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Theory of Technical Systems

A Total Concept Theory for
Engineering Design

With 143 Illustrations

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Preface

This book presents a comprehensive and unifying theory to promote the understanding of technical systems. Such a theory is useful as a foundation for a rational approach to the engineering design process, as a background to engineering education, and other applications.

The term “technical system” is used to represent all types of man-made artifacts, including technical products and processes. The technical system is therefore the subject (in the grammatical sense of the word) of the collection of activities which are performed by engineers within the processes of engineering design, including generating, retrieving, processing and transmitting of information about products. It is also the subject of various tasks in the production process, including work preparation and production planning, and in many economic considerations, company-internal and societal.

In this way, the Theory of Technical Systems is a contribution to science, as interpreted in the wider, Germanic sense of a “co-ordinated and codified body of knowledge”. It brings together the various viewpoints of engineers, scientists, economists, ergonomists, managers, users, sociologists, etc., and shows where and how they influence the forms of engineering products. It also explains the influences that a product exerts on its environment.

This Theory of Technical Systems should thus interest design engineers, and engineers involved in production, management, sales, etc. In an interdisciplinary application of value analysis, the Theory of Technical Systems should provide answers to many questions raised in this field.

Keeping in mind the particular needs of students of engineering, we hope to reveal new insights to the relationships between different branches of knowledge for engineering with this book, and to encourage a better understanding of the range and nature of problems that engineers encounter.

This book pursues a number of aims:

- to describe and classify the principles of action of technical systems, and their properties and characteristics,

- to build up a basic terminology as a foundation for a study of engineering design, and
- to formulate important perceptions about technical systems on which to base further study of engineering design, particularly with respect to the design engineer's working methods.

This set of aims may look very dry and theoretical, but the reader's task should not necessarily be to study this material as a thorough and self-contained treatise. On the contrary, after a first introduction, this book should be a constant companion, as a reference work for repeated search and discovery.

The first impulse towards compiling a theory of machine systems (as a special form of technical systems) came many years ago, from a study of design methodology. It was clear from the start that a generally applicable and well-founded design method cannot be built up without a clear model of an "abstract machine". Attempts at formulating such a model, and interacting with the developing design methodology, forced a continual revision of the ideas and perceptions. Many discussions with Dr. Hubka's colleagues in the Design Committee of the Czechoslovak Scientific-Technical Society helped to crystallize the ideas, particular help was received from Dipl.-Ing. M. Cervinka, J. Smilauer and S. Vit.

Further developments took place with friendly help and constructive criticism from Dr.-Ing. F. Kesselring. The result was the first edition of a book about theory of machine systems published in German: "Theorie der Maschinensysteme" by V. Hubka, Springer-Verlag, Berlin, Heidelberg, 1973 [109]. The second part of this discourse, a book about design theory, was also published in German: "Theorie der Konstruktionsprozesse" by V. Hubka, Springer-Verlag, Berlin, Heidelberg, 1976 [112]. In 1980, a further book appeared in German language: "Allgemeines Vorgehensmodell des Konstruierens" by V. Hubka, Fachpresse Goldach, Switzerland, 1980. It represented a development, the synthesis of the themes of design science, in a very condensed form. This volume has been translated into a large number of languages, including French, Italian, and Japanese. For the English language, a complete revision was undertaken, which among other things added a comprehensive glossary and index, and adapted the ideas more to the prevailing outlook of the English-language cultures: "Principles of Engineering Design" by V. Hubka (translated and edited by W. E. Eder), Butterworth Scientific, London, 1982 [119].

A full circle was almost reached, with publication in German of a second edition to the first of these books, under the revised title: "Theorie technischer Systeme" by V. Hubka, Springer-Verlag, Berlin-Heidelberg, 1984, sub-titled 'second completely revised and expanded edition'.

Since then, many discussions on these themes have taken place, particularly with Dr. M. M. Andreasen, and Dipl.-Ing. P. Ferreira. The main venue for such meetings has been at a series of conferences with the general title International Conference on Engineering Design: ICED 81 Rome, ICED 83 København, ICED 85 Hamburg, ICED 87 Boston. These conferences, and their planned sequels, are under the leadership of WDK-Workshop Design-Konstruktion, an informally constituted international society based on common interest in engineering design.

The Theory of Technical Systems has frequently been quoted in the world of scientific literature, which is a clear indication that the new discipline has proved useful.

The present volume is the result of active collaboration between both authors, and is again a complete revision and re-direction of its German pre-cursor, aimed specifically at the English-language audience. We have chosen to avoid any deep discussions about the works of other authors, even though their ideas have influenced this work, partly because of the limits of space set for the present book, and partly because it is aimed towards students of engineering. The problems should therefore not be clouded by added discussions. Similar practical reasons have caused us to select and document examples mainly from mechanical engineering.

The context for this book is set in chapter 1. Chapters 2 and 3 present the background on needs, and the transformations that serve to satisfy those needs. Chapter 4 contains information on processes and their properties. Technical systems and their properties are the subject of chapters 5–11. Chapter 12 summarizes some perceived applications for the theory of technical systems. All statements collected to summarize the chapters, and all summarizing propositions stated within the chapters are collected for easy reference in appendix A. Appendix B contains a discussion of some of the terminology, including the original chapter 2 from the pre-cursor of this book, and a discussion about choice of words, to make some of the philosophy clearer.

Thanks are due to the following for valuable comments to drafts of this book: Ken Wallace, Lecturer in Engineering Design, University of Cambridge; Geza Kardos, Professor, Carleton University; Charles O. Smith, Professor (retired), Rose-Hulman Institute of Technology.

The authors take full responsibility for errors or omissions and would like to hear any constructive suggestions and comments.

July 1988

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





Letter and Graphical Symbols

a	abstract	LC	law conformance property
AEnv	active environment	Liq	liquidation property
Aes	aesthetic property	Mc	cross-product of two-place relationship
Aux	auxiliary	M	material
B	behavior	MEI	machine element
c	concrete	Mfg	manufacturing property
C	condition	M&GS	management and goal-setting system
CPM	critical path method	MS	machine system (special case of TS)
D	newly designed	n	number
Des	design property	Od	operand
Di	distribution property	Od _i	operand number i
DP	delivery and planning property	Od ⁱ	operand in state i
E	energy	Op	operation
Ec	economic property	Opp	operational property
Ef	effect (exerted by TS)	Ot	operator
Eff	effector	Out	output
El	element, elementary	Pa	partial
ElEf	elementary effect	PaEf	partial effect
ELTS	elementary technical system	PaOp	partial operation
Env	environment	PaTP	partial process
Erg	ergonomic property	PaTS	partial technical system
EV	effectiveness	Pb	problem
FD	functionally determined property	Pc	principle
Fu	function	PERT	program evaluation review technique
	Fu _i function number i	Pr	property
	Fu ⁱ function with i conditions	Pr _i	property number i
FuTS	function possessed by a TS	Pr ⁱ	property in state i
f	number of steps of complexity of TS	Pro	production property
	in state of finality	PuD	purchased (bought out, out-sourced), newly designed
g	weight factor	PuSt	purchased, standard
Hu	human (individual or group)	PuTyp	purchased, typified or works standardized by supplier
HuS	human system	PV	profitability
i	serial count (number)	p	probability
I	information		
In	input		
IS	information system		

XIV Letter and Graphical Symbols

R	relationship	TgPc	technological principle
R/C	regulation and control	TP	technical process
Re	re-used	TrP	transformation process
Rec	receptor	TrS	transformation system
s	relative strength	TS	technical system
S	system	TSFu	technical system that fulfills a function
Sec	secondary	TTS	theory of technical systems
SIn	secondary input	Typ	typified
Sol	solution	W	working
SOut	secondary output	WPc	working principle
St	standardized	WSt	works standardized
T	technical	WTP	working process
Tg	technology		

Graphical Symbols

	process or process system		object system
	function		input or output
	decision process		effect