

A STUDENTS' PROJECT - DESIGNING OF A LUGGAGE SPACE FOR ESTATE CAR USING A MAP OF ENGINEERING DESIGN SCIENCE KNOWLEDGE

Klara Martinovska, Roman Janousek, Josef Dvorak and Zbynek Srp

Keywords: Design Engineering, Engineering Design Process, Methodology, Design Science

Abstract

The paper will introduce a team students' project carried out for and evaluated by an industrial partner. The team consisting of the four students - engineering designers from the Department of Machine Design, and of the one student - industrial designer from the Institute of Art and Design at the University of West Bohemia in Pilsen, Czech Republic performed the project using an enhanced theory and methodology developed on the basis of a "map" of Engineering Design Science knowledge, which seems to be very promising for achieving efficient and effective cooperation even for interdisciplinary teams.

1. Introduction

The purpose of this paper is to provide you through the project which was worked out by engineering and industrial designers within product development and their different perspectives on the technical product that is to be developed. The following sections try to introduce a possible way of developing efficient and effective cooperation between these two professions depicted on example of this project.

This approach has been developed for and during the education design projects which took place at the Department of Machine Design, UWB, Pilsen, where the students were working in multiple teams consisting of both engineering and industrial designers.

This approach has been also validated during education design projects carried out for and evaluated by industrial partners. This projects have been carried out at the Department of Machine Design, University of West Bohemia in Pilsen over the last few years. Students were working in several multiple "competing" teams consisting of both engineering and industrial design students.

2. Procedure

The methodology that we present that is used in this project stems from the engineering design methodology of [Hubka&Eder 1996] based on the theories of technical systems and design processes. This fact makes this methodology different from other methodologies in the sense that it can be used as a "map" of knowledge and not only as "rigid procedural commands" as are often used.

2.1 Clarifying and Elaborating the Assigned Task – Integrated engineering and industrial Product Design Specification

As usual this introductory phase [Hubka&Eder 1996] of the project started with a critical recognition of the assigned problem. Search for State of the Art is mostly focused on collecting information both about the company's existing product and about competitive products (Figure 1), however corresponding standards, patents, etc. are also investigated.



Figure 1. Company's own existing product and competitive products

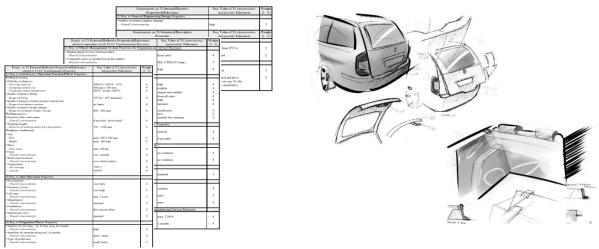
A rough examination of the possibilities of realization (feasibility study) is then performed. The resulting stated, generally implied and/or obligatory requirements [CSN EN ISO 9000] of the designed product are completed, classified and quantified in the following step. These should optimally be expressed in the form of the requested and/or maybe not requested values and/or limit values (expressed numerically and/or textually) of property characteristics and/or behavioural characteristics. The "EDS knowledge map" enables a systematic and transparent arrangement of all requirements in relationship to the processes and operators of the life cycle phases of a technical product/system (TS_(s)) in the form of a series of Transformation Systems (TrfS)

The resulting product design specification document is called the List of Requirements. This document generally consists of written formulations of the requirements of the designed product including the textual requirements of its visual appearance (Figure 2 left). In the integrated concept presented here the industrial design students are asked to visualize/predict their correspondingly clearer image of the product's industrial design (appearance). These first industrial design studies (aesthetic, ergonomic and so forth) (Figure 2 right) became graphic enclosures/extensions of the textual part of the List of Requirements. This helped both engineering and industrial design students to better develop a mutual communication platform and to hold a common course in the subsequent design phases.

Using the Integrated List of Requirements our team evaluated corresponding (values of characteristics of) properties and behaviours of the "Existing Company Product" and evaluated its current (engineering & industrial) design competitiveness by comparing it with three "competitive product" (using the weighted point method). Based on these evaluations a simplified SWOT analysis was performed, and decisions about strategic (engineering & industrial design) priorities and possible risks for the design project are specified.

A SW programme in MS Excel we used to support these specifications and evaluations (Figure 3 - Part 1) including on-line graphs for simplification of the mentioned decisions (Figure 3 - Part 2).

Based on these analyses and the recommended standard/outlined procedural path in the "EDS knowledge map" [Eder&HosnedI 2007] then we established a rough schedule for their integrated engineering & industrial design work for the project as a whole.





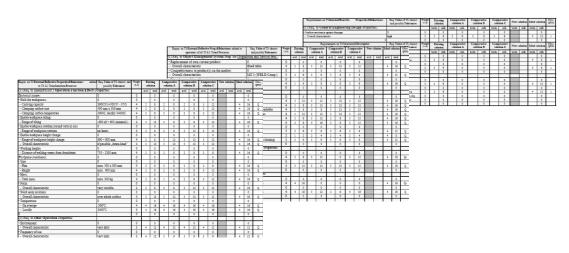


Figure 3 – Part 1. MS Excel SW support of the Product Design Specification and corresponding evaluation of the Existing Company Product, and its Competitive Product(s)

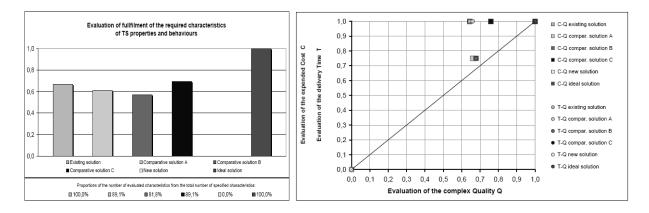


Figure 3 – Part 2. MS Excel SW representation of evaluation of the Existing Company Product for the established Product Design Specification (left), and its (engineering&industrial) design competitiveness with the competitive product(s) (right)

2.2 Establishment of the Function Structure and corresponding Industrial Design

Design and analyses of the Operation Process of a designed product helped us to establish the optimal transformation functions needed to perform the designed operations transforming the operand from its input state to the required output state according to the established technology. The optimal Function Structure of the designed technical product, which provides the Operation Process with the established transformation effects (achieved from the established active and/or reactive M, E and I inputs to the operator - technical product) for the main and assisting inputs to the transformation process, is then designed (Figure 4).

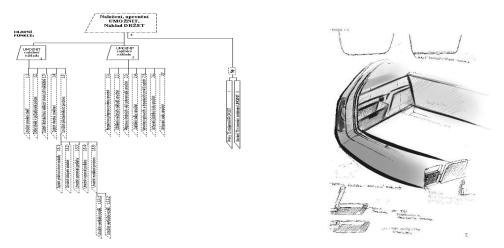


Figure 4. Function Structure with its derived/predicted appearance

2.3 Establishment of the Organ Structure and corresponding Industrial Design

The Organ Structure as a concretization of the Function Structure of a product, but it is still an abstract model of the designed technical product. It consists of organs (the carriers of functions) that realize certain modes of action (as the aim), and the relationships between those means [Hubka&Eder 1988].

A technical equivalent of the example above is shown in Figure 5. Organ structures of the designed product are mostly designed in several alternatives and their variants using the morphological matrix. It enables simple combinations of different organs which were established for fulfilling the respective functions from the established Function Structure. An optimal alternative/variant is then usually selected based on the weighted point evaluation according to the criteria selected from the Product Design Specification. Now, the predicted industrial design of the respective alternatives/variants can be used as one of the evaluation criteria for choosing the optimal variant. Until now this has not been possible in this phase when using only a usual concept without integrating industrial designers.

2.4 Establishment of the Component Structure - Engineering and Industrial Design

In the final two design phases the engineering and industrial design of the rough component structure (preliminary layout) and final component structure (dimensional layout) of the designed product (Figure 7) for the selected optimal variant of the organ structure are established.

Now using the Integrated List of Requirements evaluated the achieved/predicted (values of characteristics of) properties and behaviours of the "Newly Designed Company Product", and evaluated its current (engineering & industrial) design competitiveness by comparing it to three "competitive product" (using the weighted point method). The SW programme in MS Excel mentioned above also supported these evaluations (Figure 8 - Part 1) including on-line graphs for visualisation of the comparisons (Figure 8 - Part 2).

			Var. A	Var. B	Var. C						
		-			/						
Di	lčí funkce	1	Funkční princi	py a přísl. Orgány– 1 3	nositelé fcí 4	5					
1.1	Umožnit otevření dveří	Mechanicky	Elektricky	Pneumaticky	Magneticky	Hydraulidky					
.2	Držet dveře v požadované poloze	Mechanicky	Elektricky	Pneumaticky	Magneticky	Hydraulidky					
1.3	Zajistit dostatečnou velikost otvoru při nakládán	Snížení nakládací hrany a rozšíření tvaru	Snížení nakládací hrany	Rozšíření tvarů							
1.4	Zajistit vhodná osvětlení	2 Světla na bocích	Světla u vedlejších úložných prostor a stropní světlo	světla u vedlejších úložných prostor a na bocích							
1.5.1	Zajistit průchozí otvor Sedadly	Sklopení loketní opěrky s možnosti použití výměrné krycí plachty	Skopeni loketní opěrky bez kryci plachty								
1.5.2	Umožnit sklopení sedadel	Zachovat řešení									
1.5.3	Zajistit zarovnání podlahy	Zvýšení sedadel a výsuvná podlaha	Vložka bez výstrvné podlahy	Výsuvná podlaha							
1.5.4	Yysunutí podlahy zajistit	Kolejničky a neodklopná podlaha	Kolejničky a odklopení celé podlahy	Vyndavaci Profil, a odklopení celé podlahy	Profil a podlaha se zabudovanými kolejničkami, výklopná						
1.5.5.1	Umožnit vertikální rozdělní prostoru	roletka zabudovaná v profilech vysamé podlahy	Jednoúčeľová dleska								
1.5.5.2	Umožnit horizontální rozdělení prostoru	Plachta/sítka	Teleskopidka deska	Tří dílná rozebíratelná deska skládací	Skládací harmoniková deska na pantech						
2.1	Bezpečnou přepravu zvířete umožnit	Pevná sklopná měžě	Rolovací sitka uložená v odkládacím dílu		parroart						
2.2	Oddělení nečistých nákladů umožnit	Výsuvné odnímatí boxy	taška	Skládací krabice	Skládací kufr						
2.3	Přepravu drobných věcí pohromadě umožnit	Vyndavací boční příhrádky	Vyklápěcí pevné boční kapsy								
2.4	Umožnit zajištění tašky	Zabudovaná roleška na boku, hádky	Chrádky	háðky							
2.5	Vytvoření upínacích a dosedacích prvků zajistit	Háčky v rozích a na dně / otočné háčky	Zapuštěné otočné hádky								
2.6	Úchycení jízdního kola umožnit	V podělných profilech na dně prostoru	Příčně pomočí lyče								
2.7	Uchycení sudu umožnit	V podélných profilech na dně 🍙 prostoru	Pomocí připínacích ohrádek do boku 👘 prostoru								

Figure 5. Establishing variants of Organ Structure concept using morphologic matrix

VARIANT A

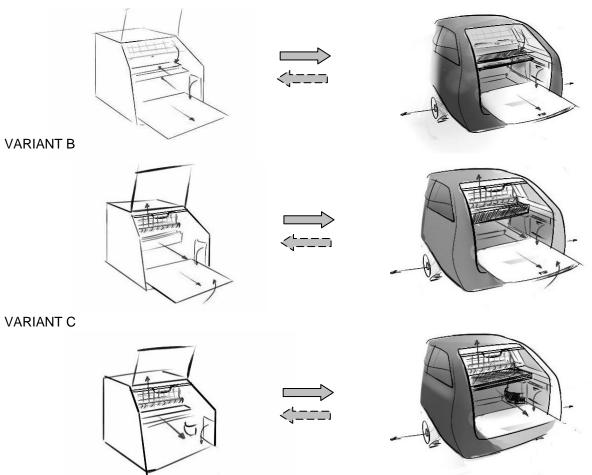


Figure 6. Organ Structure together with its derived/predicted appearance

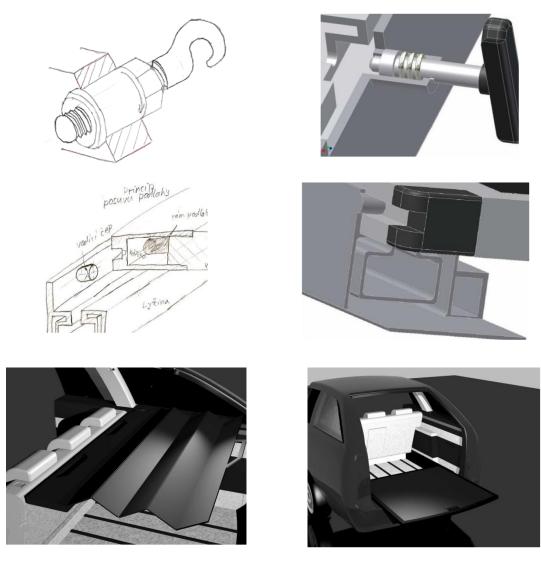


Figure 7. Integrated Engineering and Industrial Design of the Constructional Structure

																		1	Sequires	wats on TS	Slateraali	Rescure	Prope	sties 884	lantie ars		ue of TS classes, an	Weight	Existing	Comp	soles.	Comparatio		paradive	New talk		eal volution	Ches.
																						poss	ibly Tolerance:	(1-4)	solution		ka A	solution B	_	atice C				dace				
) Req. to General Engineering Design Properties:								eral 31	al erai.	total	eral tota	si erai.	total	and t	201 07	191. 1992)	$ \rightarrow $		
						-	Requir. on 75 Enternal/Reflective Prop.AlBehaviourn rulmed to Req. Value of 75 chauset. Weight Entering Co											turbes and many article downed. after Comparative Comparative New colusion Ideal tola					lin Ging Claus		0	0 0	0	0	0 0	0	0	++	0 0	2 0	0			
						2.40		erators of all				CE Definit		ibly Telerances	0.0	f Enis	10.00	Comparat colution		tolation		empirate alurion C	a Ser	1000030	Ideal solo	OTO OTO	i	3	2 6	2	6	2 6	2	6	13	2 4	4 12	1
						1110						()namen				412				eal. I se				Lord	eral. I c) of TS charact an	Weight	Enitian	0	rativ	Comparativ		parative	<u> </u>		10	2
									(1) Req. to Object Management System Prop. for Origination and Service Proc.: * Reducement of one constructions								A D	with the		10. K	ces v.	a. 101	s vis.	0		0 0	dr Tolerance:	(1 - 0)	zolution .	to and a state		solution B		atica C	New salu	rina Ide	esi solutica	GACT
							ACARDADE OF O		disct.				j Eaudauble			0		2 3	0	2 .	2	3 12		12		16 0	<u> </u>		eral at	d mi	total	anal tota	d ent	inter	gral 1	and an	later ler	
Requir. on TS External Reflective Properties & Behaviours related Req. Value of TS charac			Exis	ting .	Comparent	ine C	Comparative Comparative New						Class.	a —	1			0	6	6	<u>.</u>	0 0	4	0	0			0	0 0	0	0	0 0	0	0		0 0	0 0	0
to TS LC Transformation Processes	and possibly Tolerances	Weight (2-4)	solu		selution .		colution B		nica C	solutio		Ideal solution	QTCi	i ccup.)	1	2	× K	3	0	2	÷ E	2 0	1	9		12 0	an XY Co.	2	3 6	0	0	0 0	0	0	3	6 4	4 8	i.
(1) Req. to (main/cassist.) Operation Function/Effects Pr	operties:		etal	total	eval. to	en les	nl. tet	d eval	total	eral 1	oral e	val. tota	<u>, </u>	(may)	- í	*	0	0	<u>.</u>	6	<u>;</u> =	0 0	- '	0		0 0	-	0	0 0	0	0	0 0	0.	0		0 0	0 0	0
Technical system:	0	0	0	0		0	0 0		0			0 0		d	4	1	4	2	2	2	ž I	2 2	1	12		16 0	-		3 6	0	0	0 0	0	0	3	6 4	4 8	ũ.
Hold the workpieces:	0	0	0	0	0	0	0 0	0	- i			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
- Carrying capacity	3000 N (+500 N - 0 N)	4	2	8	2	8	2 8	3	12	3	12	4 16	0		+		-	_	-	-	-	-	+-	-	_	-				_		_	+	_	\vdash	+	_	→
- Clamping surface size	500 mm x 500 mm	4	2	8	2	8	2 8	3	12	3		4 16		1	0	0	0	0	0	0		0 0	+	0		0 0		0	0 0	0	0	0 0	0	0	+ +		0 0	0
- Clamping surface temperature	3000C, locally 14000C	4	2	\$	2	8	2 8	3	12	3	12	4 16	0		4	3	12	3 3	2	3 3	12	3 12	3		4	16 0		3	2 6	0	0	0 0	0			12 4	4 12	
 Enable workpiece tilting: 	0	0	0	0	0	0	0 0	0	0		0	0 0	0	1	4	2	3	5 3	2	1 1	12 1	3 12	1		4	16 0	and drive	0	0 0			0 0	-	<u> </u>		2 4	4 12	-
- Range of tilting	-500 až + 600 (minimāl.)	4	3	12	2	8	2 8	3	12	3	12	4 16	0	84	4	2	8	2	8		12				4	16 0	and give a req. To obj.	2	2 0		-	0 0		0	<u> </u>	-	* 14 * A	1
 Enable workpiece rotation around vertical axis 	0	0	0	0	0	0	0 0	0	0		0	0 0	0	1	4	3	12	3 3	12	3 1	12	3 12	3	12	4	16 0	roperties)	0	0 0	0	-	0 0	-	0		计量	0 0	-
- Range of workpiece rotation	no limits	4	2	\$	2	\$	3 13	3	12	3	12	4 16	0		4	2	3	3 1	12	2	8	3 12	3	12	4	16 0	repartes)				÷.	0 0	0			1 1	6 ÷	0
 Enable workpiece height change: 	0	0	0	0	0	0	0 0	0	0		0	0 0	0		4	2	3	4 3	16	2	\$	3 13	3	12	4	16 0	1											
- Range of workpiece height change	600 - 800 mm	4	2	\$	3 3	12	3 12	3	12	3	12	4 16	0	1	0	0	0	0	0	0	0	0 0		0	0	0 0												
 Weld seam locations: 	0	0	0	Ū.	0	0	0 0	0	0		0	0 0	0	1	3	2	6	3	9	2	6	3 9	3	9	4	12 Q												
 Overall characteristic 	if possible _down-hand"	4	3	12	3 1	12	3 12	3	12	3	12	4 16	9	-	2	1	2	2	4	2	4	2 4	3	6	4	s Q												
Working heights	0	0	0	0	0	0	0 0	0	0		0	0 0	0	ing	3	3	9	3	9	3	9	3 9	3	9	4	12 Q												
- Distance of welding seems from foundation	750 - 1200 mm	4	2	8	2	8	2 8	2	8	3	12	4 16	Q	1	0	0	0	0	0	0	0	0 0		0	0	0 0												
Workpiece (weldment):	0	0	0	0		0	0 0		0			0 0	0	operties:																								
• Size:	0	0	0	0		0	0 0	0	0			0 0			0	0	0	0	0	0	0	0 0		0	0	0 0												
- Plan	max. 500 x 500 mm	4	2	\$	2	\$	2 8	2	\$			4 16		-	- 4	2	8	3 3	12	0	0	3 12	3	12	4	16 Qr												
- Height	max. 600 mm	4	2	\$	2		2 8	3	12	3		4 16	Q		0	0	0	0	0	0	0	0 0		0	0	0 0												
• Mass:	0	0	0	0		0	0 0	0	0			0 0	0	4	4	3	12	3 3	12	3 3	12 3			12	4													
- Total mass	max. 300 kg	4	2	\$		4	2 8	3	12	2		4 16		_	0	0	0	0	0	0	0	0 0		0	0	0 0												
• Form	0	0	0	0		0	0 0		0			0 0	0	-																								
 Overall characteristic 	very variable	4	2	\$		\$	3 12		12	3		4 16	Q	_	0	0	0	0	0	0	0	0 0		0		0 0												
Weld seam locations:	0	0	0	0		0	0 0		0	+		0 0	0		4	4	16	0	0	0	0	0 0	4		4	16 Qr												
Overall characteristic	over whole surface	4	3	12		12	3 12		12			4 16		4	0	0	0	0	0	0	0	0 0	-	0	0	0 0												
Temperature:	0 300°C	0	0	0		0	0 0		0			0 0		4	4	4	16	3 1	12	2	8 -	4 14	4			16 Q												
- On average		4	4	16			4 16		16			4 16		4	0	0	0	0	0	0	0	0 0	_	0	0	0 0												
- Locally	1400°C	4	4	16		16	4 14		16			4 16 0 0		4												1												
(2) Req. to other Operation Properties:			-		- V -	v	0 0	0		+	•	0 0	0	4																								
 Environment: 	0				-	0	0 0	-				0 0	+	4																								
Environment Overall characteristic	uery dicty	3	0	0		v	0 0 4 12	0	0				0	4																								
Overall characteristic Frequency of use:	very daily	3		12		0	4 13	4	12	1.		4 12		4																								
· Prequency of use	9		0	0		v .	0 0	0	0		v	0 0	0	4																								

Figure 8 – Part 1. MS Excel SW support for evaluation of existing and newly designed company products, and their (engineering&industrial) design competitiveness compared to competitive products

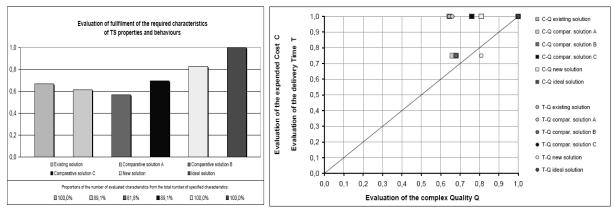


Figure 8 – Part 2. MS Excel SW representation of the evaluation of existing and newly designed company products for the established product design specification (left), and their (engineering&industrial) design competitiveness compared to competitive products (right)

3. Conclusions

The strategy presented in this paper helped us, engineering & industrial designers,

to consolidate our cooperation. This increased the design competitiveness of the product and improves its chances of succeeding in the market place we think.

This experience also helped us to recognize our roles and responsibilities within a design process. Furthermore, it enabled us to gain their own experience in cooperation and communication with different professions, which encouraged our discussions and provided us with feedback of how we are able to assert their own ideas in a design team and how we are able to accept the thoughts and ideas of each team members.

The results of the project were presented in a university exhibition called Design² held in the "Over the Stairs" gallery on the university's Bory campus. These projects were greatly appreciated not only by the teachers and students involved but also by the participating industrial and research partners.

Acknowledgements

We are very grateful to the other members of our team - students from the Department of Machine Design of the Faculty of Mechanical Engineering (FME) and Institute of Art and Design (IAD), UWB, Pilsen - Milan Votava and Zuzana Stiefova, for their help and participation in this interdisciplinary project. We would also like to express special thanks to our lecture, Professor Stanislav Hosnedl who gave us a chance to participate in this project. The authors of the paper also wish to thank the participating industrial partner – Škoda Automobilová a.s. Mlada Boleslav for technical support which enable us to solve such interesting project.

References

[Eder&Hosnedl 2008] Eder, W. E., Hosnedl, S.: Design Engineering, A Manual for Enhanced Creativity. CRC Press, Taylor & Francis Group, Boca Raton, Florida USA, 2008, 588 p., ISBN 978-1-4200-4765-3

[Hosnedl&Vanek 2001] Hosnedl, S., Vaněk, V.: Design Science for Engineering Design Practice. In: Proceedings of International Conference on Engineering Design – ICED 01. Glasgow, UK: IMechE, London, 19.-25.8.2001. Vol 3, s. 363-370. ISBN 1 86058 1.

[Hubka&Eder 1988] Hubka, V., Eder, W.E.: Theory of Technical Systems. Berlin Heidelberg: Springer - Verlag, 1988, (2nd ed. in German. 1984) ISBN 3-540-17451-6

[Hubka&Eder 1996] Hubka, V., Eder, W.E.: Design Science. London, Springer, 1996, ISBN 3-540-19997-7

[CSN EN ISO 9000] ČSN EN ISO 9000 (ed. 2, 01 0300, idt ISO 9000:2000) Quality mangement systems – Fundamentals and vocabulary. Prague: Czech Institute for Standardisation, 2002

Klara Martinovska, student, Department of Machine Design, Faculty of Mechanical Engineering, University of West Bohemia, Univerzitni 8, 306 14 Pilsen, Czech Republic Tel: +420 724 735 294, E-mail: <u>klara martin@centrum.cz</u>