing and representations of their results in a form of diagrams are analogous to products TS0, TSA and TSB.*

$$RI = W_{PI} * (1 - Ev_{PI} [\Delta(Vpr_{PI} - Vrq_{PI})]) \quad (1)$$

where:

RI Risk indicator {0;1}

W_{PI} Weight (importance) of the Property Indicator {0; $W_{PI\,max}$}
usually: $W_{PI\,max}$ = 1 or 4

Ev_{PI} Evaluation of the fulfilment of the Property Indicator {0; $Ev_{PI\,max}$}
usually: $Ev_{PI\,max}$ = 1 or 4

Vrq_{PI} : Required Value of Property Indicator

Vpr_{PI} : Predicted Value of Property Indicator

The resulting partial, subtotal and total weighted Evaluations and Risk Indicators for the respective criteria are then automatically calculated and represented in the form of diagrams as outlined in the following.

Similarly during designing and finally at the closing phase the predicted Values of the specified Property Indicators for the designed alternatives (not shown) and final designed out Technical Product (two default alternatives marked TS1 and TS2) are completed and the respective fulfilments are evaluated (Fig. 7, very right).

The following data processing and representations of their results in a form of diagrams are analogous to products TS0, TSA and TSB.

SW SP&HA provides the user with online graphic representation of the resulting weighted evaluations for any standard (sub)Class of TS Properties and the compared Technical Products as depicted e.g. in Fig. 8.

Next, data processing provides SW user with sum values and online diagrams showing resulting Product-Design and Product-Design evaluations and risk indicators for all the compared TS (Fig. 9).

Software tool SP&HA also provides user with evaluation and in the two dimensional '3D diagrams' supporting analyses of the mutual Product-Design and Product-Business competitiveness of the compared Technical Products (TS) regarding the three previously mentioned criteria of 'delivery' Q, T and C (Fig. 10).

All those diagrams (examples in Figs. 8, 9 and 10) are supplemented by tables (bottom) containing statistic data about the set of the input values to each 'column' (e.g. min. and max. values, mean quadratic deviations, etc. with changeable 'signal' colours) to avoid possible wrong interpretations of the graphically shown (only) average weighted respective values.

All diagrams are also supplemented by bottom (red) and top (green) optionally pre set dashed lines (see in Figs 8, 9 and 10). Columns higher than green line indicate TS Strengths, columns lower than the red line indicate TS Weaknesses from the viewpoint of the corresponding criteria (i.e. TS Property (sub)Class, TS Quality and/or TS Constructional Competitiveness respectively). It also supports demanding evaluations and minimises danger of evaluation mistakes.

6. Conclusions

The outlined management tool for Property Driven Designing of Technical Products as well as its SW SP&HA support which stems from the Theory of Technical Systems (TTS) [Hubka 1988] has been proved to help both experienced and even novice engineering designers and engineering design project managers to manage and execute their interdisciplinary creative teamwork and continuously evaluate results of their work more efficiently. An important innovative advantage of the presented SW tool is indication of inherent risks in the TS. A new theory based method of possible risks during the TS Life Cycle was developed and implemented.

The advantages of the introduced engineering design management tool and its SW support have been especially proved during a number of 'property driven designing' of technical products in interdisciplinary students' projects (Fig. 11). Results and valuable feedback have been appreciated not only by teachers and students involved but especially by the participating industrial and research partners.

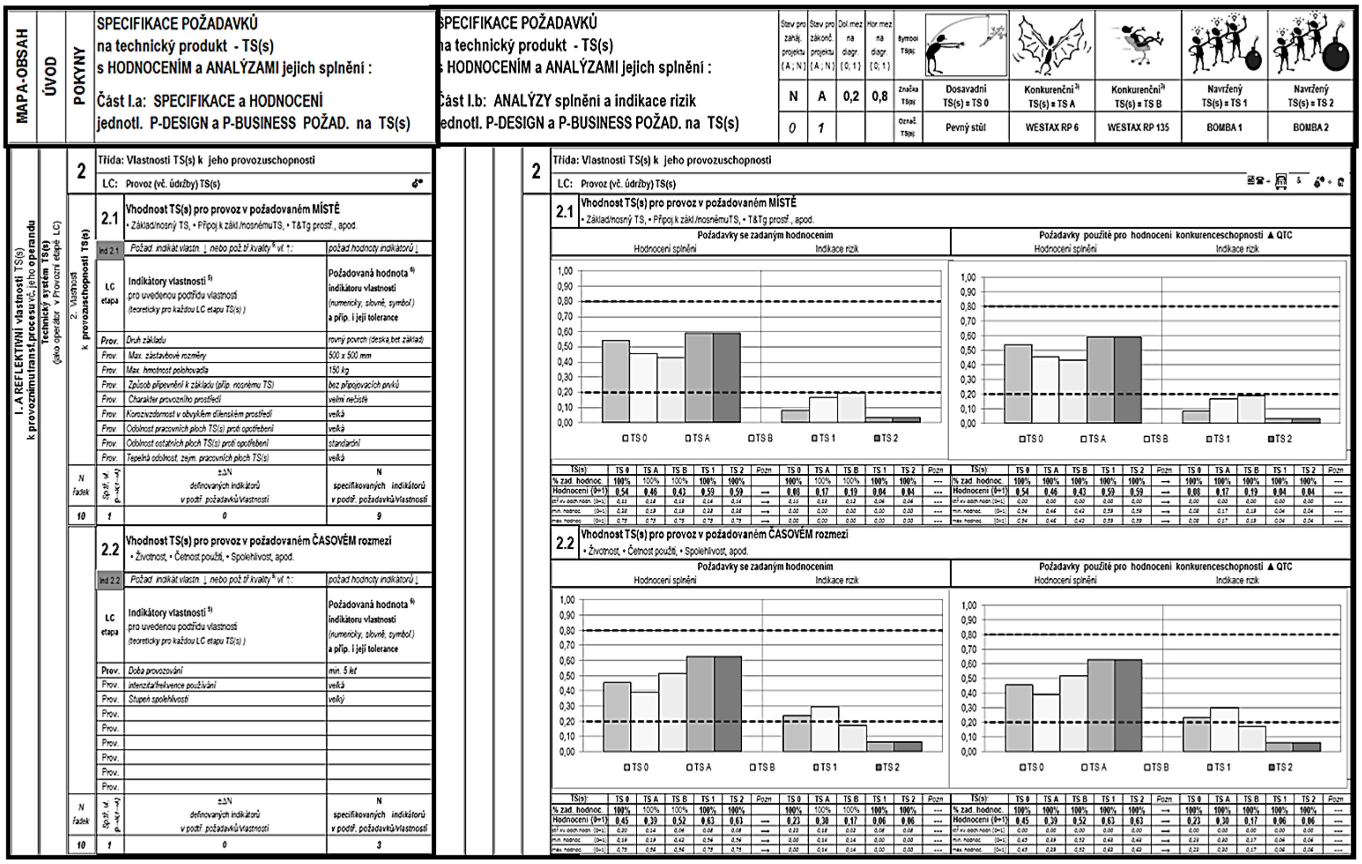


Figure 8. Example of diagrams depicting partial evaluations of predicted fulfilment of the specified requirements and corresponding risk indicators for the respective Property (sub-)Classes by designed and other compared Technical Products

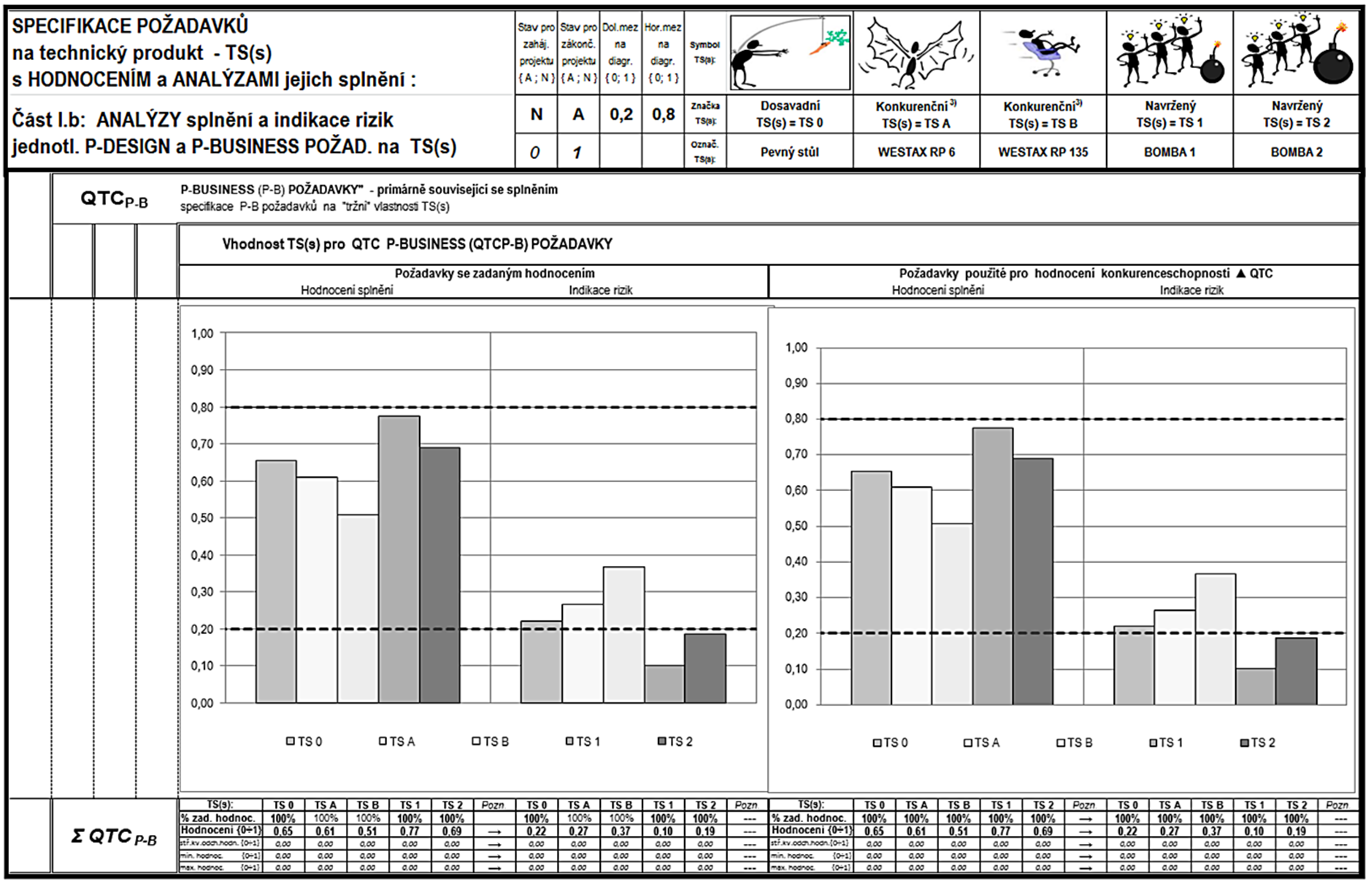


Figure 9. Diagrams depicting summary evaluations and risk indicators

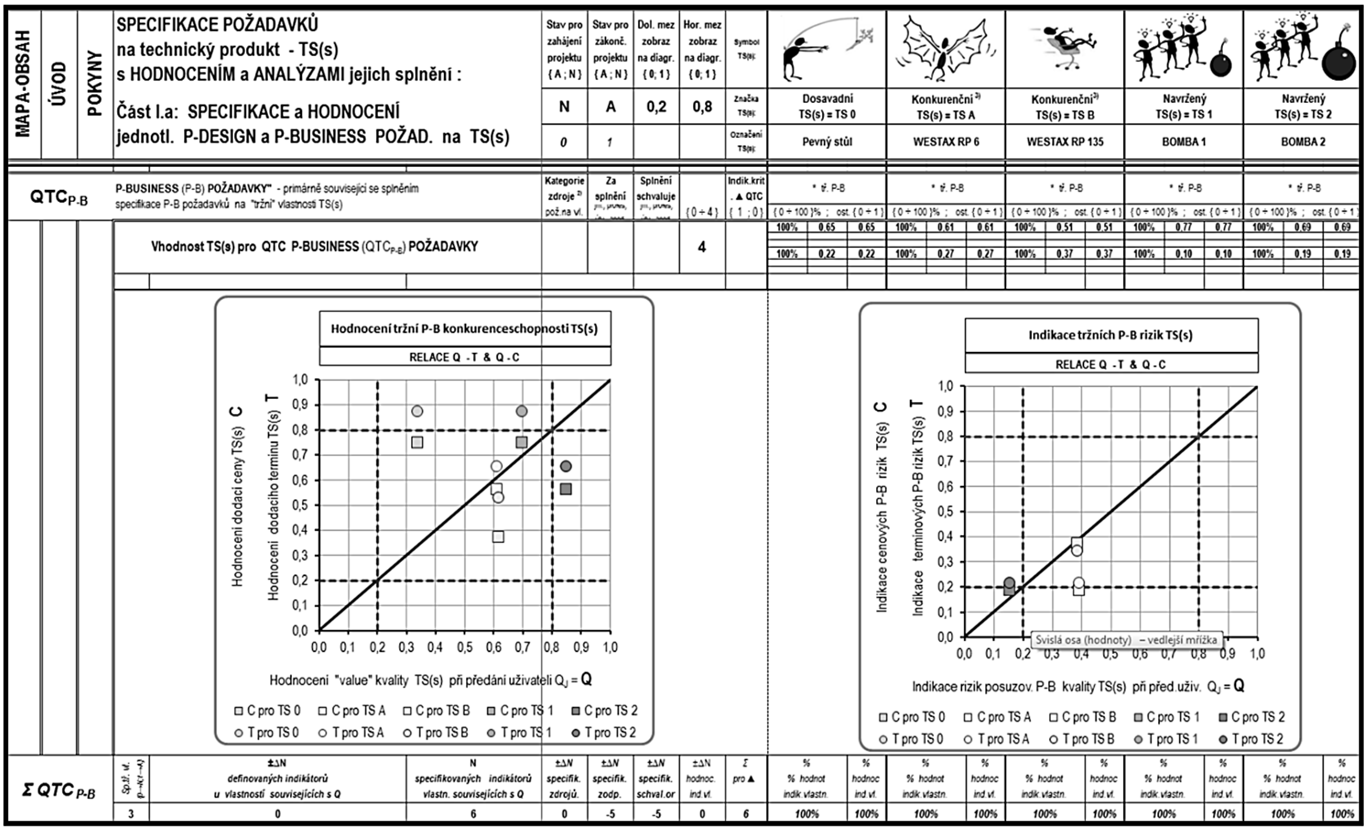


Figure 10. Diagrams for evaluation of the predicted final Product-Business competitiveness of the designed Technical Product compared to other existing and compared Technical Products

Since 2004 this philosophy has been utilised and validated in more than 130 student teams (from 5 to 7 students each) on 29 very different topics of the interdisciplinary engineering and industrial design projects assigned, consulted and evaluated by 13 Czech and foreign industrial companies (Fig. 12).

Each year the projects were performed from scratch within 13 weeks of the winter term by engineering design and management students from our Faculty of Mechanical Engineering together with industrial design students from the Faculty of Art and Design, and consulted by students from the Faculty of Health Studies, and also optionally supported by students from our Faculty of Electrical Engineering, from University of Zielona Gora (PL) and Deggendorf Institute of Technology (G) (Fig. 12).

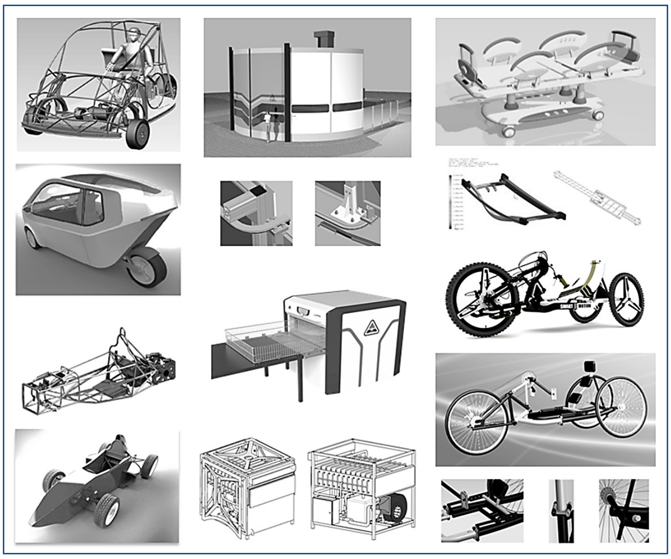


Figure 11. *Samples of results of student engineering and industrial design projects assigned, consulted and co-evaluated in cooperation with industrial partners*

Students mastering the presented theory based, but flexible, methodology of 'property driven designing' of technical product, and significantly supported by the outlined management methodology and its SW support SP&HA are able to understand the general approach, priorities and aims of the design work more easily. It also obviously increases their creativity, resulting in a lot of very new solutions. A number of them have been submitted and have already obtained the certificates of Utility Model published by the Industrial Property Office of the Czech Republic in Prague.

Finally, TTS based property driven designing has been also more or less applied in a number of university engineering design diploma theses, which have been undertaken for dozens of industrial companies and successfully evaluated by their reviewers.

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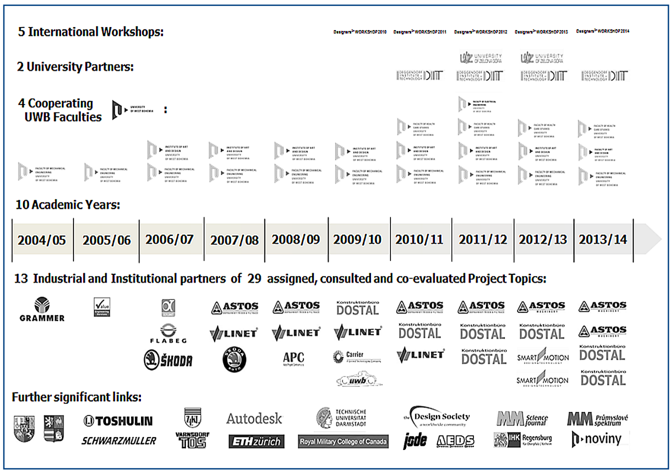

Figure 12. *Industrial, university and institutional partners involved in student property driven design projects since 2004*

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