A Simultaneous Value Analysis of the Product and the Technology

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The past few years have seen an increase in the demand for sheet steel coated for purposes of environmental protection and also to protect the steel against corrosion. The reasons for this increase of demand are as follows: With the changes of the environment, there are more sources of corrosion attack, and the intensity of corrosion has also increased. Therefore, hot-dip galvanizing is used widely to protect steel products against corrosion. Galvanized steel products are used in almost every industry, but the highest quantities are used in two fields. One of them is the construction industry, where galvanized steel is used everywhere from building structures to eaves, gutters, joinings, assemblies and permanent shuttering. Formed sheet steel is used for light-steel solutions in the construction industry for the production of elements and cover. Due to its numerous advantages, it is used widely in the construction industry. Besides significant weight benefits, it is also easy to transport and assemble, and it is also characterized by a high resistance against corrosion. The other main area of the use of galvanized sheet steel is transport. Large quantities are used in modern car manufacturing globally. Railway carriages, bridges and the power line towers are also made from galvanized steel, and it is also an important material in shipbuilding and seaside constructions due to the highly corroding effect of sea climate. In order to ensure efficiency in development, our company's management found it necessary to use Value Analysis within the framework of a project. What lends special interest to the development is that after the value analysis of the product, the value analysis of the technology also became necessary. Our research has found that the ideal solution is a simultaneous value analysis of the product and the technology.

Value analysis of hot-dip galvanizing

The purposes of the project

Resulting from the fact that our products have to meet ever strictening requirements, and also from the fact that technologies are changing at an ever accelerating pace, the importance of a permanent analysis of technological processes has become highly important.

The purposes of the value analysis of hot-dip galvanizing are the following:

- to meet the requirements of users and producers
- to eliminate quality problems resulting from the production process
- to reduce the costs of the processes
- to reduce the use of material and energy
- to improve the utilization of capacity of the main production process and of the technology
- to improve efficiency
- to eliminate hard human physical labor
- to improve work safety, health protection and environmental protection.

The subject of the project

The subject of our value analysis is the process of hot-dip galvanizing. The hot-dip galvanizing of cold-rolled broad sheet by way of the Sendzimir technology takes place using state-of-the-art, automatic machines. As a result of the process, a high-value diffuse coating is formed on the steel surface. The process of hot-dip galvanizing involves the dipping of the properly cleaned sheet iron into zinc. While the steel is dipped into the zinc, due to the high temperature, the zinc diffuses into the surface of the base metal, alloys with it and forms a coating.

The technology has three main sections:

- entry section
- technological treatment
- exit section.

In the first section of the development, the value analysis of the product is necessary because it is the product that will be used directly by the user. The customer is the source of product requirement, while the source of technology requirement is the product. The steel strip, which is not yet heat-treated, is delivered into the coil conveyor by a hydraulic cart. Here, the coil end is unwound, and the material is taken to the straightener unit with the help of trundles. The straightener smoothens out any surface irregularity caused by the previous winding up of the coil so that the surface can be cut by the crop shears. The shears crop the unusable coil ends of the material, and they also remove the badly welded sutures. The cold-rolled strip is spliced on an automatic welding machine. During splicing, continuous galvanizing is ensured by a strip storage unit with a holding capacity of 160m. The storage unit is hung above a heat-treating furnace, and it is filled 100% during the process. The thermal preparation and tenderizing of the surface of the steel strip about to be galvanized is done in a 50-metre-long natural gas-operated furnace, which is also equipped with supplementary electronic heating. During the tenderizing heat treatment, all pollution is burned off the surface of the sheet (oil and fat products, oxides), as the required coating will only form on a clean metal surface. This is followed by the cooling of the material in a way which ensures that the 120 tons of zinc in the galvanizing kettle remains at the required galvanizing temperature even with the added heat coming from the metal strip.

After the entry section, the material is conveyed into the galvanizing kettle in the technological treatment section. The galvanizing kettle contains 120 tons of zinc, alloyed with aluminium and lead. The exact content of the kettle is: 99.6 – 99.8% Zn; 0.08 – 0.12 % Pb; 0.16 – 0.24% Al. while in the kettle, the zinc saturates the surface of the basic metal due to the high temperature (450-470 C°). The zinc is then alloyed with the metal and creates a coating on the surface. To ensure the required coating thickness, the unnecessary liquid zinc is blown back into the kettle with the help of special blowers. The sheet leaves the kettle at a temperature of 450-470 C°, and it is cooled down to 100-120 C° with the help of air fans after a trip of 30 metres. The sheet is further cooled under 60 C° in a water cooler tank. In order to remove any harmful metallurgic phenomena and to ensure the required flatness of the galvanized strip, the material is led through a skin pass mill, where it receives a permanent shape change of 0.8-0.15 %. Depending on climatic conditions, the surface of the galvanized metal may receive white rust during storage and transport. To prevent this, the sheet is chromatized in post-treatment. Another task of the exit technological section is to ensure continuous operation of the machinery even during the removal of the finished coil. The exit looper coils up the galvanized strip. When the required amount or diameter is coiled up on the exit looper, the crop shears cut the material. The welding sutures and test-piece is also cut off here. The coil is pushed by a hydraulic shield onto the transport vehicle, where the material is measured, packed and transported to be used or further processed.

Information Concerning the Technological Process

The phases and equipment of the cold-rolled strip galvanizing process are summarized in the following table:

Equipments of entry section	Equipment of technological treatment	Equipments of exit section
Equipments	**Equipments**	**Equipments**
Coil conveyor	Galvanizing kettle	Straightening machine
Straightener	Control equip. of zinc coating's thickness	Chromatizing kettle
Welding machine	Blower	Dryer
Heat-Traiting furnace	Measuring device of zinc coating's thickness	Exit looper
Downcoiler	Water cooler	Crop shears
Thickness measuring device	Skin pass mill	Coil conveyor
Entry looper		
Phases	**Phaeses**	**Phases**
P1 deliver to plant	P9 galvanizing	P13 straighten by stretching
P2 picking up	P10 regulation of zinc coating	P14 chromatizing
P3 unwinding	P11 cooling of strip	P15 cooling the strip
P4 straightening	P12 measuring of zinc coating	P16 looping/storage of strip
P5 croping of coilends		P17 croping of strip
P6 welding		P18 winding
P7 looping of strip		P19 packaging
P8 annealing		P20 storage
		P21 delivery

PRODUCT REQUIREMENT ANALYSIS

For the value analysis of the technological process it is important to identify the product requirements as well, and to analyze the process in consideration of these requirements.

User requirements regarding hot-dip sheet iron:

I_1 Usability in construction industry
I_2 Excellent processing properties
I_3 Excellent formability
I_4 Homogeneous zinc coating
I_5 Optimal layer thickness
I_6 Excellent layer without surface defects and cracks
I_7 High degree of corrosion protection
I_8 Excellent temperature resistance
I_9 High ageing resistance
I_{10} Cathode protection against corrosion
I_{11} Good cohesive behavior of zinc coating
I_{12} Aesthetic surface

PRODUCT FUNCTION ANALYSIS

The functions of the product are defined based on consumer / user requirements.

Product functions (hot-dip galvanized sheet steel) are to:

F_0 Allow additional processes
F_1 Ensure formability
- F_{11} Ensure dimensional accuracy
- F_{12} Meet the elasticity requirements

F_2 Allow mechanical processes
- F_{21} Ensure dimensional accuracy
- F_{22} Meet the elasticity requirements

F_3 Ensure applying further coatings
- F_{31} Ensure homogeneous surface
- F_{32} Ensure adhesion

F_4 Allow additional assembly
F_5 Meet durability requirements
- F_{51} Resist against mechanical attack
- F_{52} Resist against corrosion attack
  - F_{521} Resist against atmospheric attack
  - F_{522} Resist against other corrosion attack

F_6 Meet the medical regulations
- F_{61} Resist against micro-organism
- F_{62} Allow cleaning

F_7 Meet aesthetical requirements

The second phase of the analysis is that of technology requirements. What and how the technology has to do to meet the product requirements fully.

The technology has to meet the following requirements:

I_1 To produce protective coating
I_2 Clean the strip
I_3 Ensure the cohesion of coating
I_4 Continuous galvanizing of strip
I_5 Continuous adjustment of process
I_6 The maintenance of plant can be calculated
I_7 Continuous quality-control
I_8 Protect the environment

I_9 Eliminate of harmful metallurgical effects
I_{10} Prevent white rust forming
I_{11} Ensure the correct bath composition and temperature
I_{12} Make the product ready for distribution
I_{13} Easy operation
The functions of the technology are to:
F_0 Produce protective coating
F_1 Ensure material
F_{11} Transport the material
F_{12} Pick up the material
F_{13} Make endless strip
F_2 Pretreat the surface
F_{21} Clean the surface
F_{22} Ensure the adhesion
F_3 Apply the coating material
F_{31} Ensure the coating material
F_{32} Ensure the correct temperature
F_{33} Ensure the layer application
F_4 Post-treat the surface
F_{41} Improve the mechanical properties
F_{42} Prevent white rust forming
F_{43} Cool the strip
F_5 Make product ready for distribution
F_{51} Ensure quantity
F_{52} Protect from damage
F_{53} Allow the identification
F_{54} Allow the delivery
F_6 Regulate the process
F_{61} Indicate defects
F_{62} Eliminate defects
F_7 Allow correction
F_{71} Control quality
F_{72} Allow continuity
F_8 Coordination
F_{81} Handling of material and product
F_{82} Protect the environment
F_{83} Allow switching
F_9 Ensure maintenance

For an easier overview and assessment of functions, we have prepared a function-parameter-equipment matrix, with parameters and equipment assigned to the functions (Figure 1.). The definition of the function parameters also helps define and install most adequate machinery. Figure 2. contains FAST Diagram of hot-dip galvanized steel.

Figure 1. Function-parameter-equipment matrix. Source: Authors' edition

Function	*Parameters*	*Value*	*Equipment*
F11 to transport material	coilweight outside diameter of coil inside diameter of coil line speed	max 15 mt 800 - 1650 mm 500 or 610 mm max 8 m/min	coil conveyor
F12 pick up the material	coilweight outside diameter of coil inside diameter of coil	max 15 t 800 - 1650 mm 500 or 610 mm	coil conveyor downcoiler
F13 to make endless strip	frequency current intensity / amperage	acc. to parameters of coils	end scrapping welding machine
F21 to clean the surface	line speed furnace tempreture tempreture of strip heat treated	30 m/min nominal 750 C^o 430 - 480 C^o	heat treating furnace
F22 to ensure the cohesion	line speed protective gas composition protective gas pressure	30 m/min 85% N_2 15% H_2 200 - 300 mbar	heat treating furnace
F31 to ensure the coatingmaterial	bath composition	Zn 99,6 - 99,8% Pb 0,08 - 0,12% Al 0,16 - 0,24%	galvanizing kettle
F33 to ensure the layerapplying	layerthickness air tempreture coatingmaterial consumption	acc. to standaard 40 - 70 C^o acc. to standaard	control equip. of zinc coating's thickness
F41 to improve the mechanical properties	tensil force permanent deformation	max 6820 N 0,8 - 1,5 %	straightening machine
F42 to hinder the white rust forming	tempreture concentration of bath	50 C^o 35%	thermostat chromatizing kettle
F43 to cool the strip	dryer capacity tempreture	8400 m^3 / hour 100 - 120 C^o 60 C^o	dryer water cooler
F51 to ensure the quantity	coilweight	max 10 t	coiler
F71 to control the quality	coatingthickness measurement range adhesion	100 - 350 g/m^2 0 - 400 g/m^2	layerthickness measuring device with isotope
F72 to allow the continuity	looper capacity	max 160 m max 72 m	entry looper exit looper
F81 to make handling	line speed	6 - 34 m/min	roller

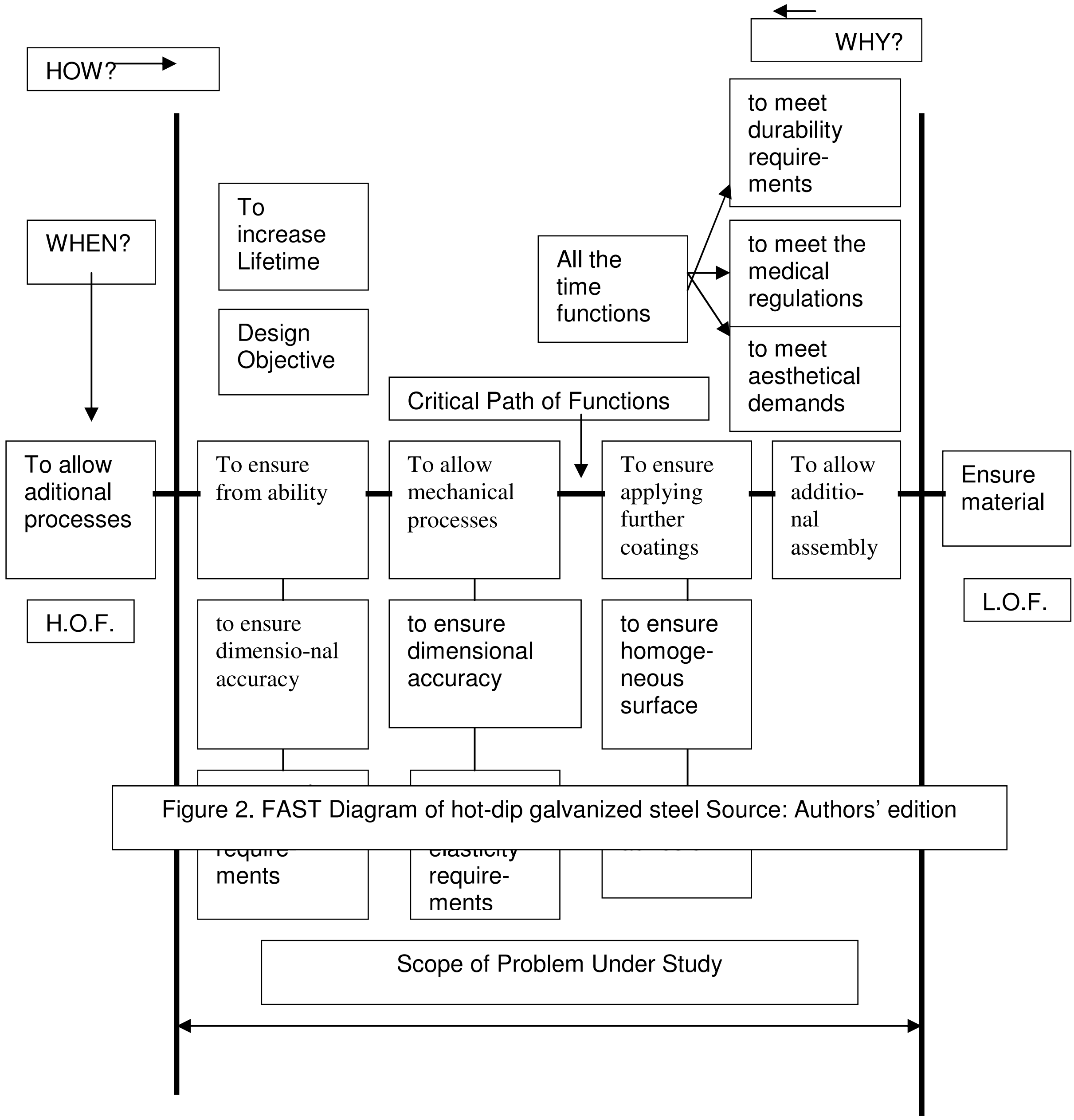

Figure 2. FAST Diagram of hot-dip galvanized steel Source: Authors' edition

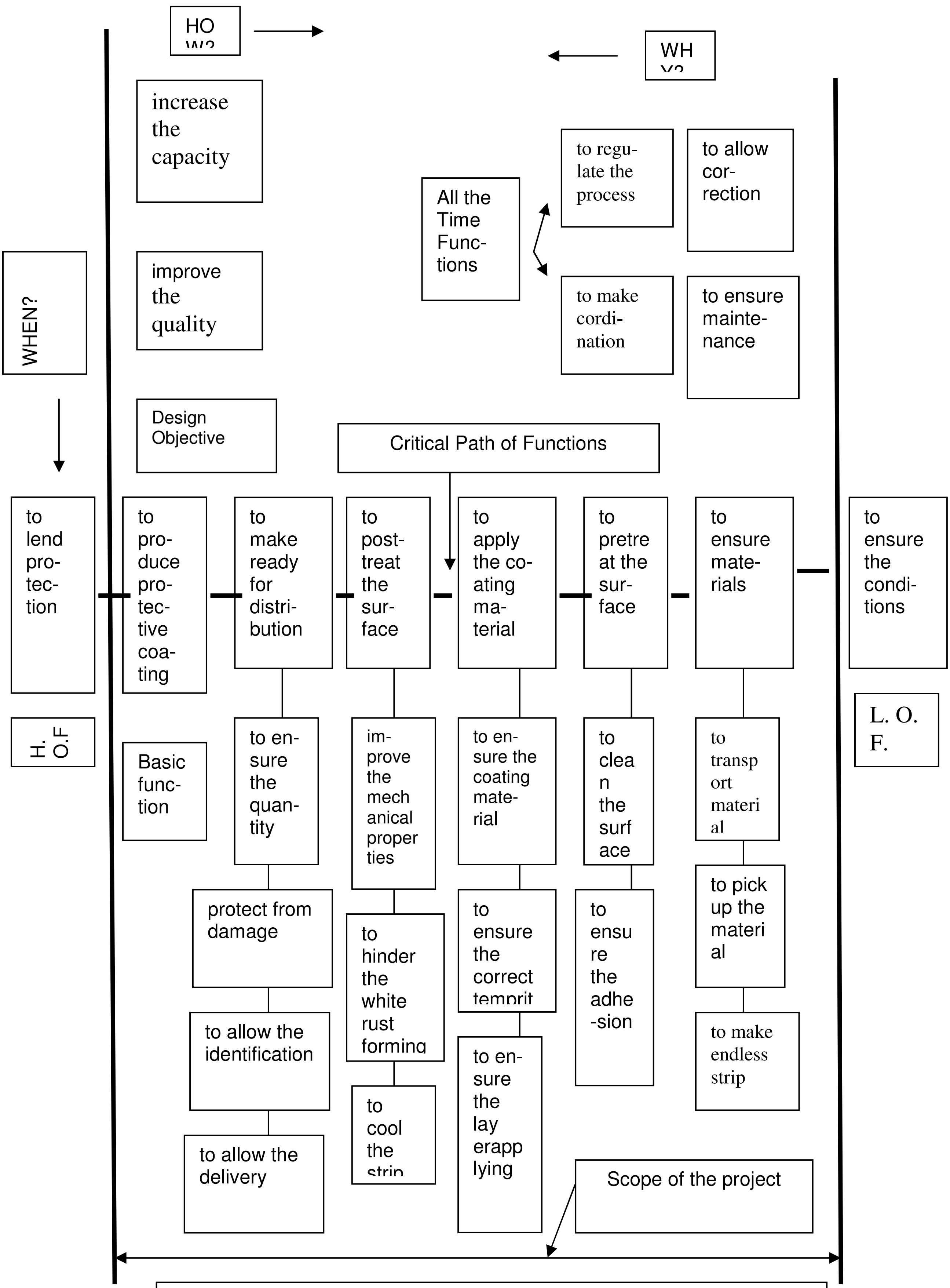

Figure 3. Fast Diagram of the Technolgy Source: Authors' edition

Proposed technology innovations (examples)

To increase the cooler capacity of the heat treating furnace, to control function F2 " to pretreat the surface". This would be necessary because otherwise the excess heat of the sheet may overheat the heat treating furnace and the 450 C^{o} exit temperature cannot be kept, and low cooling intensity may reduce the production line's capacity. The cooling capacity can be increased in the following ways: increase the number of cooling cartridges. However, for this, the structure of the furnace needs to be changed, which is costly.

The next possibility is to increase the capacity of the cooling fan, not only by increasing its rotation and pressure but also by providing a larger quantity of cooling air. The cheapest solution is to increase the cooling surface. A possible method to do that is to weld longitudinal cooling flanges on the existing cooling cartridges.

Results

Function analysis and the assessment of function costs have made it possible for the team to identify the points of intervention that the proposed innovations target. Although in our case, we used the value analysis for the development of an existing product, the results can definitely be regarded as innovations. According to experts', these potential innovations could not have been identified without value analysis. We can conclude that function and cost analysis, and team work almost inevitably leads to the launch of the innovation process (Kaufman et al., 2006).

Summary

For many decades, value analysis used to focus on cost reduction. However, Hungarian and international experts have called attention to the fact that value analysis has become one of the most effective tools of the innovation process (Bytheway & Charles, 2007; Iványi et al., 2002; Sato et al., 2005).

Marketing research has directed attention to the fact that the fast technological changes "eliminate" from the market the machines and equipment that are still in a good technical condition and were considered modern not long ago. For example, reducing the price of floppy disks would not boost sales because floppy drives are not installed in new computers anymore. In countries where value analysis is used widely (the USA, Japan, South Korea, etc) it is part of the innovation process already, which makes it possible to accelerate the product's market entry and to avoid unnecessary costs. Value analysis is not used widely in the Hungarian national economy. This deserves even harder criticism in light of the fact that the Society of Hungarian Value Analyst (SHVA) has been a member of SAVE International since 1996, and has contributed to the most recent achievements in value analysis. It is important to note here also that, with SHVA's support, value analysis is currently included in the curriculum of 11 institutions of higher education in Hungary. Students who meet the qualification criteria can obtain the first level of SAVE International's international certification (AVS: Associated Value Specialist).

The College of Dunaújváros is also among the educational institutions where is value analysis is taught as a subject. Our college has made it possible for hundreds of Hungarian and international (Ukrainian, Chinese, Turkish, etc) students to obtain the AVS certificate. Another important aspect of the present project is that we have turned it into a Case study, and we have used it successfully in the curricula of Hungarian and international students.

We hope that value analysis will become part of business practice soon, and will thus contribute to the recovery from the crisis.

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