Methods and Techniques used in Industrial Engineering to solve Typical Issues

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Abstract: Paper deals with comparative estimation for the methods in industrial engineering in order to solve typical issues. The introduction contains an inventory of main issues in the field and some of the most representative related, traditional or modern, methods and techniques.
A comparative evaluation of these methods was proposed having as main goal to offer to the interested specialists a point of view on the affordability and suitability for each of these methods.
The evaluation is based on criteria selection in a direct or weighted procedure using a pointing system. Weighted comparative evaluation for a set of chooses criteria are able to establish a classification and a reference point in the process of selection for the most suitable method in a given case.
The paper valorises some information and elements from main references together with author experience in teaching activity including practical work and projects.

Key-words: industrial engineering methods, comparative evaluation, engineering principles.

1 Introduction

Engineering is sometimes defined as the application of science to the solution of problems of society at a profit. Starting from a grouping of engineering functions or practical activities a discussion on the engineering methods and techniques becomes possible.
This paper is concerned specifically with the application of engineering and scientific methods, scientific research, and management concepts and methods to the problems of industrial production.

Industrial production refers to the methods used in factories for the efficient manufacture of goods. Two important aspects of industrial production are product technology, which is concerned with the design and characteristics of the product itself, and process technology, which includes the design, organisation, and operation of the machines and the planning and control systems used in producing manufactured goods. Discussion on the comparative evaluation of industrial engineering methods should include both groups of aspects.

2 General considerations regarding methods of industrial engineering

Paralleling the development of improved methods for achieving efficient production were increasing concerns for the health, safety, and comfort of workers and for the effects of industrial production on the environment.

The discussion of production management emphasises aspects that are important in almost any setting-managing human resources, selecting equipment and technology, managing systems flows, financing operations, and controlling the use of capital.

Mathematical and computer-based methods and techniques used in the fields of industrial engineering and operations research are also covered. These methods consist of the development of rigorous mathematical models and procedures to test the soundness of alternative decisions, to find ways of improving processes, and to aid in the understanding of the complex interactions that characterise most operating systems.

Application of engineering principles and techniques of scientific management contribute to the maintenance of a high level of productivity at optimum cost in industrial enterprises.

In manufacturing operations, production management includes responsibility for product and process design, planning and control issues involving capacity and quality, and organisation and supervision of the workforce. Production management's responsibilities are summarised by the "five M's": men, machines, methods, materials, and money.

The management of men, machines, and methods involves maintaining a flexible production process with a work force that can readily adapt to new equipment and schedules. The managers responsible for industrial production require an enormous amount of assistance and support because of the complexity of most production systems, and the additional burden of planning, scheduling, and co-ordination. Historically, this support was provided by industrial engineers whose major concern was with methods, standards, and the organisation of process technology.

Industrial engineering supporting methods contribute to three important decisions.

♦ First, industrial engineers, production managers, and other specialists must choose and design the technology to be used. Their decisions must include the choice of equipment and tooling, the layout of plant space and facilities, the starting with a choice of technology, the capacity of the system must be determined.

♦ Next, given a choice of technology, the capacity of the system must be determined. The capacity of the system is designed to be a function of the amount of available capital, the demand forecast for the output of the facility, and many other minor factors. Establishing too much capacity, too soon, can burden a company with excess costs and inefficient operations. Too little capacity can make it difficult and expensive to increase output later if the market develops rapidly; this can place a company at a significant cost disadvantage if other competitors, with larger facilities, produce a product at a lower cost or with more consistent quality.

♦ Finally, given a basic commitment to capacity, decisions must be made on the adaptability of the production volume to meet the inevitable changes in market demand that the firm will experience. Capacity in most production systems is adjusted by hiring or firing workers, by scheduling overtime or cutting back on work hours, by adding or shutting down machines or whole departments or areas of the facility, or by changing the rate of production within reasonable limits.

Because of the enormous complexity of typical production operations and the almost infinite number of changes that can be made and the alternatives that can be pursued, a productive body of quantitative methods has been developed to solve production management problems. Most of these techniques have emerged from the fields of industrial engineering, operations research, and systems engineering.

There is virtually no scientific discipline which may not be used in the design of some large-scale system and singles out probability, mathematical statistics, computing, system logic, queuing theory, game theory, linear programming, cybernetics, group dynamics, simulation, information theory, servomechanism theory, and human engineering. To this list there might also be added decision theory, non-linear programming, some elements of econometrics, and communications theory as related to random processes.

The necessity and imperativeness for solving inconveniences of the successive approach or sequential revealed, particularly last years, a lot of new methods having as declared objective the correlated approach of the life stages of a product. Such new concepts could be found under different designation like *Concurrent Engineering (CE), Simultaneous Engineering (SE) or Strategic Approach to Product Design (SAPD)* etc.

All mentioned denominations and may be some others reveal a new vision in which any product is not separately approached on his stages. The new approach has as a focusing goal the whole life cycle, stages been considered in their interdependency so that inconvenience of the separate approach could be avoided. Old and new methods are using same common concepts and notions and their diversity is a proof, by one side of importance of the field and by the other side of the unsatisfactory solving of real cases.

Table 1.Methods or techniques used to convince on new value.

Abbreviation	**Method**	**Performance Improvement of Product**	**Performance Improvement of Organisation**	**Cost Reduction of Product**	**Cost Reduction of Organisation**	**Planning New Value**
CR	Cost Reduction			1	1	
DFA	Design for Assembly			1	1	
DRA	Decision and Risk Analysis					1
DTC	Design to Cost			1		
FA	Function Analysis	1	1	1	1	1
HK	Hoshin Kanri Planning					1
IL	Integrative Learning		1			
JIT	Just in Time		1		1	
KT	Kepner Tregoe		1			
LP	Linear Programming		1			1
MB O	Management by Objectives		1			1
MS	Methods Study			1		
NA	Needs Analysis	1	1	1	1	1
OD	Organisation Development		1			
PA	Portfolio Analysis	1				1
PM	Performance Management		1			
PM	Performance Measurement			1	1	1
PM	Project Management		1			
PM	Participative Management		1			
QA	Quality Assurance	1	1			
QC	Quality Control	1				
QFD	Quality Function Deployment	1				
SDM	System Dynamic Modelling	1	1	1	1	1
SE	Simultaneous Engineering		1		1	
SP	Strategic Planning	1	1	1	1	1
SP	Scanlon Plan		1			
SPC	Statistical Process Control	1				
ST	Statistical Tolerancing	1		1		
ST	Sensitivity Training		1			
ST	Sociotechnical Systems		1			
TF	Technology Forecasting	1	1			1
TM	Taguchi Method	1		1		

TQC	Total Quality Control	1	1	1	1	
TQM	Total Quality Management	1	1	1	1	
VA	Value Analysis	1	1	1	1	
VE	Value Engineering	1	1	1	1	
VM	Value Measurement	1	1	1	1	1
VM	Value Management	1	1	1	1	1
VP	Value Planning	1	1	1	1	1
WS	Work Simplification			1	1	
ZD	Zero Defects	1				

An other interesting aspect that could be revealed consists in reusing and developing of a common set of solving ways, each new propose method or technique trying to convince on its new value, affordability and efficiency. Table 1 is a limited example for illustrating this idea [5].

Some of the previous methods and possible many other were appreciated considering a synthetic comparative evaluation which considers some of the most relevant operational criteria [3] (see Table 2).
For previous set of methods same authors have proposed a comparison on several degrees (see Table 3) using ten diverse criteria (see Table 4) [3].

Table 2 . Synthetic comparative evaluation.

CE Method	**Conceptual optimisation**	**Simplification**	**Conformity of process**	**Functional optimisation**
Axioms of design	Yes	Yes	Yes	Yes
Design For Manufacturing & Assembly	Yes	Yes		Yes
Robust design	Yes			Yes
Rules of process design		Yes	Yes	
Systematic design	Yes	Yes	Yes	
Group technology	Yes	Yes		Yes
Failure Mode Evaluation Analysis	Yes			Yes
Value analysis and value engineering	Yes			Yes
Reversive engineering	Yes			Yes

Table 3. Comparison on several degrees using ten diverse criteria.

CE Method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Axioms of design	B	N	B	B	B	B	B	N	L	B
DFM & DFMA	B	B	B	B	L	B	B	N	L	B
Robust design	N	L	L	L	B	N	N	B	B	N
Rules of process design	N	N	N	B	N	N	N	B	B	B
Systematic design	N	N	B	B	B	B	B	N	N	B
Group technology	L	N	B	B	B	N	N	N	B	L
FMEA	N	N	L	L	B	N	N	N	N	N
VA &VE	B	N	L	L	B	L	B	N	N	B
Reversive engineering	N	N	N	L	N	B	B	B	B	N

Legend: 1-10 = criteria for methodological evaluation conforming table 4; B, N, L = levels for accomplishment of the method (Better - B, Normal - N, Lower - L).

Table 4. Criteria for methodological evaluation.

No.	Criterion
1	Implementation cost and effort
2	Training and practice necessity
3	Design effort
4	Management effort
5	Team necessity for product planning
6	Quickly results
7	Creativity
8	Systematic approach
9	Qualitative or quantitative character
10	Training and forming character

It is very interesting that finally suggestions for use for some of mentioned methods could be found as can be seen in table 5 [3]. Suggestions have considered some of the most representative range of products from industrial engineering.

Other remark could be related to *Design For "X" (DFX)* concept, were X can be Reliability, Robustness, Serviceability, Manufacturability, etc. This concept has also grouped some of the methods of the engineering approach, each of method having the declared aim contained in the denomination.

The comparative evaluation procedure of methods

Starting from general aspects and considerations previously presented, the paper proposes a general and concise comparative evaluation procedure which can be useful for any set of methods in order to select for use or to appreciate suitability for a particular case. The procedure introduces two different groups: one with general and the other with specific criteria (see Table 6).

Table 5 . Suggestions of the most representative range of products from industrial engineering.

CE Method	Suitability
Axioms of design	A,B,C,D,E
DFM & DFMA	A,B,C,E,F
Robust design	A,B,C,D,E,F
Rules of process design	C,E
Systematic design	F
Group technology	A
FMEA	A,B,D
VA &VE	A,B,C,D,E, F
Reversive engineering	A,B

Legend: A- mechanical and electromechanical products; B electronic- products; B electronic- products; C – production processes; D - software, control, integration of systems; E - material transforming processes

The user can select criteria from such a list or from a larger one considered best fitted to his particular case and can start the comparative evaluation. Comparison should be made within criteria selected from the same group in order not to alter the affordability of criteria. Comparative evaluation involves use of a comparison matrix in which methods are compared each other.

To build such a matrix a set of comparative evaluation criteria should be used, distinct on general and specific criteria. A suggestion for starting this matrix is to use both general and specific criteria appropriate to the each particular case in order to complete an objective comparison and selection (see Table 7).

Table 6. The procedure that introduces two different groups of criteria.

Symbol	General evaluation criteria	Symbol	Specific evaluation criteria
A	Level of approach	P	Planning program
B	Compatibility with the case	Q	Efficiency
C	Economic aspects considered	R	Capacity
D	Technical aspects considered	S	Resources
E	Potential acceptance from users	T	Timing
F	Development capacity of method	U	Human factor
G	Generalisation capacity of method	V	Scientific apparatus

The user can select criteria from a similar list or from a larger one considered best fitted to his particular case and can start the comparative evaluation. Comparison should be made within criteria selected from the same group for not altering the affordability of criteria. Comparative evaluation involves use of a comparison matrix in which methods are compared each other (Table 7).

Comparison should consider notes or points in a more or less large scale (for instance 0 and 1 or 1 like in previous example from Table 7 or using 1, 2, 3, 4 or 1, 3, 5, 7, 9 marks).

Two matrix considering general and specific criteria properly differentiate the methods so that finally each method obtain a setting value as a weighting factor which could guide the analyst in his decision for use or not use certain method.

Table 7 Matrix used for comparative evaluation.

	A	**B**	**C**	**D**	**E**	**F**	**G**	
A	1	1	0	1	0	1	0	
B	0	1	0	1	0	0	1	
C	1	1	1	0	0	0	1	
D	0	0	1	1	1	0	1	
E	1	1	1	0	1	0	1	
F	0	1	1	1	1	1	0	
G	1	0	0	0	0	1	1	
Σ	4	5	4	4	3	3	5	28
%	15	17	15	15	11	10	17	100

In the example matrix a possible situation could be revealed, the equivalence of the setting value for more or less of proposed method. In such a case suggestion is to continue the comparative evaluation procedure using a larger scale.

3 Conclusions

Despite the large number of methods already existent in the field of engineering design, because of their limited and often dedicated application the concern for introducing and developing new other is very actual.

There are not universal methods and limitation for some method could be either objective or subjective. That is why some concepts, particularly in CE, have proposed the connected use of methods in order to complete each other.

For an improved perception and utilisation of such a diversity of methods a comparative evaluation should be used. The proposed procedure is a mixture of qualitative and quantitative evaluation that could be used as a starting guide in the primary stage of the approach of a practical situation.

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