

Vzdrževanje v zasnovi celovitega obvladovanja kakovosti

The Role of Maintenance in the Total Quality Management Concept

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V času globalizacije, revolucije v računalniški znanosti in spreminjanja, ki temelji na načelih re-inženiringa, gre vizija razvoja proizvodnih sistemov v smeri zmožnosti in učinkovitosti odprtega in hitrega sistema nadzora kakor tudi kakovosti po načelih celovitega obvladovanja kakovosti (COK - TQM). Re-inženiring in razvoj sistema kakovosti predstavljata moderne tehnike, katere zajemajo vse komponente poslovanja podjetja v funkciji zahtev trga na tehničnem kot tudi tehnološkem področju. Posebna vloga v teh postopkih pripada enemu od ključnih podsistemov proizvodnega sistema, a to je vzdrževanje. Pričakovanje glede zasnove vzdrževanja v prihodnje je celovito proizvodno vzdrževanje (CPV - TPM) v funkciji celovitega obvladovanja kakovosti, v pogojih uporabe novih tehnologij. Ustrezna zasnova proizvodnega sistema vzdrževanja je pogoj za kakovost proizvoda, medtem ko je celovito preventivno vzdrževanje bistven pristop COK-a.

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(Ključne besede: proizvodni sistemi, vzdrževanje, celovito proizvodno vzdrževanje, celovito obvladovanje kakovosti)

In the era of globalization, the computer science revolution and the restructuring based on the principles of re-engineering, the vision of the production-system development consists of the following: efficiency, effectiveness, an open and rapid control system as well as the quality with a total quality management (TQM) approach. Re-engineering and the development of the quality system represent modern techniques that embrace all the business components of the enterprise in the function of market demands and technical as well as technological range. The special role taken in those processes belongs to one of the principal subsystems of the production systems, i.e., maintenance. The future prospect of the maintenance concept is total productive maintenance (TPM) as part of TQM, on the condition of the application of new technologies. A suitable concept for production-system maintenance is the condition for the quality of the product, whereas total preventive maintenance is the essential TQM approach.

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1 MAINTENANCE IN THE QMS PROCESS MODEL AND THE NET OF QUALITY

The basic conditions for fulfilling maintenance requirements (machines, various types of equipment and tools) include the control and maintenance of systems in a working state, preventive activities for eliminating and/or decreasing system failures, corrective maintenance, the reduction of external influences on machines and equipment as well as their functioning, operational safety, optimal costs, etc.

Maintenance offers the necessary preconditions for a product to gain its planned

characteristics in harmony with the corresponding requirements of the EU, referred to as "the new approach". In order to accomplish its mission, maintenance as a process must match the requirements of the ISO 9000 standard and be created according to the Process Model (Fig. 1) ([1] and [2]).

Maintenance, as a process in the Net of Quality, can be seen through three principal conception groups (see Fig. 2) ([1] and [3]).

- A - the analysis of the effectiveness of the system and maintenance resources,
- PMt - the Process of Maintenance - activity and results,

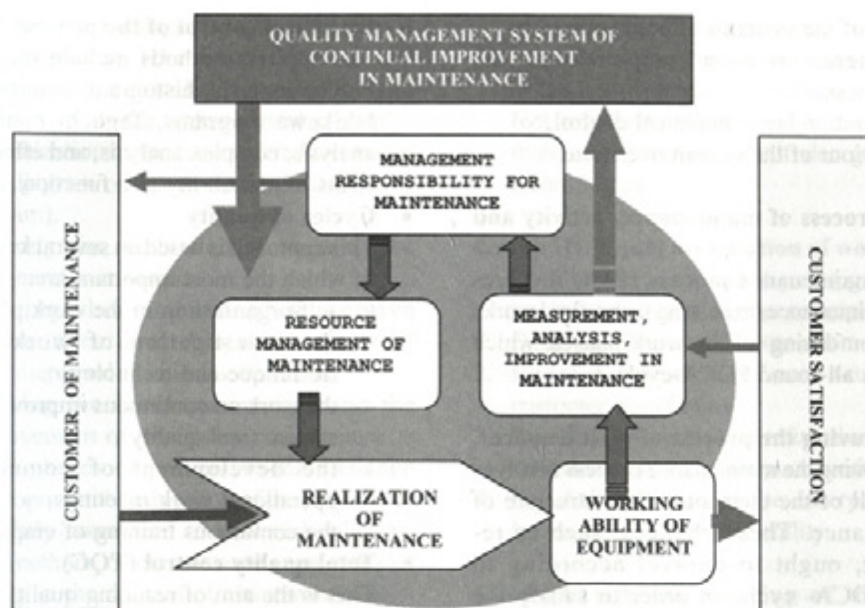


Fig. 1. Process model of maintenance in the QMS

- IPMt – the improvement of the constituent process of maintenance.

Each of these groups behaves in accordance with the law of Deming's circle of quality (PDCA-circle).

A - Analysis of the effectiveness of the system and maintenance resources

Elements that are particularly important for an analysis of the maintenance process refer to

maintenance resources as inputs as well as the system effectiveness as a measure of the maintenance success.

- Maintenance Resources - material, equipment, tools, methods and labour.
- Effectiveness is a function of time and it consists of reliability, availability and the convenience of maintenance.

Analysis (A) of the system's effectiveness and the methodology of maintenance indicates:

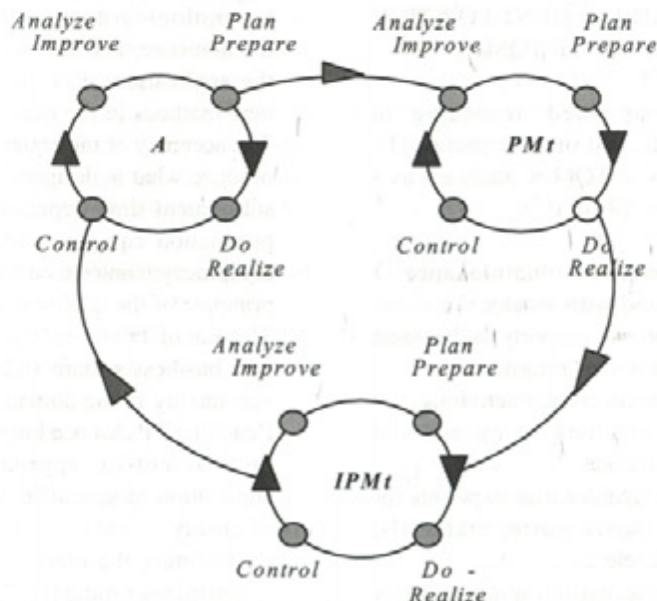


Fig. 2. Maintenance in the Net of Quality - Deming's circle of quality

- the level of the system's effectiveness,
- the influence of each component on the effectiveness,
- the distribution law - statistical control,
- the behaviour of the system over time.

PMt - the process of maintenance, activity and results

The maintenance process (PMt) involves preparing maintenance, executing tasks, final works and inspection during all the work phases, which represents an all-round PDCA-cycle.

IPMt - improving the process of maintenance

Improving the maintenance process involves changes to all of the elements in the structure of the maintenance. These changes, such as re-engineering, ought to unravel according to Deming's PDCA- cycle, in order to satisfy the quality system and acquire the expected results.

Improving the process of maintenance consists of:

- a change in the structure of the production system,
- a change in the concept of maintenance,
- a change in the control of spare parts and materials,
- a change in the organisation, the structure of the working forces and the motivation,
- a change in the maintenance status of the production system, etc.

2 MAINTENANCE ADJUSTMENT FOR THE DEVELOPMENT OF TQM

TQM is accomplished according to categories, which are divided into six groups [1]. In this paper the access to TQM is analyzed as a function of maintenance ([4] to [6]).

Group I: Changing traditional maintenance

• Just in time, overload with stocks

The just-in-time approach supports the business function of maintenance relating to:

- the planning of maintenance activities,
- the managing of stock resources and maintenance activities,
- the managing of maintenance expenses for all categories (spare parts, materials, equipment, work, etc.),
- the reversible information about activity execution.

• Statistical control of the process

The applied methods include the following: Pareto analysis, histogram, control diagrams, Ishikawa diagrams, Taguchi method, factor analysis, complex analysis, and effectiveness in terms of probability as a function of time.

• Cycles of quality

This approach is based on several key principles, of which the most important are:

- self-organization in the work place,
- the investigation of work processes (technique and technology),
- the work on continuous improvement of the system (and quality),
- the development of communication, operational work meetings,
- the continuous training of employees.

• Total quality control (TQC)

This is the aim of reaching quality in some or all the works in all processes.

Group II: Applying scientific methods to maintenance

• Total preventive maintenance (TPvMt) – the complete representation of preventive maintenance - scientific prevention ([1] and [5])

The relation between TQM and the maintenance system lies in the word "total", which refers to both control and quality. Quality control in the production system would not be "total" if it did not apply to maintenance. Advanced production technologies demand a new approach to maintenance, and this new approach demands the application of advanced technologies and new methods in the domain of maintenance.

The accuracy of the equipment and its ability to produce what is designed for the first and each subsequent time depends on the condition of production equipment and the quality of the equipment maintenance. Consequently, the basic principle of the quality system is respected.

The aim of TPvMt is to master all the segments of a business system and to prevent a state of non-quality in the domain of its functions.

Reaching TPvMt is a long process that is based on a scientific approach along with the application of scientific methods and the tools of quality:

- Defining the place of maintenance in the business-production system and constant exploration of those relations.

- ABC (Pareto) analysis of the equipment's characteristics (the importance of the organisation, reliability, availability and productivity of the technological system).
- Systemization of the causes of failures based on a diagram of "causes-effects" (Ishikawa diagram).
- Defining the method of diagnosing the equipment's condition.
- Defining the methods of preventive maintenance according to the type of equipment and the causes of failure.
- Defining the development time and the improvement of preventive maintenance.
- In all phases of preventive-maintenance development the education of the employees is tightly connected to new technologies, new methods of maintenance, new tools of quality in the domain of maintenance, etc.
- **Taguchi method - scientific design**
The Taguchi method is part of the integral access to product design, process and the quality system, which is supported by principles such as:
 - defining the quality loss-function,
 - the continuous improvement of quality,
 - decreasing the costs as a condition for success in the market,
 - decreasing the withdrawal of performance in the function of the continuous improvement of quality, etc.
- **Quality techniques - scientific recognition**
Quality techniques represent an approach to quality based on a scientific methodology. They represent the sum of knowledge (the accuracy of information, analysis, synthesis, and control) focused on the satisfaction of the needs and demands of customers. Some methods are described within the ISO 9004-4 standards, for instance:
 - the histograms for a visual presentation of information,
 - the control diagram and charts,
 - the ABC (Pareto) diagram,
 - the Ichikawa diagram,
 - the diagram of dispersion,
 - the Tree diagram,
 - the expert systems for decision aids, etc.
- **High-technology cycles - scientific application**
High-technology cycles behave like quality cycles, by engaging in such a way that high

technology comes to be in the function of the majority of employees, and consequently adds to the improvement of quality.

Not only does high technology contribute to the improvement of quality, it also generates new technologies.

Group III: Equal distribution of work functions

This very important paradigm of quality control is characterized by four principle approaches:

1. Equal distribution of automation - spare time,
2. Equal distribution of new technologies - customer satisfaction,
3. Equal distribution of the functions of quality-customer comprehends your work,
4. Equal distribution of the enterprise quality - increase of the process ability.

Group IV: Re-engineering of the process - maintenance

Re-engineering and the quality system are the main concepts of enterprise development, regardless of their proportion and profit. They are imperative for the development of all business components and market competition and they reflect on all the business elements of an enterprise.

Group V: Including the customer in the process

This approach group enables the adaptation of the organization to the demands and needs of the customer, which has a particular contribution to TQM development and embraces the following:

- designing with the help of the customer - including the customer in the system,
- controlling by organisation with the help of the customer,
- Kansai engineering - including the latent wishes of the customers and employees.

Group VI: Quality of knowledge (learning, reviewing and implementing the acquired knowledge)

The quality of knowledge within the organization depends on the efforts in:

- creating technologies of knowledge, i.e. artificial intelligence,
- accelerating the changes in knowledge in order that the work becomes educational,
- the quality that transforms all the employees into researchers in the function of improving the work processes,

- international competition, which reinforces the organization in the battle for survival,
- information technologies, global and local webs for computer utilization in each work place.

3 TOTAL PRODUCTIVE MAINTENANCE

Total Productive Maintenance (TPM) is a maintenance program that involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production (effective production time, decrease of system failures, decrease of production and maintenance costs, etc.) while at the same time increasing employee morale and work satisfaction ([5] and [6]).

TPM emphasises maintenance as an important as well as necessary component of business. Maintenance is no longer regarded as a non-profit activity. The downtime for maintenance is scheduled as part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to keep emergency and unscheduled maintenance to a minimum.

3.1 The Pillars of TPM

J. Venkatesh [7] has depicted Total Productive Maintenance as a model in the form of a house with a roof carried by seven pillars and a

base that consists of five layers, whose names begin with the letter "S" (Fig. 3)

Each pillar represents a whole in itself and is integrated into the process of maintenance as an inseparable part that makes TPM a totality.

Pillar 1 - Jishu Hozen

This pillar is geared towards developing operators to enable them to take care of small maintenance tasks, thus liberating the skilled maintenance people to spend time on more value-added activities and technical repairs. The operators are responsible for maintaining their equipment in order to prevent it from deteriorating.

Pillar 2 - Kaizen

"Kai" means change, and "Zen" means good (for the better).

Kaizen stands for small improvements; however, it is carried out on a continual basis and involves all the people in the organization. Kaizen is the opposite of big radical innovations. Kaizen requires no or little investment. The principle behind it is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value".

Pillar 3 - Planned Maintenance

The aim is to have trouble-free machines and equipment producing defect-free products for total customer satisfaction. This breaks down the

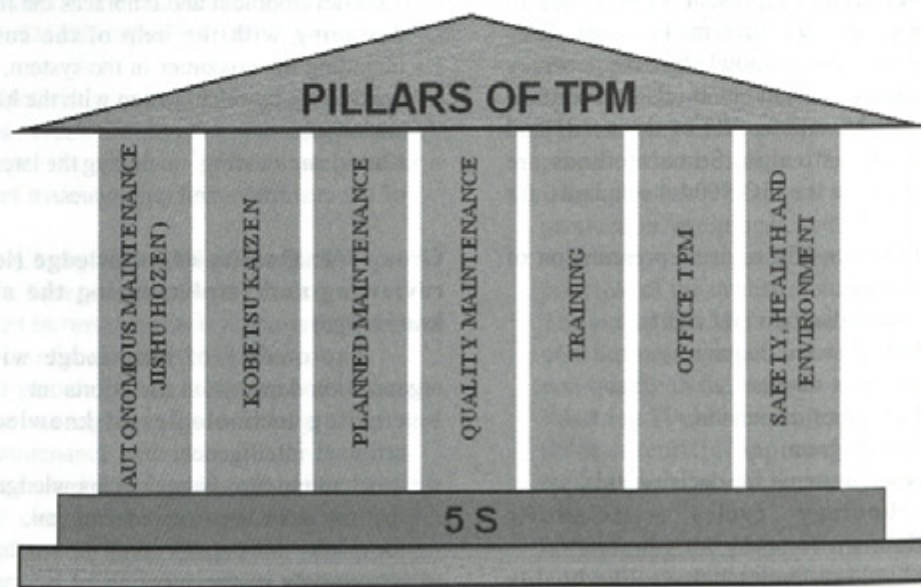


Fig.3. The pillars of TPM [7]

maintenance into four "families" or groups, as defined earlier.

- preventive maintenance
- breakdown maintenance
- corrective maintenance
- maintenance prevention – proactive maintenance

With planned maintenance we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to maintain their equipment better.

Pillar 4 - Quality Maintenance

The aim is customer delight as a result of the highest quality through defect-free manufacturing. The focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain an understanding about which parts of the equipment affect the product quality and begin to eliminate current quality concerns, then move to potential quality concerns. The transition is from reactive to proactive (Quality Control to Quality Assurance). Target:

- Achieve and sustain zero customer complaints.
- Reduce in-process defects by 50%.
- Reduce the cost of quality by 50%.

Pillar 5 - Training

The aim is to have multi-skilled revitalized employees whose morale is high and who are eager to come to work and perform all the required functions effectively and independently. Education is given to operators to upgrade their skills. It is not sufficient to know only "Know-How", they should also learn "Know-why". Through experience they can master the "Know-How" in order to overcome and solve certain problems. They do this without knowing the root of the problem and why they are doing so. Hence, it becomes necessary to train them on knowing "Know-why".

Table 1. The equivalent meanings of "5S"

Japanese Term	English Translation	Equivalent 'S' term
1. <i>Seiri</i>	Organisation	Sort
2. <i>Seiton</i>	Tidiness	Systematise
3. <i>Seiso</i>	Cleaning	Sweep
4. <i>Seiketsu</i>	Standardisation	Standardise
5. <i>Shitsuke</i>	Discipline	Self-discipline

The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phases of skill are:

- Phase 1: Do not know.
- Phase 2: Know the theory but cannot do.
- Phase 3: Can do but cannot teach.
- Phase 4: Can do and teach.

Pillar 6 - Office TPM

Office TPM should be started after activating the four other pillars of the TPM (JH, KK, QM and PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures with the aim to increase office automation.

Pillar 7 - Safety, Health and Environment

Target:

- Zero accidents,
- Zero health damage,
- Zero fires.

In this area the focus is on creating a safe workplace and a surrounding area that is not damaged by processes or procedures. This pillar will play an active role in each of the other pillars on a regular basis.

3.2 Basis - 5S

Table 1 shows the meaning of each of five letters "S" in Japanese, with their equivalents in English[6]. Problems cannot be clearly seen if a workplace is unorganized. Cleaning and organizing the workplace helps the team to discover and solve problems. Making problems visible is the first step towards improvement.

1. Seiri - Sort out

This means sorting and organizing the items as critical, important, frequently used items, useless

or items that are not needed at the moment. Critical items should be kept for use in the immediate vicinity and items that will not be used in the near future should be stored elsewhere. As a result of this step, the search-time is reduced.

2. Seiton - Organize

The concept here is that "Each item has a place, and only one place".

The items should be placed back after use in the same place.

3. Seiso - Shine the workplace

This involves cleaning the workplace, free of burrs, grease, oil, waste, scrap, etc. There should be no loosely hanging wires or oil leakage from the machines.

4. Seiketsu - Standardization

Employees need to discuss together and decide on standards for keeping the work place, machines and paths neat and clean. These standards are implemented for a whole organization and are inspected randomly.

5. Shitsuke - Self-discipline

Considers 5S as a way of life and brings about self-discipline among the employees of the organization. This includes wearing badges, following the work procedures, punctuality, dedication to the organization, etc.

4 SIMILARITIES AND DIFFERENCES BETWEEN TQM AND TPM

The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools, such as employee empowerment, benchmarking, documentation, etc., used in TQM are used to implement and optimize TPM ([2] and [7]).

Table 2. *The differences between TQM and TPM*

Category	TQM	TPM
<i>Object</i>	Quality (Output and effects)	Equipment (Input and cause)
<i>Means of attaining the goal</i>	Systematize the management, and it is software oriented	Employees participation, and it is hardware oriented
<i>Target</i>	Quality for IPMt	Elimination of losses and wastes.

The similarities between TQM and TPM are:

- Total commitment to the program by upper-level management is required in both programmes.
- Employees must be empowered to initiate corrective action.
- A long-range outlook must be accepted, as TPM may take a year or more to implement and is an ongoing process. Changes in the employees' mindset toward their job responsibilities must take place as well.

The differences between TQM and TPM are summarized in Table 2.

5 REENGINEERING, QUALITY SYSTEM AND MAINTENANCE

The development of 21st-century society is characterized by three main trends: globalization, the computer science revolution and the restructuring of production systems (industry) based on the principles of re-engineering (Business Process Reengineering - BPR), where maintenance plays a special role ([5] and [8]).

In technical-technological reengineering, maintenance has the role of enabling and maintaining new as well as pre-existing production capacities. Similarly, maintenance is subjected to its own re-engineering.

In re-engineering, the process of implementing the quality system is realized slowly at its beginning (see Fig. 4). After re-engineering (BPR), the business results (BR) increase to a certain level (t1). A further increase in the business results (after t1) prolongs the improvement of the quality system (QMS). Maintenance (M), as logistics, enables the verification of the complete cycle of re-engineering and the quality system [5].

Maintenance is the tool for the implementation of the QMS to the level of a TQM, under the condition of aspiring to a TQM.

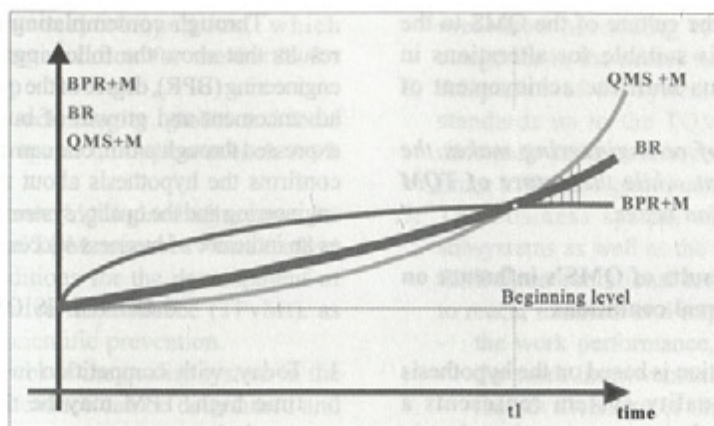


Fig. 4. Business-result (BR) change of a production system in the function of re-engineering (BPR), quality management system (QMS) and maintenance (M)

Table 3. Characteristics of the company "ŽITOPROMET" A.D. business moves during the period of the investigation

Year	Investments (currency)	Description of reengineering activities and quality	QMS Advancement	Business results - BR
				Profit (currency)
I	1,453,571	Construction of a 1000 tonne silo, investments in the preparation of projects, etc., equipment, training of the employees in production and maintenance Preparing QMS documentation	20%	12,857
II	1,354,014	Reconstruction of equipment, train tracks, telephone network, construction of a 1000 tonne silo, training of the employees in production and maintenance Preparing QMS documentation	30%	42,121
III	457,500	Procuring process equipment, laboratory equipment, training of employees in the production and maintenance Certifying QMS	50%	77,950
IV	568,000	Installation of equipment, training of the employees in production and maintenance. Applying certified QMS	70%	291,265
V	510,891	Reconstruction of various pieces of equipment, training of the employees in production and maintenance. Advancing QMS	80%	182,520
VI	570,748	Procuring new computer equipment, computer networking, training of employees. Advancing QMS - Winning the "Oscar of Quality"	90%	227,551

On the other hand, the culture of the QMS to the level of the TQM is suitable for alterations in business components until the achievement of business excellence.

The nature of re-engineering makes the organization different, while the nature of TQM makes the organization better.

5.1 Investigation results of QMS's influence on business results in real conditions

The investigation is based on the hypothesis (Fig. 4) that the quality system represents a superstructure above the system re-engineering; in other words, it represents an incentive to reach a higher level of business success within an enterprise until a need appears for new re-engineering.

The object of the investigation is the company Žitopromet A.D. - Spuž, Montenegro, winner of the Oscar of Quality (SRJ) in the year 2000 in the category of small and medium-sized enterprises (SMEs), whose QMS was certified by an RW TÜV evaluation body from Essen. This company produces various sorts of flour.

The results were gathered over a period of six years in which this company implemented the re-engineering of all the production systems (increasing capacities and broadening the product range) and at the same time intensively advanced the quality system by lowering the costs, increasing revenues and gaining competitiveness in the market.

Table 3 shows the data on investing in re-engineering, the degree of advancement in the function of the quality system and the results of the business-result changes that appeared as a consequence of the latter.

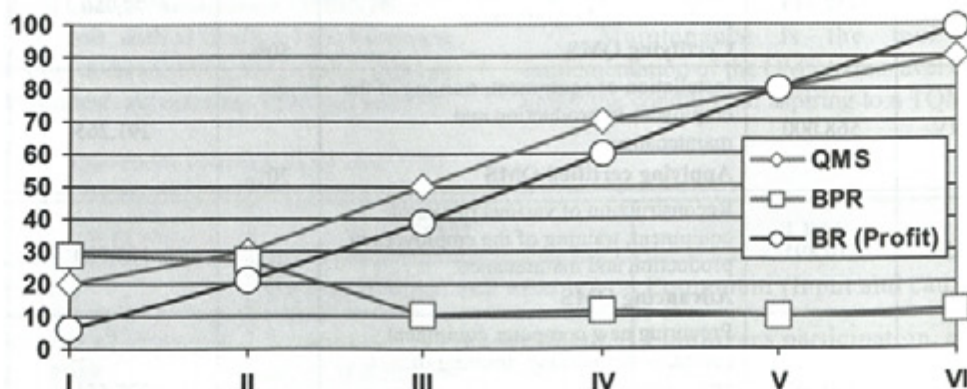


Fig. 5. Business-result (BR) advancement of company "Žitopromet" in terms of the reengineering (BPR) and the quality management system (QMS)

Through contemplating and analysing the results that show the following: investments in re-engineering (BPR), degree of the quality system (QMS) advancement and growth of business results (BR) expressed through profit, one can derive a diagram that confirms the hypothesis about the influence of re-engineering and the quality system on the profit growth as an indicator of business success (see Fig. 5).

6 CONCLUSIONS

1. Today, with competition in industry at an all-time high, TPM may be the only thing that stands between success and total failure for some companies. It has been proven, as a program, to work. It can be adapted to work not only in industrial plants, but in construction, building maintenance, transportation, and in a variety of other domains.
2. Employees have to be educated and convinced that TPM is not just another "program of the month" and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to the resources invested may be expected.
3. The quality of the knowledge within the organization depends on the given efforts in:
 - creating technologies of knowledge, i.e. artificial intelligence,
 - accelerating the changes in knowledge, so that work becomes learning,
 - the quality that transforms all the employees into researchers in the function of the improvements of work processes,

- the international competition, which reinforces organization for the battle for survival,
 - information technologies, global and local webs for computer utilization at each work place.
4. Maintenance has the highlighted adjustment for the application of TQM, whose reversible effect creates the conditions for the development of the total preventive maintenance (TPvMt), as the method of scientific prevention.
 5. The achieved level of the quality system in the domain of maintenance can be determined and measured according to all the alteration categories in the access to total quality.
 6. Adaptation of the system to the QMS quality standards up to the TQM level represents a necessary superstructure of re-engineering in order to reach higher business results.
 7. The business system and all the business subsystems as well as the maintenance need to fulfil three conditional levels of work in order to reach, maintain and improve TQM:
 - the work performance,
 - the work improvement,
 - the advancement of the improved work.

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