The implementation of knowledge-intensive services in drawing out and bottling of natural mineral water

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As suggested by its title: "The Implementation of Knowledge-Intensive Services in Drawing Out and Bottling of Natural Mineral Water", the objective of the paper is seen in describing theoretical basis of implementing knowledge-intensive services in the environment of Slovak enterprises and, based on the example of a specific production company, to demonstrate the possibility of using such services when resolving partial practical issues as well. Specific features of the nowadays provided services: of non-material nature – services are not represented by commodities but by activities; a new trend of services providing – rendered services are often associated with products from other branches of industry; intertwining of a variety of both material and immaterial services being rendered; strong linkage of the service produced to a specific place and time of providing; non-warehousing of the service for future use; simultaneous service-producing and consuming – accommodation providing and restaurant operating services, possibly also relaxation, wellness, health resort and related services.

Key words*: Mineral water, Pareto diagram, Purpose-built model, Services, Innovation, Water Companies,*

Introduction

Service is a specific activity that can be offered by a party to another one in whichever market. On one hand, it does not produce any attainable ownership, and on the other one it is intangible. Besides the previously mentioned intangibility, the distinctiveness of service is also based on its evanescence, connectivity and variability. A more detailed definition of the service derives from a combination of the following aspects:

Integration of an external factor into the performance of the service; intangibility of performance; the need of synchronous contact between the customer and service provider; readiness to deliver the service; satisfying individual requirements on services.

Definitions of categories of services (Kováč, 2008):

- Services – S: Service is an activity that can be offered by a provider to the client on the market while it is intangible and does result in attainable possession.
- Business Services – BS: Services for companies present a sub-category of business-related services, i.e. services for enterprises, transportation services, communications, distribution, commerce or financial services.
- Knowledge Intensive Services KIS, or Knowledge Intensive Business Services – KIBS: by definition, KIBS present services for those businesses the added value creating activities stem in collecting, creating and disseminating knowledge with the aim to develop customer-oriented services or product solutions, and hence to satisfy needs of the customer.
- Technological Knowledge Intensive Business Services – T KIBS: These share the common feature of applying top-notch technologies when devising and performing the service.

Productivity itself is less intensely perceived with services provided than with products. Turnover, profit, costs, and hence the very business making principle refer to the possible risk of underestimation of production of services being rendered.

Existing, according to Bishop (2008), are specific ways of enhancing the productivity of services – as the production automation alternative. Presently, available are technical means also for the service basic constituents such as customer care and mutual communication with the customer; or support of provided services or parts thereof through a specific material product. Productivity of the service provided can be significantly enhanced by the introduction of computer-assisted control, enlargement of the know-how ration in various media, etc.; specific innovation of a service supported by implemented novel technology; traditional approach based measures to intensify the work, efforts to save consumed energies and pertinent materials, etc.

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The significance of services also follows from the knowing that services are there on each stage of creation of the company values and are fully integrated into the stage. Enhancement of rendering services for businesses subsequently influences also the migration of the industrial workers into the domain of service providing. Therefore, currently there are more and more companies that came to doing business in services – offering not only the basic customer service but also a kind of added value having the form of selling various specialized knowledge in the production field or in the process innovation or design solutions to other companies, thus to allow concerned companies to multiple their lines of business.

1. Identification and basic types of knowledge-intensive services

Services directly connected with preparation and productions of a business present the core of KIS and KIBS. KIS assist the client also in their social environment – let us mention e.g. specialised services in support of legal and accounting regulations or consultancy pertaining to standards and restrictions, controlling of structures, e.g. observance of environmental directives, health care and safety standards, and a raft of similar legislative issues. KIBS offer summarised basic information, specific advice and various mediation services and can also help in educating miscellaneous company employees. Some KIBS are more of less targeted to commerce, to defining and understanding relations with customers, with owners of various commodities in a range of markets, to market surveys, marketing and public relations as well.

Technological Knowledge Intensive Business Services – T KIBS – present a subgroup of KIBS, which can be characterised by significant utilisation of technologies at creating and providing services. Let us throw in several specific examples: supplier and subsequent consultation services in hardware and software systems; the most recent research and development in technical and natural sciences; data mining and data processing services; scientific research and experimental development of intricate materials and technologies; survey of new markets pertaining to high-tech technologies and products; technology testing and technical analyses; trainings covering the most recent technologies. One of the principal differences between KIBS and T KIBS is the structure of employees – in T KIBS, the structure comprises predominantly scientists, technical and technological experts and specialists, whilst in the KIBS structure present are lawyers, accountants, consulting managers and marketing specialists.

2. Roles and functions of KIBS in terms of innovations

The very services for specific innovations are also developing. A new technical discipline engaged in systematic development and subsequent creation of services using appropriate tools, methods and models came into existence, and even though development of these services does not also entail the service managing aspects, its principal focus is on developing new products in the field of services. In the innovation of services, new trends have emerged (European Innovation Action Plan, 2009): in general, increasing is the number of wealthy and very large companies focused on providing services, thus increasing the competition; globalisation proceeds throughout the world also through information system (IS) and information-communication technology (ICT) networks; extending is openness, increasing is the active labour force and hence off-shoring in services as well; emerging are economically strong Asian centres; the need of expansion of a variety of specialists to build up the knowledge-based economy is emerging too. Important stimuli for innovations in services: depending on closeness of customers, associates, on competencies and on the competitors, characteristic for services is the “innovation challenge”, as well as the need of narrow specialisation; depending on innovation of networks and on intensity of the ICT development, services are ensuring globalisation; typical for companies that are developing services are characteristics based on competencies, diversity and interdisciplinary nature of the employees. The directions of development of the service sector can be characterised by various classification elements. The changes are implemented due to the dynamic business environment and new customer needs, and this means that firms operating in the service sector are gaining knowledge and ideas for innovation through relationships with customers and suppliers. Very important factors affecting the very innovative activity of the service provider are, in addition to the actual provider, also its suppliers and customers. These entities can perform, as to the innovation activity, the function of the service provider and initiator of the innovation, supplier of innovative solutions, implementer, consumer, or a combination of these functions. When analysing services we build our assumptions on two principal classification criteria (Pazour, 2007):

1. *Position of service provider in the innovation process* –there are sectors having a dominant position in devising innovative solutions on one hand and, there is a branch of services that utilises innovative solutions devised in other sectors on the other hand.
2. *Way of stimulating implementing innovations by the service provider* – innovations are stimulated by demand on one hand, when customer is the driving force, and there are sectors of services where, from the point of stimulating innovation activities, the service provider vs. customer interaction is almost insignificant and stimuli for introducing innovations appear on the offer side of services.

3. The methods used when collecting and processing data

3.1 Failure Mode and Effects Analysis - FMEA

In question is a preventively acting method focused upon analysis and prevention of occurrence of faults and oriented to the requirements and satisfaction of the customer. Description and subsequent reduction of the number of faults of a product, part or technological procedure are investigated from the perspective of a would be customer or product user, and it allows to highly effectively manage quality all along the planning, developing, manufacturing and selling path. Making use of teamwork and of the systemic approach advantages, FMEA allows to identify early and subsequently eliminate already spotted faults, non-compliances and problems before these would become manifest at the customer. FMEA, as a highly flexible and always vital document, also allows securing feedback in the supplier–consumer relations. If this is the case, elimination of potential faults presents the stimulus for changing the direction, i.e. to innovate. FMEA is applicable wherever a rigorous analysis and subsequently introduced systemic measures can substantially influence, mitigate or eliminate determinable negative impacts. It regards the customer and/or the manufacturing process negatively influencing deficiencies (design FMEA and/or process FMEA). Negative impacts on the environment are analysed by the environmental FMEA. Failures occurring in the field of hygiene and safety of work are managed by the safety (or risk analysis) FMEA. This method is though utilised with considerable success also in the market economy, sales or in services. According to the expected field of use, the shape or form of the method can be appropriately adopted. In any case, a more or less subjective quantification of the fundamental factors affecting the genesis of errors, defects or non-conformities with the help of certain pre-specified criteria is involved. This way arrived at the quantitative assessment of usually negative phenomena allows to arrange them into a sequence or order further to a certain degree of significance that is, generally, attained by applying a mathematical formula. Thus it is then possible, from a specific point of view, to compare (otherwise incomparable) phenomena and to adopt measures to mitigate their effects on the subject of analysis. Upon introducing the corrective measures, it is again FMEA that would be used once again to analyse their effectiveness and to quantify the usefulness of activities performed.

In the coming clauses, we will focus on the FMEA methods that utilise three factors of the failure occurrence to determine the rate of risk, and subsequently their priorities as well. In the practice, one can encounter FMEA methods that employ one to six factors. A disadvantage of the FMEA method is that the structure and interconnections are disappearing among individual faults during the analyses. Failures are simply organised into a list and subsequently analysed. Hence, a danger arises that some possible significant failure will not be analysed whereas it will be simply forgotten when vanishing is some possible mutual continuity of analysed failures as well. The deficiency can be partially eliminated by applying structural methods such as e.g. the fault tree analysis (FTA) or through elaborating a system describing possible faults (system FMEA). Further on we will be dealing with the FMEA methods most frequently utilised in quality management. Even though in concern are methods that are foreordained to function as preventive methods on the stage of designing new systems, processes, products, i.e. when the design influences all phases of the product life cycles, they can be utilised also with problematic systems, processes, products when already existing deficiencies and faults are being eliminated.

3.2 Design of FMEA

It is a method aimed at the prevention of structural defects in the product. It examines any conceivable and possible failures of the entire system or parts of it based on systemic functions of the product being considered. Potential sources of faults may be structural, but also have the nature of the production. Following the actual status, subsequently adopted analyses are measures to ensure quality. Their implementation is coordinated and verified by an authorised officer. Constructional or design FMEA is resolving questions of the type: “How to design, draw, devise with the best results“, while the success criterion is the anticipated response of the customer. The FMEA form is illustrated in Tab. 1.

From filling out procedure **–** based on Tab. 1.

The procedure is as follows:

1. Defined are the product and a system of describing possible faults (e.g. according to integral parts or the functions). Identification and a possible connection with the related design FMEA are recorded in the upper part of the form, as indicated in the printed form.
2. In the specified order, the system components (integral parts, functions) are described in detail.
3. Any possible failures that can occur are written next to individual items.
4. The possible implication of the view of the customer is attached to each possible fault.
5. The cause responsible for the fault is defined for each possible fault (the cause must be clearly determined).
6. The significance “VZ“, which expresses the effect of the fault on the customer in points, is determined for each possible fault. (Tab. 2)
7. The probability of occurrence (“PV”) point-wise assessment is assigned to each possible fault. (Tab. 3)
8. By assigning the points, the probability of detection ("PO") of any possible faults before delivery to the customer (under the current circumstances) is determined. (Tab. 4)

9. The current mechanism of controls or the adopted measure (system) is assigned to each possible fault.
10. MR/P is calculated as the product of occurrence, significance and the possibility of exposing the fault.
11. Risk level / priority MR/P = V * PV * PO.
12. Crucially significant/fatal faults are determined according to the MR/P index.
13. Corrective or preventive measures and the officer responsible for their implementation are suggested for each significant fault.
14. Corrective and preventive measures are performed.
15. If the MR/P index fails to signal an acceptable status, repeat the steps starting with point 2.

Tab. 1. FMEA form.

COMPANY name and logo	**Failure mode and effects analysis** **Design FMEA (x)**	**Product name:** **FMEA of the process ( )**	**Product number:**
	Confirmed by the pertinent department:	**Model / system / series:**	**Revision number:**
	Process definition:	**Prepared by (name/Dept./date):**	**Revised by (name/Dept./date):**

Place / function operation	**No.**	**Failure mode**	**Failure effect**	**D**	**Failure cause**	**Current status**					**Recommended actions**	**Responsible**	**Improved status**				
						Current controls	**PV**	**VZ**	**PO**	**MR/P**			**Action taken**	**PV**	**VZ**	**PO**	**MR/P**

PV – failure occurrence probability, VZ – failure significance, PO – probability of failure detection, MR/P – risk level/priority *Page /*

Tab. 2. VZ weighted coefficients for design FMEA (DFMEA).

A: “VZ“ coefficient

	Significance of the failure mode for the customer	Assessment factor
Insignificant	It is improbable that the fault could result in a noticeable influence on the product or the system. The customer will possibly not even notice the fault.	1
Marginal	The fault is marginal, only marginally affecting the customer. The customer will be possibly become aware of the only marginal imperfection of the system.	2 - 3
Mild	Some customers will be unhappy with the fault. The customer is sure to notice the fault.	4 - 6
Large	The fault that is annoying to the customer. Neither safety nor legal regulations have been violated.	7 - 8
Critical	Extremely gross fault jeopardising the safety of the customer or that of his/her environment; or violated have been legal regulations.	9 - 10

Tab. 3. PV weighted coefficients for design FMEA (DFMEA).

B: “PV“ coefficient

	Probability of the failure mode occurrence	Frequency of faults	Assessment factor
Extremely Unlikely	Fault occurrence is extremely unlikely.	1 in 1 500 000	1
Remote	Expected can be only a scarce occurrence of faults.	1 in 20 000 1 in 10 000	2 3
Occasional	The fault may occasionally surface , though in minor extent only.	1 in 2 000 1 in 1 000 1 in 200	4 5 6
Reasonably Possible	Based on experience expected can be a frequent occurrence of faults, as such solutions were continuously resulting in problems in the past.	1 in 100 1 in 20	7 8
Frequent/ Critical	It is almost certain that faults will be occurring to a large extent.	1 in 10 1 in 2	9 10

Tab. 4. PO weighted coefficients for design FMEA (DFMEA).

C: “PO“ coefficient

	The probability that the weak constructional point will be revealed	Assessment factor
Sure - high	In question is a functional fault that will be sure revealed during the process of approval	1 - 2
Higher - unlikely	The fault will be highly probably revealed, and the product will never reach the customer. (e.g. 100% automatic inspection)	3 - 4
Medium - small	The fault effect is easy to be identified, and the approval process should reveal the fault.	5 - 6
Low - very small	Fault effects difficult to be identified by routine controls, and the approval process would hardly reveal the fault.	7 - 8
Improbable. - impossible	The fault does show any signs, or they are impossible to be revealed.	9 - 10

Process FMEA (PFMEA)

Works on all potential failures of the process of production, assembling, technologies, etc. Even though the process is the analysis subject, the most important feature of the discussed method is the impact of possible faults on the customer. By analogy, similarly as it was with the design FMEA, based on the actual current status the responsible and authorised officer coordinates and monitors measures and actions taken to ensure desired quality.

The process FMEA resolves issues such as: "How to, if possible without any faults, produce, implement, give effect to something, whilst it is a must to keep real-life conditions of the specific manufacturer on the mind.

From filling out procedure – based on Tab. 1.

The procedure is as follows:

Define the selected process by inputs, outputs, limitations and resources. Identification of the process and a possible connection with the related PFMEA and/or the related process FMEA are recorded in the upper part of the form, as indicated in the printed form.

Describe the process activities (principal operations) in detail (model of the process).

Any possible failures that can occur are written next to individual items.

1. A possible implication of the view of the customer is attached to each possible fault.
2. The cause responsible for the fault is defined for each possible fault (the cause must be clearly determined).
3. The significance "VZ", which expresses the effect of the fault on the customer in points, is determined for each possible fault (Tab. 5).
4. The probability of occurrence ("PV") point-wise assessment by the index (a measure of process capability) Cpk is assigned to each possible fault. If only a verification series data are available, it is used to be the Ppk (Tab. 6) index.
5. By assigning the points, the probability of detection ("PO") of any possible faults before delivery to the customer is determined (under the current circumstances). (Tab 7).
6. The current mechanism of controls or the adopted measure (system) is assigned to each possible fault.
7. MR/P is calculated as the product of occurrence, significance and the possibility of exposing the fault.
8. Risk level / priority MR/P = V * PV * PO.
9. Crucially significant/fatal faults are determined according to the MR/P index.
10. Corrective or preventive measures and the officer responsible for their implementation are suggested for each significant fault.
11. Corrective and preventive measures are implemented and performed.
12. If the MR/P index fails to signal an acceptable status, repeat the steps starting with point 2.

Tab. 5. VZ weighted coefficients for process FMEA.

A: "VZ" coefficient

	Significance of the failure mode for the customer	Assessment factor
Insignificant	The customer will possibly not even notice the fault.	1 - 2
Marginal	The customer will be influenced by the fault only marginally.	3 - 4
Mild	The failure occurrence will make the customer unhappy.	5 - 6
Large	Customer will be extremely unhappy and angry at the un-functional product.	7 - 8
Critical	Fault occurrence poses a risk of safety or violates legal regulations.	9 - 10

Tab. 6. PV weighted coefficients for process FMEA.

B: "PV" coefficient

	Possibility of fault occurrence	Process capability	Assessment factor
Extremely Unlikely	The process is statistically managed. The allowance in excess of Xp±4s. Fault extremely unlikely.	Cp ≥ 1.67	1
Remote	The process is statistically managed. The allowance in excess of Xp±3s. Faults can occur only sporadically.	Cp ≥ 1.33	2
Occasional	Process is statistically managed	Cp ≤ 1.33	3
Reasonably Possible	Allowance not in excess of Xp±2.5s. A fault occurring at times.	Cp ≥ 0.83	4 5 -6
Frequent/ Critical	High probability of faults occurrence that can be only hardly prevented.	Cp ≤ 0.83	7 8
Critical	Process out of control. Faults are frequent, and their occurrences cannot be prevented.	Cp ≤ 0.33	9 10

Tab. 7. PO weighted coefficients for process FMEA.

C: "PO" coefficient

	The probability that process fault will be revealed	Assessment factor
Extremely high	The process securing system would highly possibly reveal the possible fault or the fault is detected automatically.	1 - 2
High	The fault should be problem-free revealed.	3 - 4
Remote	Fault occurrence not always revealed. A small number of faults will remain undetected.	5 - 6
Very mild	A Large number of faults will remain undetected.	7 - 8
Sure not to be revealed	The process securing system would highly possibly not reveal the possible fault or the fault is impossible to be detected.	9 - 10

3.3 Cause-and-effect diagram

The cause-and-effect diagram (Ishikawa or fishbone diagram) is a graphical illustration of possible causes (factors) and their effects on the outcome (Fig. 1).

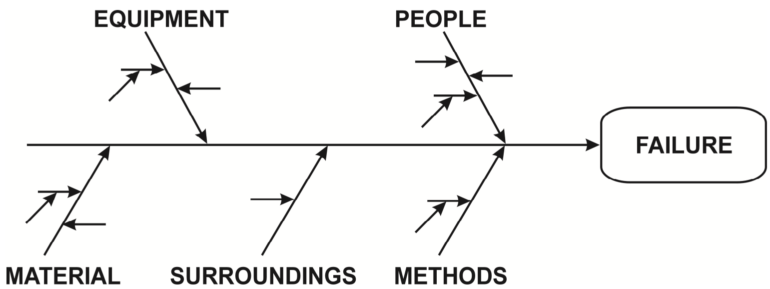

Fig. 1. Schematic illustration of the tree structure.
Source: Tkáč, Turisová, 2010.

In question is a tree-wise identification structure that, by its shape, resembles a fishbone. The graph orientation (even though it is not clearly marked) always aims to the root (head of the fish). Priority is given by possible assessment of the edges. The cause-and-effect diagrams are most frequently construed based on brainstorming targeted to the collection and generation of possible problem causes when it pinpoints the highest probabilities and verifies possible causes of their occurrence. Ishikawa diagram is used for (Tkáč, Turisová, 2010):

- determining and describing the structure of all possible causes invoking the consequence under consideration,
- determining and understanding associations between the consequence and its causes,
- searching for the most probable decisive causes,
- forming of a database of causes and their classification into categories.

3.4 Pareto diagram

The Pareto analyses are a diagnostic tool that is used to promptly and simply determine critical categories (of faults, items, activities, etc.). The tool utilises absolute and relative cumulative numerousness of occurrence of phenomena to identify the most important ones. It is based on the empirical (derived from the practice) principle that in total, by the rule, only several few factors (elements or phenomena) stand for the majority of numerousness of their occurrences (Tkáč, Turisová, 2010).

The so-called Pareto diagram is being used to interpret the principle (Fig. 2).

The theory became known only under the 80–20 rule. According to it, relatively a high number (roughly 80 %) of occurrences in the whole is generally due to a relatively small number (only 20 %) of the item types. Example: pretty frequently up to 80 % of a company's revenues originate from only 20 % of customers.

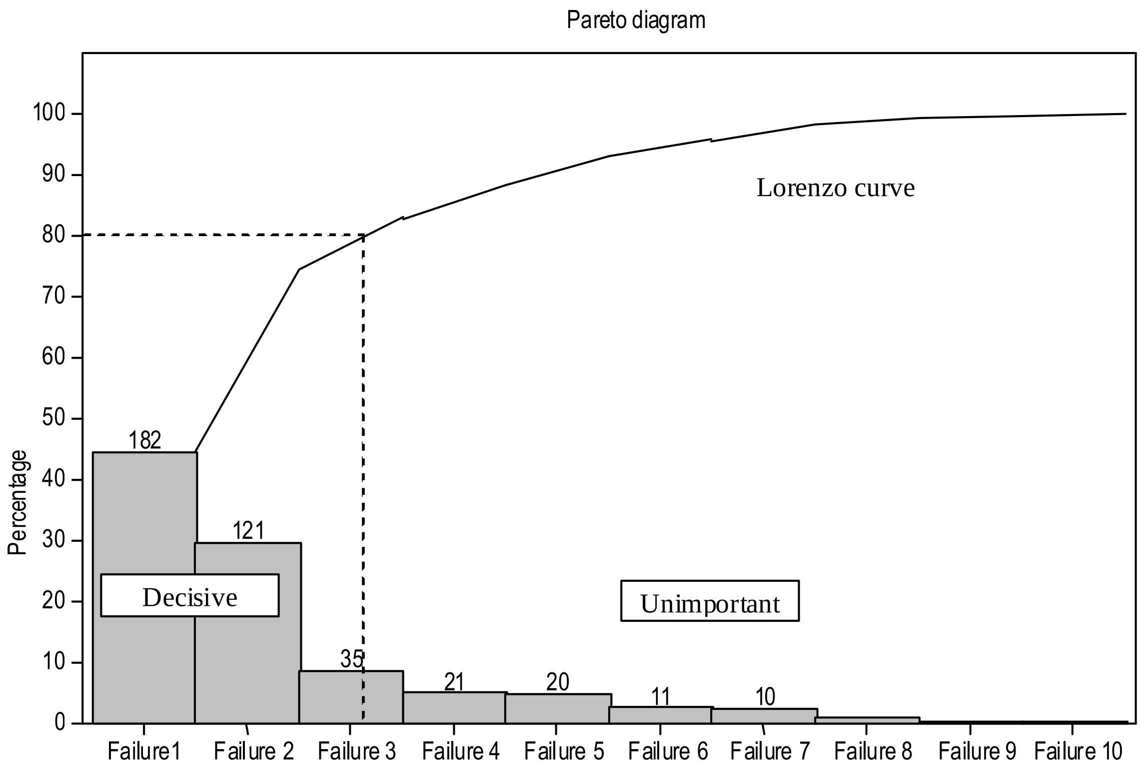

Fig. 2. Schematic illustration of the tree structure.
Source: Tkáč, Turisová, 2010.

4. About the company

A company named Kláštorná s.r.o. was formed in 1997. From the very beginning, the company was primarily involved in bottling natural mineral water into the consumer packing. Those days, one could happen on the Kláštorná bottled natural mineral water in its unforgettable containers in restaurants and coffeehouses all over Slovakia for the first time – small glass bottles, one of the first ones to be introduced to the market and promptly gaining its loyal consumers. Later on, as the proportion of PET plastic bottles on the market grew, the company started to bottle the water into plastic containers too, and the "Pearl of Mineral Waters" was all of a sudden found on shop shelves as well. Since formed, the company got about several significant phases, and nowadays it can be introduced as one of the most progressive bottler of natural mineral water in the Slovak Republic.

The quality of the produce is continuously being monitored during the entire production process. Stationed immediately downstream behind individual devices are quality controlling posts equipped with sensors that check the quality of charging, caps tightening and proper etiquette placement. If any product fault is detected, the product is automatically disclosed from the production process. If the mechanism detects multiple subsequently passing faulty products, the entire production process is stopped, and restart is possible only post performing a thorough inspection, fault detection and its elimination. The new technology is more demanding as to the operating personnel knowledge, but at a time it has eliminated the share of physical work in the production process. Thus, a minimisation of the "human factor failure", which extremely significantly enhances the quality of production, that is, at any time, prepared to meet even the most rigorous expectations of the customer, is its most marked benefit.

5. Proposed implementation of the T KIBS model in the considered company

The introduction of top-notch technologies is associated with a higher degree of more intricate automation. The number of operating personnel is falling, and precision and quality of production are on the rise. On the other hand, the requirements for qualification of the operator are increasing. Emerging, especially in the opening phase of the new production line introducing, are various "beginners'" errors or failures. A situation that may last for a prolonged period is in concern, whereas the operators are inexperienced and are unable to respond readily to the variety of changes that life can bring about. Thus, enhanced demands, frequent downtimes, possible deterioration of quality and also losses due to damage to the produce are often tolerated whereas they are taken for an unavoidable toll of introducing new technology. If the technology is powerful, which in the case of KLÁŠTORNÁ obviously is, whereas it is introducing two high-capacity lines in parallel, then by introducing associated increased costs may often be pretty high. One of the possibilities how to avoid the above mentioned increased costs is to introduce the T KIBS model in early phases of introducing the very line.

Considering the complexity of the T KIBS model, putting the line into practice is presumably prompter than with the traditional takeover procedure. Let us outline advantages of the complex approach to T KIBS implementing: attainment of innovative potential of the highly qualified specialists; improving processes to the standard level in relatively short period of time; avoiding possible faults already on the process planning stage, and not during operation; securing of high level theoretical-implementation potential; despite the undisputable fact that T KIBS presents an expensive affair, considering time limitations of its utilisation is making operation of the lines significantly more cost effective in the long run.

KLÁŠTORNÁ decided to confer process of installing new production lines to an external team of innovators that consisted of:

- Constructor, professional designer of the given types of lines,
- Serviceman, specialist from the line supplying company,
- Employees of KOSTOLNA company having experiences with previous lines,
- Specialist in improving performance and quality of processes,
- Project manager, and
- Economist.

The team included three academicians, two external specialists and other experienced employees of KLÁŠTORNÁ, inclusive of the authors of the present paper. At the start, the team of innovators performed analysis of the already existing bottling installations. Established were basic performance parameters, and the so-called zero status of improving was defined using analytical methods. The selected basic parameters served as indicators of the process improvement. Whereas the team was unable to perform benchmarking whereas the devices were of unique nature, it proceeded to the theoretical exploration of the available documentation and to identifying critical spots. A brainstorming was performed and based on that, rather complicated and extensive causes-and-effects diagram has been elaborated. Only a brief selection of relatively extensive Ishikawa diagram is illustrated in fig. 3.

Immediately after installing of new lines the pilot operation commenced, and FMEA was utilised to prevent the occurrence of faults during the trial run. The overall completed FMEA consisted of tens of pages. In the tables below (Tab. 8 and 9) we have briefly drafted the manner in which was the FMEA performed having in mind that some of the possible faults were identified and resulting measures and actions taken to eliminate them or at least to reduce their effects were described.

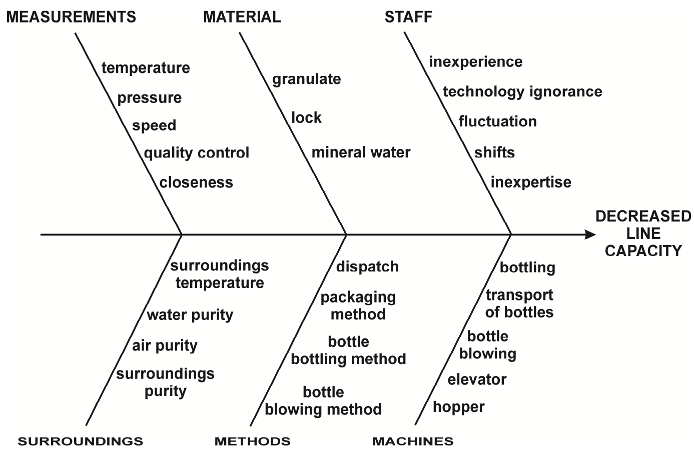

Fig. 3. Schematic illustration of the tree structure.
Source: original design.

Tab. 8. FMEA – A form.

KLÁŠTORNÁ, s.r.o.	**Failure mode and effects analysis** **Process FMEA (x)**	**Product name:**	**Product number:**
	Confirmed by the pertinent dept.:	**Model / system / production line**	**Revision no.:**
	Process definition: **Manufacture and filling of bottles**	**Prepared by (name/Dept./date):**	**Revised by (name/Dept./date):**

Place / function operation	**N**	**Failure mode**	**Failure effect**	**D**	**Failure cause**	**Current status**					**Recommended actions**	**Responsible**	**Improved status**				
						Current controls	**PV**	**VZ**	**PO**	**MR/P**			**Action taken**	**PV**	**VZ**	**PO**	**MR/P**
hopper		Short fill / overfill	Downtime		Wrong batching	none	8	7	6	336							
elevator		Non-functional	Downtime		Jammed	none	8	7	8	448	Regular cleaning	xy	After-shift cleaning	4	7	4	112
bottles blowing		Wrong temp.	Wrong bottle shape		Setting	meter	9	8	4	288							
		Wrong press	Non-functional press		Setting	meter	9	8	4	288							
transport of bottles		Jammed	Downtime		Bottle shape	none	6	5	6	180							
charging		Short fill / overfill	Improper volume of mineral water		Improper setting	none	9	7	8	504	Maintenance	xy	Maintenance during breaks	2	7	3	56
dispatch		deformation	degradation		Improper operating	none	7	9	8	504	Check by foreman	xy	check	6	6	5	180

PV – failure occurrence probability, VZ – failure significance, PO – probability of failure detection, MR/P – risk level/priority *Page 1 /2*

Tab. 9. FMEA – B form.

KLÁŠTORNÁ, s.r.o.	**Failure mode and effects analysis** **Process FMEA (x)**	**Product name:**	**Product number:**
	Confirmed by the pertinent dept.:	**Model / system / production line**	**Revision no.:**
	Process definition: **Manufacture and filling of bottles**	**Prepared by (name/Dept./date):**	**Revised by (name/Dept./date):**

Place / function operation	**N**	**Failure mode**	**Failure effect**	**D**	**Failure cause**	**Current status**					**Recommended actions**	**Responsible**	**Improved status**				
						Current controls	**PV**	**VZ**	**PO**	**MR/P**			**Action taken**	**PV**	**VZ**	**PO**	**MR/P**
Granulate		moisture	Wrong consistency		Improper storing	none	4	7	8	224	Measurements	xy	hygrometer	4	7	2	56
		impurity	Jammed jets		Damaged container	Subjective	2	9	6	108							
Cap		Loose fit	Loose fit		Fin	none	3	6	7	126							
					Wrong geometry	none	3	8	8	212	Adjust	xy	3X in a shift	3	8	3	72
Bottles packaging		Too tight	Deformation		Wrong adjustment	none	5	5	5	125							
Logistics		Short of substrate	Downtime		Bad supply	Check storehouse	4	9	3	108							
		Caps	Downtime		Bad supply	Supplier	7	9	6	382	Improve supply	xy	Claim	4	9	3	108
Mineral water		Insufficient flow rate	Downtime		Weather	Input check	8	8	6	384	Alternative work	xy	Maintenance	8	2	6	96
		Impurity	Degradation		Device cleanliness	Output check	4	9	3	108							
		Chemical composition	Lowered quality		Seasonality	Output check	2	9	3	54							

PV – failure occurrence probability, VZ – failure significance, PO – probability of failure detection, MR/P – risk level/priority *Page 2 /2*

When observing the level of faults, we focused on illustrating the most significant faults that were occurring most frequently. This is illustrated in the below Pareto diagram.

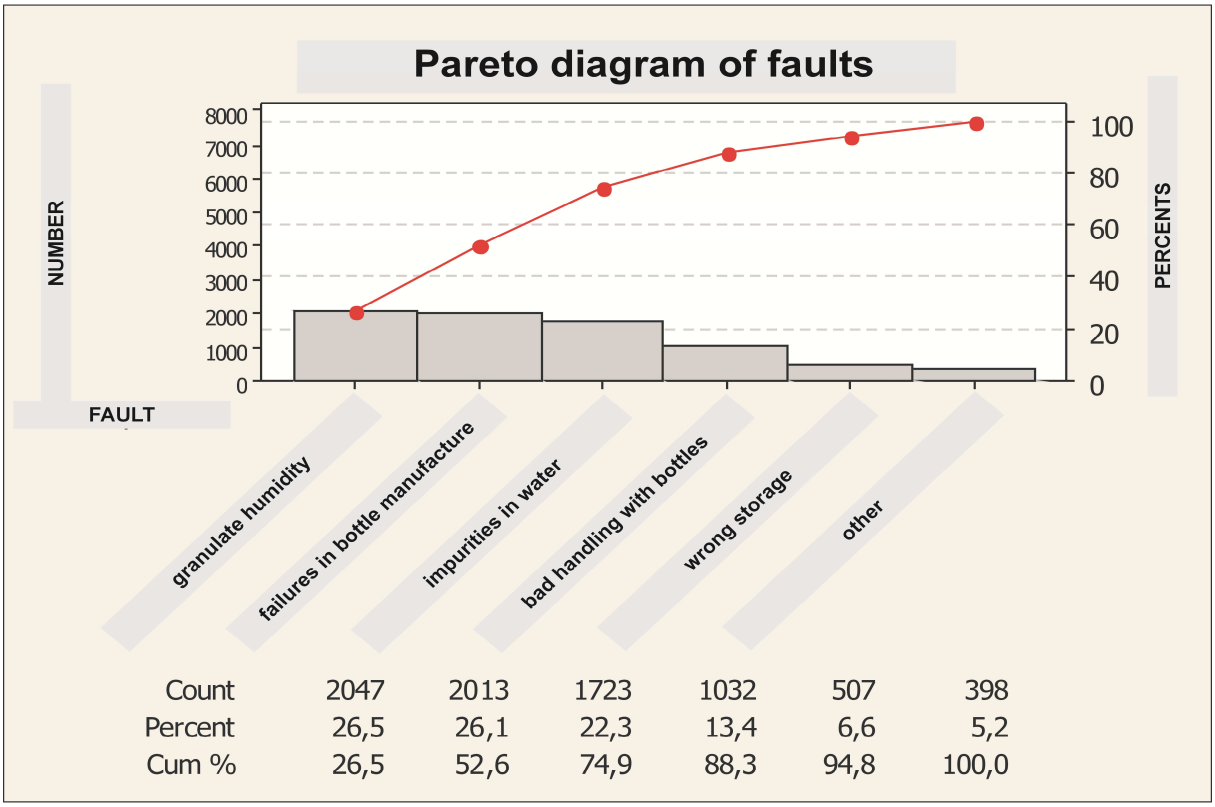

Fig. 4. Pareto diagram of faults.
Source: original design.

Subsequently, we defined corrective actions that were based on that the occurrence of those faults had to be decreased to a minimum. At first, we define the MR/P(x)function for individual faults, and then we can proclaim that by implementing the corrective measure we attempt to lower values of these factors or indicators for individual fault types.

$$\min_{x} MR / P \tag{1}$$

Individual measures can be followed through the costs. When following operating costs, we also test the occurrence of the costs related to reworks and claims (internal, i.e. in-company as well).

Based on those mentioned above, we proposed some optimisations targeted to cut the rework costs and costs of claims. We work on the principle that savings in these costs should be lower that it is in the case with a growth of costs of changes and adjustments.

$$\Delta NPR \leq NnZ \tag{2}$$

$$NPR_0 - NPR_1 \leq NnZ \tag{3}$$

Therefore, we are following volume of costs spent on adjustments and claims. Adjustment and faults elimination costs (NPR) are defined as a function of the value of some points established as the limit to be monitored within the FMEA value.

Then we can define and also $NnZ(x)$, where x stands for limit MR/P value when followed by the FMEA method. We assume that the mentioned functions are of convex shape, and hence it holds that:

$$[NPR(x)]'' > 0 \tag{4}$$

$$[NnZ(x)]'' > 0 \tag{5}$$

At a time, we assume the following:

$x_1 < x_2 \rightarrow NPR(x_2) < NPR(x_1)$, whereas at higher chosen limit value we will insist on a higher rate of active measures, and hence alleviation or elimination of faults. On the other hand, if we consider a lower limit level, a larger number of faults will remain unchanged, and thus a higher need of reworking is anticipated as well,

$x_1 < x_2 \rightarrow NnZ(x_1) < NnZ(x_2)$, whereas at higher chosen limit value we will insist on a higher number of active measures and hence higher costs of introduced changes. On the other hand, if we consider a lower limit level, more processes will remain unchanged, and thus lower costs of changes resulting in the elimination of specified faults are anticipated.

Now it can be said that the limit value should be optimised, and hence

$$\min_x \left[NnZ\,(x) - \Delta NPR\,(x)\right] \text{, resp. } \max_x \left[\Delta NPR\,(x) - NnZ\,(x)\right] \qquad (6)$$

We assume that a number of costs expended on changes would result in the elimination of costs expended on reworks and claims. For the reason, we need to find a criterion that would ensure maximum difference between the values, which is based on equation (2).

In our case, using the specified optimisation we have subsequently arrived in the best imaginable condition using the critical value of 180.

The chosen fault acceptability limit was set to 180 points. Generally, limits from 100 up to 125 points are used in practice. The given increase was implemented due to the introductory elaboration of the FMEA method. It is very difficult to foresee the faults occurrence risk in the line commencement process. Considering the small number of pieces produced, there is the only so-called short-term capability of the device at our disposal that can be burdened by high variability. On the first stage of thus introduced FMEA, it was important to identify the critical spots, and to determine possible factors that would be able to negatively influence not only the implementation phase but the entire period of both bottle charging lines operation.

Based on the FMEA determined critical factors, i.e. high-risk faults, a series of measures was adopted, while some of them are outlined in the FMEA table. A part of these actions with corrective nature was targeted at increasing the lines stability, and hence was only of a temporary effect. The other ones served as the basis for the elaboration of work routines. Modifications of the basic line settings recommended by their supplier were determined so that their performance and quality of production were as high as possible. A team of external specialists suggested minute structural changes or fixtures with the aim to ensure production continuity and efficiency. Early alert systems were established, and parameters of control diagrams for a long-term capability of processes were set.

The very T KIBS model realization took two weeks; the first week during which were the lines installed presented the production preparatory phase, and the other week can be described as the production management one. As early as after the third day of the pilot run all basic parameters were set, and both lines were operating at full capacity. An integral part of the T KIBS implementation was education–professional, focusing on training and skills of operators, and also training in quality improvement and costs reduction. An economic system of costs minimisation and continuous improving productivity was elaborated. Safety regulations and environmental aspects of adopted measures were the other parts of the training. In general, it can be stated that the T KIBS model satisfied the task to introduce successfully two high-performance, innovative lines into a practical environment of KLASTORNA company operations.

Conclusions

Whereas Slovak companies are intensely confronted with the rising level of competition, and so that they would be able to compete successfully in the global markets, it is a must that they would speedily adapt to ever–changing conditions of the global economy. Successful adaptation, though, necessitates adopt and implement a set of tasks and measures.

An approach based on the T KIBS model presents one of the options of how to attain European quality in Slovak conditions as well. Anyway, for ages, it holds that to purchase the top-notch technology is by far not enough. There can be found examples from the past when modern technology was insufficiently used, whereas the following factors were critical from among the entire production process:

- insufficient number of customers,
- improper logistics,
- etc.,

which caused that the overall effect proved to be minimal despite the modern technology. T KIBS offers complex solutions, and as we have demonstrated it in the present paper, can be implemented in Slovakian conditions as well.

As a rule, new technologies have to be accompanied by also respective:

- System of management,

- Highly qualified personnel,
- Sufficient market demand,
- Appropriate suppliers,
- etc.

In this paper, we have presented a very simple and purpose-built model of T KIBS implementation. Not some extensive, innovative centre, neither a strategically extensive design activity, was in question. The T KIBS idea was implemented in a single phase of the life-cycle of freshly introduced charging lines.

The practical benefit of the paper is seen by presenting the possibility to implement modern, innovative tools for resolving specific real-life issues. In Slovakia, we have very few companies specialised in providing complex T KIBS services. The paper demonstrated that the potential of scientific activities of regional R&D organizations or universities can be successfully utilised. In this way, an ad hoc team of solvers can be formed when resolving a specific project. A selection of such team members can be subordinated to the task, and the duration can be significantly delineated. Such an approach significantly reduces T KIBS implementation costs in practice, and the company acquires qualified top specialists and developers for relatively low costs for the period crucially needed.

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