The New role of Industrial Engineering in a Flat World

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Many industrial areas as well as management paradigms have been changed in the last recent 30 years. Mass customisation, global value stream networks, accelerated innovation and product development cycles, new business models, new competitive factors. What are the influences of this development on the traditional discipline Industrial Engineering? What are the new requirements on Industrial Engineers in a flat world? Where are the new challenges and paradigms for Industrial Engineering?

The traditional definition of Industrial Engineering says: „Industrial engineers design and improve work systems. These systems include people, equipment, materials, information, energy, and money.

Industrial engineers traditionally focus on process improvement, production planning and control, operations research and simulation, statistics and quality control, facility layout and project management and systems engineering.

Industrial Engineering has been developed in the 20th. century in USA, Europe and Japan with some regional differences (Fig.1.). The globalisation wave in the last decades also influences this discipline. The American, European and Japanese schools of Industrial Engineering are integrated, there are also many interesting impulses for IE - e.g. new methods and tools (Lean Product Development, Systematic Innovations, WOIS, Blue Ocean Strategy, Customer Value Creation), technologies (digital factory, internet, GPS, RFID, new manufacturing technologies) as well as new application areas of industrial engineering (services, office and administration processes, logistical networks, product development processes).

	USA	**Europe**	**Japan**
Focus of Industrial Engineering	Systems Optimisation, Statistical Process Control, Simulation, Bottleneck Management, Project Management	Complex process optimisation, CIM, CAD/CAM, Flexible Automation, Systems Engineering, Digital Factory	Waste Elimination, Simplification, Visualisation, Low Cost Automation, Common Sense, Lean, TPS, Kaizen
Typical Role of Industrial Engineer	Systems Integrator, Optimiser	Production Process Optimisation	Lean Manager
Who are the Industrial Engineers?	Industrial Engineering Department, Operation Management	Department of Work and Process Organisation, Production Planning Department	Hancho – Supervisor on Shop Floor, Every Employee from CEO to the Worker on the Line has some IE Skills
Typical Concepts and Methods in Industrial Engineering	Operation Research, Simulation, Six Sigma, TOC	Work Measurement, Capacity Calculation, Layout Planning, Process Management	Lean Thinking
Leading Influence	Institute of Industrial Engineers, Maynard´s, Lean Institute, Goldratt Institute	REFA, MTM, Fraunhofer	Toyota, Nissan, Omron

Fig. 1. Development of Industrial Engineering in Different Countries

	Yesterday	Tomorrow
Corporate strategy focus	Productivity	Innovation
Corporate processes	Standardisation	Improvement
Change management focus	Best practices, benchmarking, increase customer value	New Practices – Blue Ocean, create new or different customer value
Employees	Focus on the “empolyee´s muscles” (peformance – physical intelligence) and brains (kaizen – mental intelligence)	Focus on the employee´s heart (self motivation, emotional intelligence) and soul (moral and ethics – soul intelligence)
Competitive factors	Hardware, software	Brainware, co-ware
Corporate culture	No mistake and error culture	Culture of trials and experiments
Intercorporate relationships	Competition, fight	Co-operation, partnership
Management philosophy	Trade Off Thinking - High Quality **OR** Low Cost, Affordable **OR** Customized	Breakthrough Thinking, High Quality **AND** Low Cost, Affordable **AND** Customized
Management focus	Quality, Productivity, Flexibility	Innovation and Knowledge Management
Improvement concepts	Lean Manufacturing, Six Sigma, TOC	Systematic Innovation, Lean Product Development
Innovation focus	Product and Process innovation	Business and Thinking Innovation
Management principles	Management by objectives, process and project management	Management by opportunities, company as a living organism

Fig. 2. New paradigms influencing further development of industrial engineering

Mass customisation, individualisation, global competition, fast overcoming of traditional rules and standards cause that many change processes are running in companies world wide under the slogan “give your customer what he wants – but faster than your competitors”. The essential question is – what does the customer really want? What is customer value?

There are three fundamental concepts in industrial engineering focused on customer value:

1. Lean Management
2. Theory of Constraints
3. Six Sigma (Fig.3.)

Over the last decade, many companies have tried to copy Toyota‘s principles. They are applying methods for waste elimination from production and business processes, they compare benchmark indicators like value added index or working hours per product. But the essence of Toyota’s excellence is not captured in the „common sense“ methods like 5S, Kanban, value stream management or manufacturing cells. Toyota has been developing this system consistently for over 50 years. Toyota has developed a system of knowledge which creates reusable knowledge, maintains it, and leverages its use in the future. Nobody from Toyota employees wrote a handbook of Toyota Production System, this is a business of other management gurus. The values and principles of the Toyota Production System are developed in the minds and daily jobs of all the employees. All the knowledge gained throughout the design or production process, what works and what doesn't work, could be captured and consistently applied for all future projects**.** Toyota doesn´t call its system "lean" , but it is lean, Toyota doesn´t speak about knowledge management, but it does it!

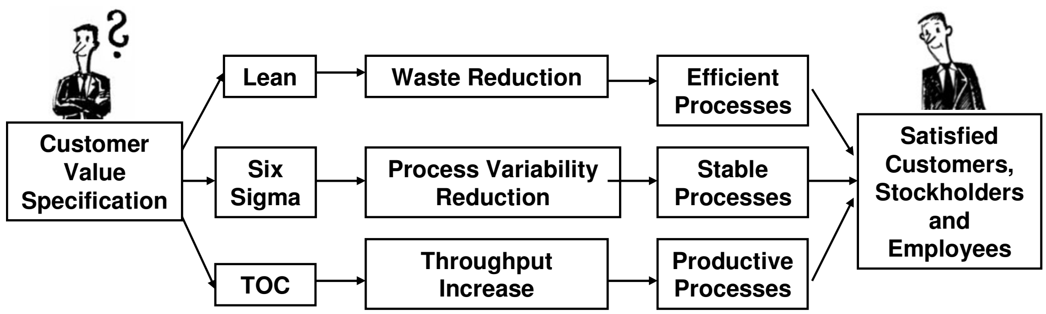


Fig. 3. The main business concepts – Lean Six Sigma and TOC

The lean concept originated in Toyota is oriented on waste identification and elimination from the whole process chain (Value Stream Management). In other words – lean focus is maximisation of added value in all the production, logistical, administrative and development processes. TOC (Theory of Constraints) is based on the identification and elimination of the system´s constraints with the goal ongoing throughput improvement. The throughput is defined as the rate at which the organisation generates money through sales. In other words throughput is the added value in the process chain per time unit. The Six sigma philosophy specifies the value in the eyes of the customer (voice of the customer) and identifies and eliminates variation from the value stream. Six Sigma, Lean and TOC continuously improve knowledge in pursuit of perfection and involve and empower the employees. The main problem of these most important business concepts is that they have tools to give to the customer exactly what he wants (without waste and quickly), but they don´t have the systematic approach how to create a new value for him.

Many companies are oriented on low cost strategies. But some cost attack programmes or transfering production facilities to the low cost countries showed that it is not the right and strategic solution. In recent years many West European and US manufacturing firms have moved their production plants to the low cost countries. Over time, they recognised that they had lost some competitive advantages because some departments were physically separated (e.g. product design and development, production engineering , production, logistics) and the communication and co-operation between them was limited. Also many cultural differences reduced the effects of the low cost location. Not even massive implementation of lean management, Six Sigma or other world class concepts bring sometimes any radical improvement. Company success is not only in the optimisation of current processes (doing right things right) but first of all in innovation (looking for new – but as fast as possible). The productivity world will be replaced by the world of creativity, the world of perfect planning will be replaced by the world of experiments and generating new ideas and opportunities. Not perfect planning of the change but fast realisation of the change is the way towards success.

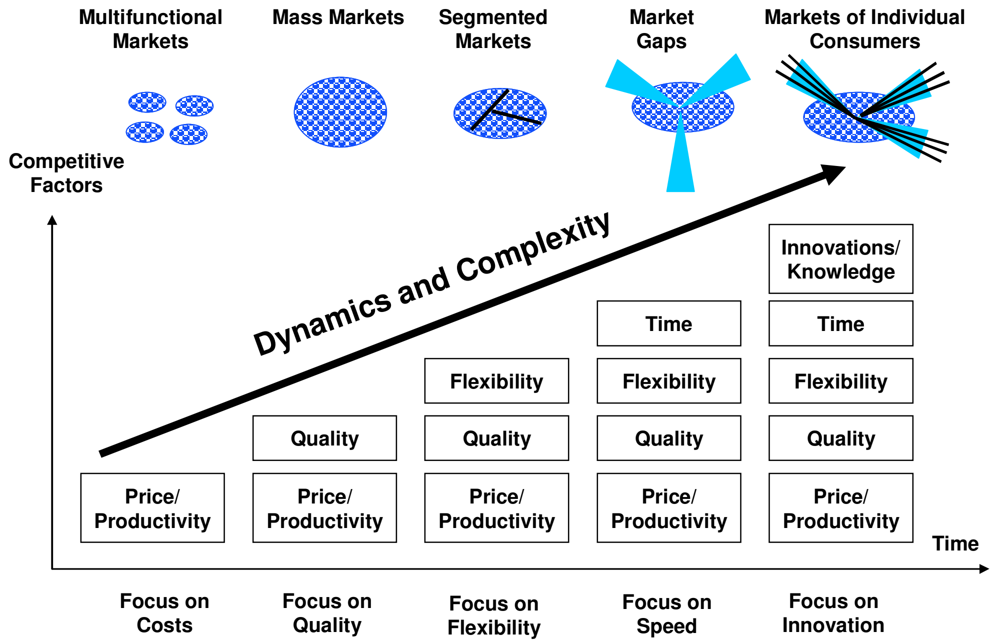


Fig. 4. Development of competitive factors in the recent 30 years

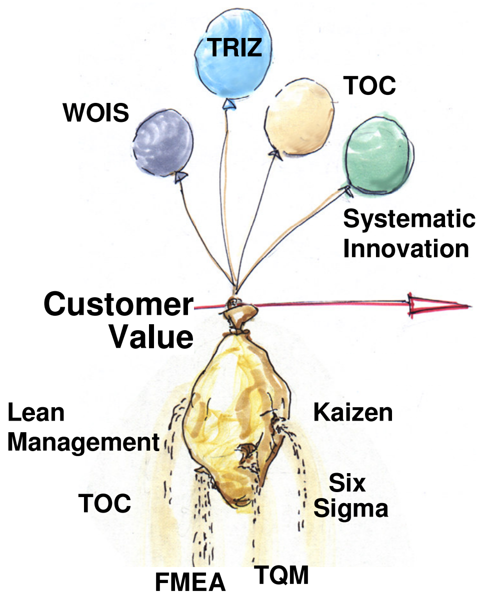
M. Zeleny defines innovation as the change in the hardware, software, brainware or support network of a product, system or process that *increases the value for the user or customer*. From this definition it should become clear that not every *invention* (a discontinuous, qualitative change) is an innovation, and so not every *improvement* (a continuous, quantitative change) is an innovation. Innovation adds value – claims Zeleny.

Customer value distinguishes the innovation from the simple change. But the innovation is not to be only a breakthrough technical solution. Generation of technical changes on the product or technological advantage in the production process have not necessarily led to success. Many companies have a perfect product, produced by an excellent technology. They have the only limitation – the customers don´t buy them, because they don´t see any reason to buy them. They did not find the customer value. Innovation must generate "something new" for the customer life – simplicity , risk elimination, convenience, better price, fun, image and emotions, style or environmental friendliness.

The new customer value can be generated by

- New value
- Different Value
- Higher Value

All systems contain contradictions - something gets worse as something gets better (e.g. strength versus weight). The traditional approach usually accepts a compromise or a trade-off, but this is often not necessary. Powerful, breakthrough solutions are the ones that don't accept the trade-offs. Such solutions are actively focused on contradictions and they are looking for ways of eliminating the compromise.



$$\frac{\text{Customer Benefits (Useful Functions)}}{\text{Costs + Harmful Functions}}$$

Customer Benefits↑ (Higher)	**Costs (Constant)**
Customer Benefits (Constant)	**Costs ↓(Lower)**
Customer Benefits ↑(Higher)	**Costs ↓(Lower)**
Customer Benefits ↑ ↑ (2 x Lower)	**Costs ↑(Higher)**
Customer Benefits ↓ (Lower)	**Costs ↓ ↓ (2x Lower)**

Fig.5.: Customer Value Improvement

The WOIS approach developed by H.Linde has been successfully used in breakthrough product, process and business innovations in many companies:

The main elements of the WOIS innovation methodology are:

1. Definition of the strategic orientation
2. Definition of contradictions. Answers to the questions -What and Why?
3. Solution of contradiction (46 innovation principles, technical and physical contradiction, solution maps, laws of evolution, bionics). Answers on the questions – How?
4. Concurrent innovations in product, processes, organisation, resources and marketing.
5. Implementation and evaluation

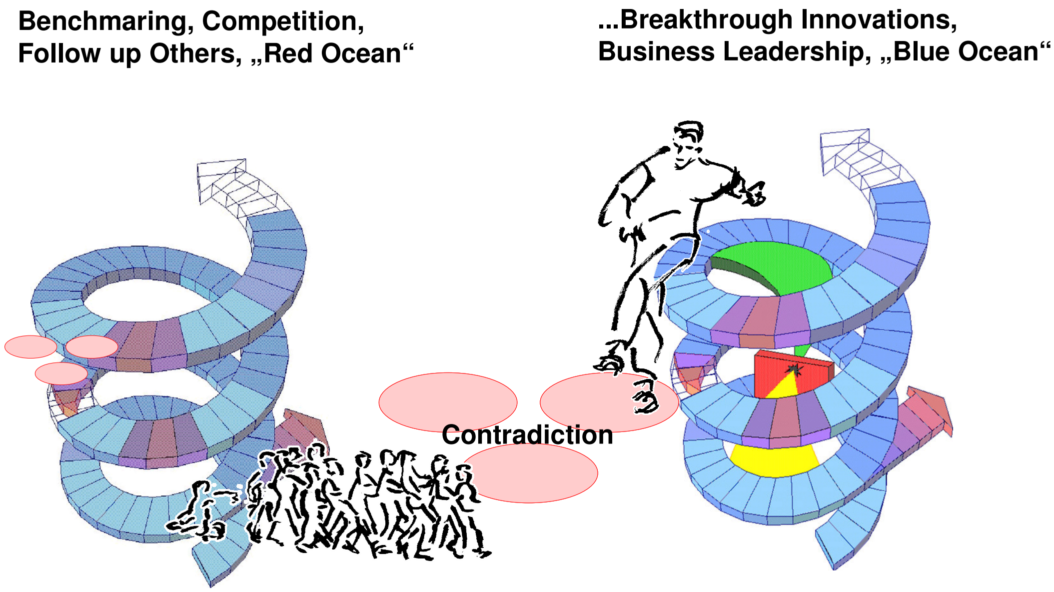


Fig.6.: Overcoming tradeoffs through contradictions (Linde)

The basic conditions and principles of successful innovation using WOIS are:

- The innovation project starts with deep analyses - market analysis, product trends, analysis of technological trends, process analysis, analysis of production and assembly trends, trends in sales and service systems, analysis of the product as a system and its environment, analysis of system functions, analysis of existing solutions (patents, competitive solutions, solutions of other areas, generation of solution maps, benchmarking), analysis of system generations and evolution.
- Integrated, team based design and development process – marketing concept, product and process are designed by the same multifunctional team (marketing, design, process planning, production, logistics, controlling, customer).
- Use of the knowledge of the system evolution and system generations – strong orientation on the past and future development trends. Not only new products or processes are created, but also the knowledge and strong learning effect is generated through the innovation process.
- Culture of creativity, acceptance of failures, space for experiments, prototypes, testing new ideas.

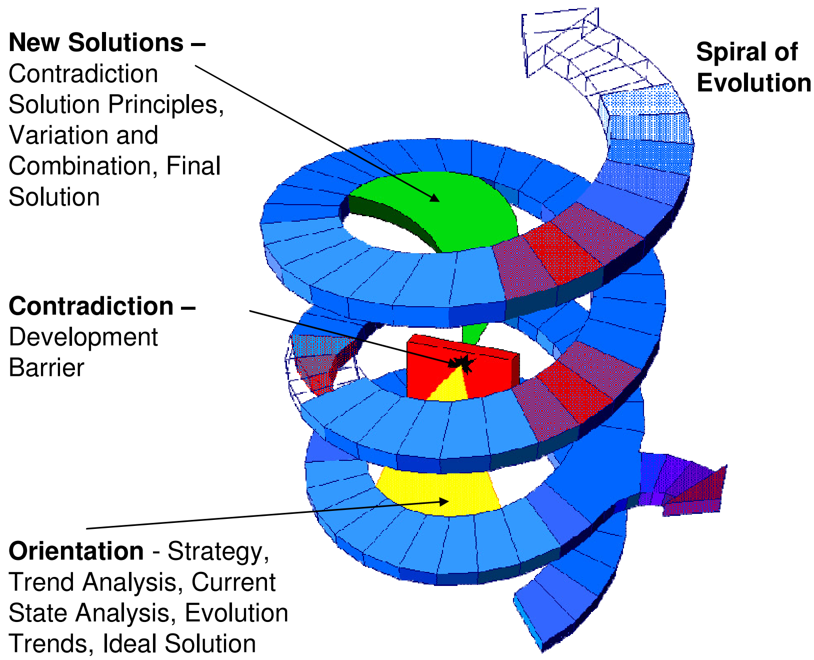


Fig.7.: Contradiction based innovation strategy WOIS (Linde)

Example

Project: Innovation of hospital bed

Project duration: 6 month

Project team: designer, production engineer, external consultant, logistic expert, process engineer, service, marketing, customer

Project inputs: Target price, target markets, product life cycle, production volume

Project goals: New product with higher customer value (new functions, better parameters, lower costs)

Project steps: Fig.8.

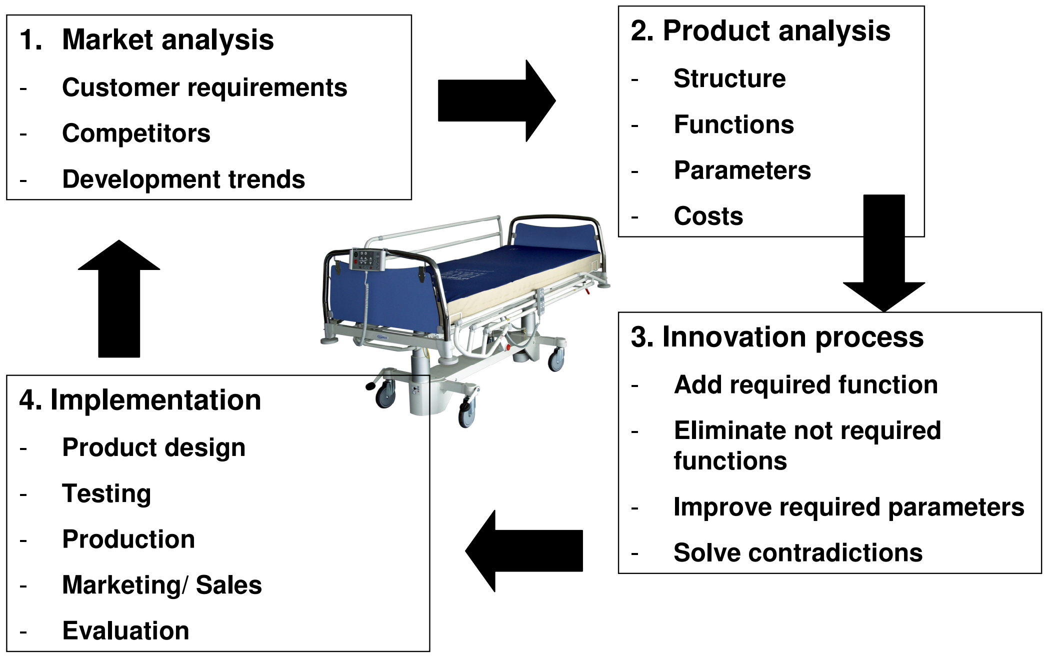


Fig.8. Innovation project – hospital bed

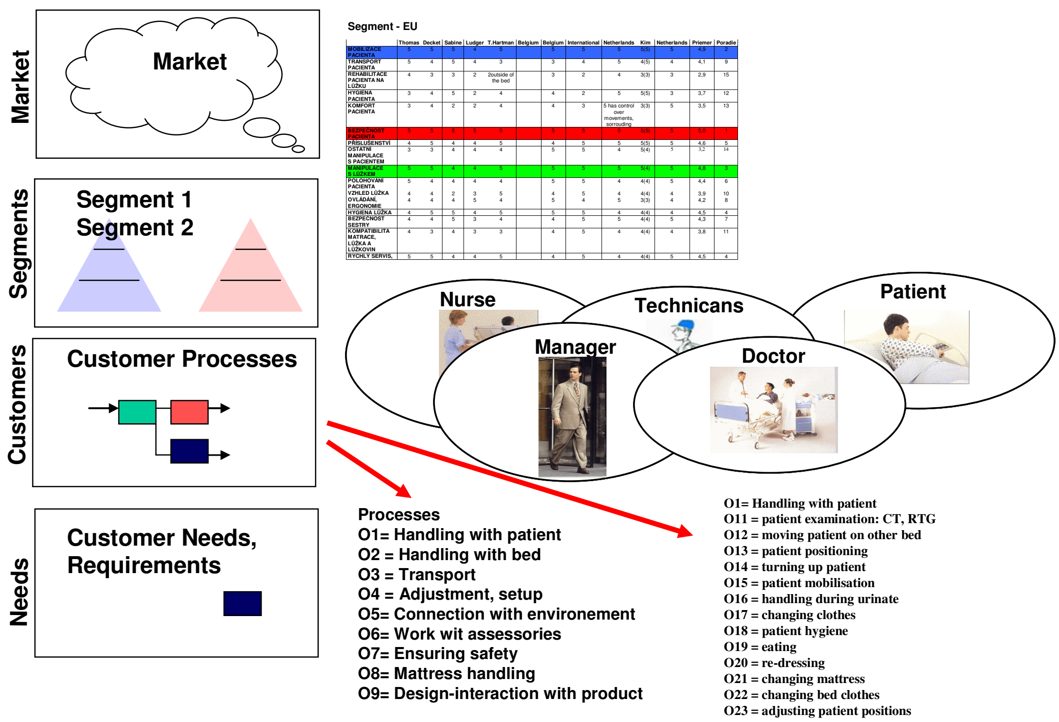


Fig.9. Market and customer analyses

Different market and market segments were analysed, five important customer groups and their requirements were identified (inteviews, analyses and observations in the hospitals) – Fig. 9..

From the customer requirements the design contradictions were defined and the evolution trends and new solution alternatives were generated (Fig. 10, Fig.11., Fig. 2).

Odstraněno: 1

	x1 = Number of componentes	x2= Number of drives	x 3= Number of wheels	x4 = Number of mobilisation elements	x5 = Weight	x6 = Numnber of varialble parts								
Y ↑ = Mobilisation=f(...)				↑										
Y ↑ = Safety=f(...)														
Y ↑ = Handling with bed=f(...)	↑	↑												
Y ↑ = Hygiene =f(...)														
Y ↑ = Assessories														
Y ↑ = Costs	↓	↓		↓		↓								
Y ↑ = Stiffness					↑									
Y ↑ =Handling comfort					↓									
Y ↑ =Variability						↑								

Fig.10. Design Contradiction Matrix

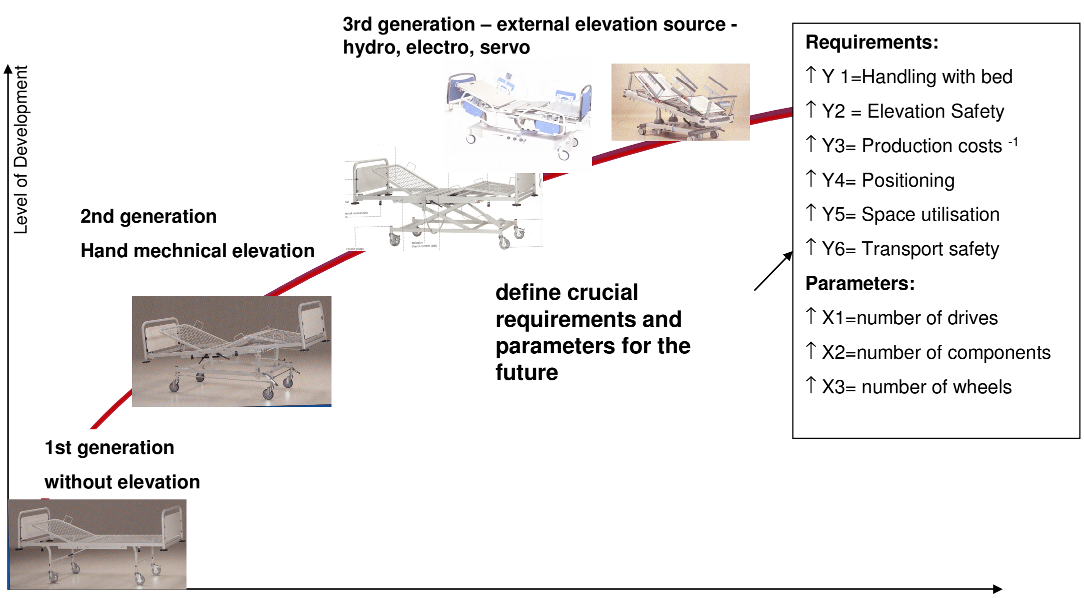


Fig.11. Evolution trend analysis

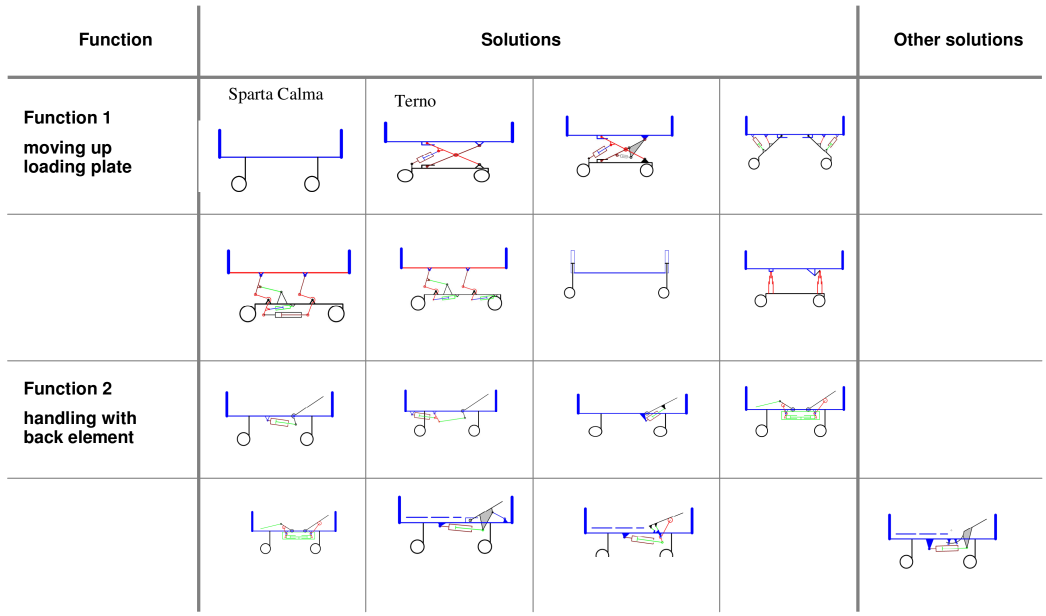


Fig.12. Solution concepts

Project results

Product sale increase:	+20%
Number of parts:	-15%
Production costs:	-30%
Production time reduction:	-40%
New functions	+10%

The difference between an excellent and a good company is not in the machines, the software or the organisational structure. The difference is in the co-ware – co-operation, creation and dissemination of knowledge through the company.

Now, we could summarise the answer on the basic question of this paper: What is the new role of industrial engineering in a flat world?

1. The industrial engineer will still focus on value stream improvement, but not only in manufacturing. Administrative, product development, customer service and logistical processes offer huge improvement potential.
2. Integration of traditional concepts for process improvement like Lean, Six Sigma and TOC. These concepts for waste elimination, reduction of process variation and throughput increase will be combined with concepts for customer value creation.
3. Today, the typical job position of industrial engineers is in the production and logistics departments. In the future, the industrial engineers will penetrate into the departments

for product and process development and innovation management, where the higher opportunities to reduce costs, eliminate waste and improve quality rather than production are.

4. Industrial engineers have to increase their orientation on the people. Not only in the traditional sense – ergonomics, but also in the areas of emotional intelligence, co-operation, knowledge management, coaching, training, leadership, communication, etc. The companies should be able to solve the following important questions regarding knowledge management: How to reach and keep the best talents and individuals? How to share, communicate and develop the best corporate practices in the organisation? How to transfer knowledge between employees on the projects and actions in the company? How to increase and measure knowledge? How to change knowledge into innovation as fast as possible?
5. Design and development of teamwork in the entire company – this is the crucial competence of industrial engineers for the future. Not only the classical autonomous teams in production or logistics oriented on performance and productivity, but also the creative teams of strong individuals, focused on innovations ability, will be important. The other important task is build multi-cultural teams in the global production networks.
6. Work analysis and measurement is the traditional competence of industrial engineers. New opportunities of this discipline are in logistics, distribution, office and product and process development.
7. Industrial engineers will penetrate from production departments to other company areas. There are many new application fields for traditional IE methods – e.g. 5S in information systems, simulation and value stream management of supply chain networks, simplification and streamlining of management processes – waste in meetings, reporting, etc.

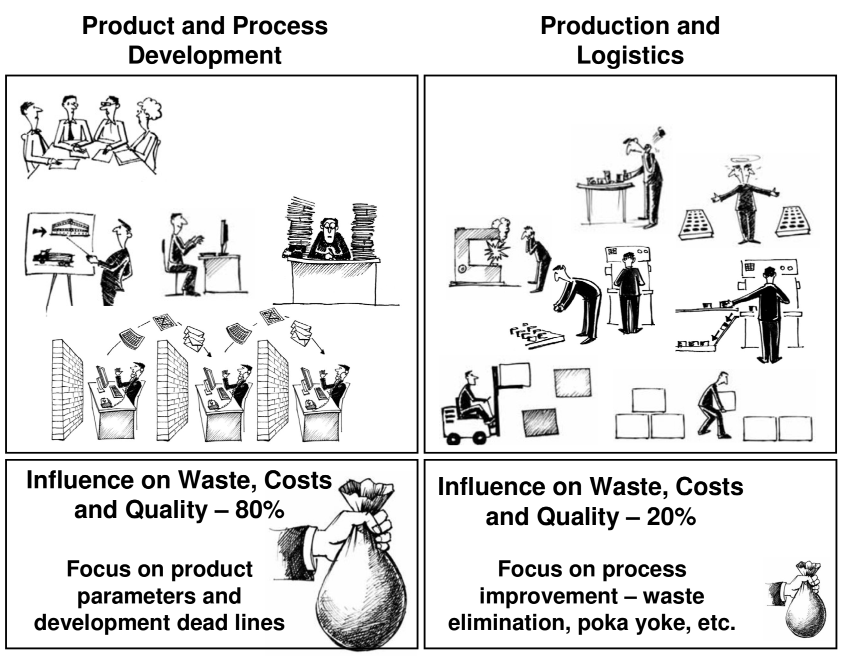


Fig.13.: Traditional isolation of product and process development and production – where is the right place for an industrial engineer?

Solution map in customer value creation

A. Product/Service Innovation

Step	Description	Methods
1. Customer definition	Defining market segments and customer groups	Market analysis, Ideal Final Solution (IFR), S Curve Analysis, Function and Attribute Analysis, Problem Evaluation, TOC – Thinking Process, Kano Model, Customer Requirement Analysis
2. Customer requirement definition	Defining real customer requirements on the product/service in each group	Physical or technical contradiction, constraint, conflict, missing function, excess function, opportunity analysis, risk minimisation, cost reduction, function optimisation, WOIS, Ideal Final Solution (IFR)
3. Trend analysis	Analysis of the trends on the market, analysis of the product/service evolution trends,	S curves, evolution trends, forecasts, fashion trends and lifestyles , new market needs, new research results and inventions, analysis of competitors, new technologies
4. Product analysis	Product/service analysis and comparison with ideal solution (maximisation of the useful functions / minimum costs and harmful functions)	Analysis of product evolution potential, product structure and component analysis, mind mapping, brainstorming
5. Function analysis	Analysis of useful and harmful functions on the product/ service	Functional analysis, constraints, conflicts, missing function, excess function, optimisation, risk minimisation, cost reduction
6. Parameter analysis	Analysis of parameters of useful and harmful functions on the product/ service	Morphological analysis, pair comparison, function and relationship modelling – sufield analysis
7. Analysis of costs for the functions	Cost analysis for creation or improvement of useful functions and elimination of harmful functions	Cost analysis, value analysis
8. Definition of contradictions	Defining basic contradictions, their overcoming will create new, higher or different customer value	Contradiction matrix, physical or technical contradictions, TOC conflict cloud, brainstorming, current reality tree
9. Solution of contradictions and generating innovative solutions	Solution of contradiction, design of new solution	Inventive solution principles for technical or physical contradictions, sufield analysis, evolution principles, resource analysis, DIVA,

		knowledge and principle database, ARIZ, brainstorming, lateral thinking, Osborn list, Scamper, Synectics, bionics
10. Product and process development	Product and process development, testing and evaluation	LPPD – Lean product and process development, DFMA, DFx, Critical chain, Simultaneous engineering, technologies for product and process simulation, A3 reports
11. Start of production and market penetration	Start up production, logistics, distribution, marketing	Ramp up, simulation, project management, A3 reports

$$\textbf{Customer Value} = \frac{\textbf{Useful functions, Customer Benefits}}{\textbf{Costs + Harmful Functions}}$$

B. Process improvement

B1. Waste elimination, cost reduction (Lean)

Step	**Description**	**Methods**
1. Current state analysis	Value stream analysis, waste and its roots identification	Value stream mapping, audit, observations, workshop, process modelling, current reality tree, evaporating cloud
2. Future state definition and transition process preparation	Future state definition, metrics and indicators, time line	Future state map, future reality tree, prerequisity tree, transition tree, hoshin kanri, A3 reports
3. Process improvement	Waste elimination from the processes	MOST, 5S, lean workplace, poka yoke, jidoka, visualisation, work standardisation, SMED, TPM, LCIA, process kaizen
4. Process integration	Waste elimination between the processes	Manufacturing cells, spine layout, kanban, autonomous manufacturing and service teams, flow kaizen
5. Process synchronisation	Synchronised flow, one piece flow of material and information	Heijunka, stop line, andon, internal and external milk run

B2. Reduction of process variability – quality, time, due dates (Six Sigma)

Step	**Description**	**Methods**
1. Core Problem Definition	Problem and the goal definition	CTQ, VOC, KNE, SIPOC, relationship matrix, PF diagram, cause and effect diagram, QFD

2. Measure	Process and its enviromnent measurement	IPO diagram, KNE, QFD, FTA, FMEA, cause and effect matrix, process maps, Pareto analysis, cause and effect matrix, opportunity diagram brainstorming, 5x Why
3. Analyse	Root cause analysis, analysis of the influence on the process output	7/7 quality tools, ANOVA, process capability, statistics, DoE, COPQ, FPY, 5W2H
4. Improve	Design and testing new solution	DoE, statistical analysis, correlation, regression, MSA, poka yoke, hypothesis testing, brainstorming,
5. Control	Implementation, standardisation, stabilisation	Process standardisation, escalation procedures, process monitoring, audits

B3. Throughput improvement (TOC)

Step	**Description**	**Methods**
1. Identify the system´s constraint	Indentification of the bottleneck which limits the system´s throughput	Value stream mapping, capacity analysis, simulation, workshop, production audit, process observations, current state tree
2. Decide how to exploit the system´s constraint	Buffer and work in front of the bottleneck	DBR, Kanban, Conwip, FIFO buffers, supermarkets
3. Subordinate everything else to the above decisions	Principle of the relay race – if you have work do it as fast as possible, if you don´t have work – wait	Buffer management, DBR, Kanban, Conwip
4. Elevate the system´s constraint	Increase of availability and capacity of the bottleneck	MOST, SMED, TPM, quality and scrap reduction in front of the bottleneck, reduction of process variability, alternative process plans
5. Go back to the step 1	Looking for a new bottleneck	

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