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Strategic Approach to Maintenance Management: A Case Study

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In the conditions of business globalization, competitiveness is mostly realized through increased productivity, quality and agility. This requires a review of all processes, especially those that create or support the creation of new value. Maintenance process becomes very important in creating new value and thus competitiveness. Maintenance process performances are numerous, with appropriate inter-relations that are dependent on many factors, internal and external. For these reasons, it is difficult for the management to effectively manage the maintenance processes.

Maintenance process performances are the basis for the analysis of the process state and achieving certain objectives. However, they do not allow the consideration of the impact of maintenance on competitiveness. To achieve this, the analysis of maintenance performances, based on the application of the approach of Kaplan and Norton (Balanced Score Card), as the basis for the development of new model, is presented in this paper. This gave the opportunity to determine the effect of the maintaining process on competitiveness in each competitive organization.

In this paper, besides the description of methodology, the results of the impact of maintenance on competitiveness in one medium-size organization are shown.

Strateški pristup upravljanju održavanjem: analiza slučaja

Izvornoznanstveni članak

U uvjetima globalizacije poslovanja, konkurentnost je uglavnom realizirana povećanjem produktivnosti, kvalitete i agilnosti. Ovo zahtijeva preispitivanje svih procesa, posebno onih koji kreiraju ili podržavaju stvaranje nove vrijednosti. Proces održavanja postaje veoma važan u stvaranju nove vrijednosti i time konkurentnosti. Performanse procesa održavanja su brojne, s odgovarajućim među-relacijama koje zavise od više čimbenika, unutarnjih i vanjskih. Iz ovih razloga, veoma je teško za menadžment da efikasno upravlja procesima održavanja.

Performanse procesa održavanja predstavljaju osnovu za analizu stanja procesa i postizanja određenih ciljeva. Međutim, oni ne dozvoljavaju razmatranje utjecaja održavanja na konkurentnost. Da bi se ovo postiglo, u ovom radu analizirane su performanse održavanja, zasnovane na primjeni pristupa Kaplana i Nortona (Balanced Score Card), kao osnove za razvoj novih modela. To omogućuje da se utvrdi utjecaj procesa održavanja na konkurentnost u svakoj organizaciji koja je na tržištu.

U ovom radu, uz opis metodologije, prikazani su rezultati utjecaja održavanja na konkurentnost u jednoj organizaciji srednje veličine.

1. Introduction

In the conditions of global market, it is necessary to achieve greater competitiveness on the basis of price, quality and quick response to the market demand. For example, in its famous book, Foster [1], in Chapter 4 (Strategic Quality Planning), points to the new market demands, primarily related to product and organization quality, and Goetsch and Davis [2], in Chapter Two, made special analysis of the relation between quality and competitiveness. This requires a review of business strategy and all key processes.

Pietersen [3] emphasizes the need for reinventing strategy using strategic learning to create and sustain breakthrough performance, and Rao et al. [4] define, in the first chapter, the quality as a strategy. Of course, the

focus in on the processes which enable achievement of new value for the customer and the processes that support it.

Arsovski [5] suggests a strategic approach in defining and creating business processes, with the reference to different phases of the process life cycle. Becker [6] points to the complexity of the requirements towards processes, delimitation between processes and the importance of outsourcing in the process management. By its nature, maintenance processes are the supporting processes to the basic (primary) processes. In delimitation between other (primary) and the support processes, Wagner [7] points out to the differences between them which arise from their role in the chain of value creation and stakeholder requirements.

Slack et al. [8] consider the support processes as part of a process-oriented operation management. In Chapter 8, which relates to the capacity management, they use overall equipment effectiveness (OEE) as a measure of the capacity effectiveness by multiplying availability rate, performance rate and quality rate. Maintenance processes affect all three components of OEE. In the paper [9], the authors, using a simulation approach, consider the quality objectives, and within them, particularly the quality costs and their impact on the product price. In second step, by the identification of the most influential factors through a Kaizen approach, the improvement of processes that ensure the achievement of the appropriate objectives and global objective as a whole, is done. This approach is in [10] extended even out of the company, which as extended enterprise is seen as a part of a supply chain, a cluster or network, with new requirements in terms of process realization, the role in creating value and responsibility of each company in the global supply chain.

Scheer, Hess and Kronz [11] view business processes as the link between IT and organization. They believe that no business intelligence exists without process intelligence, and within the key performance indicators tree they stress performances related to the time, quality and costs. Nilsson, Tolis and Nellborn [12] discuss the problem and perspectives of business modeling and examine different approaches and methods and emphasize the need for the evaluation method for creating chains/alliances through appropriate meta-models, which include quality as a performance measure.

Oakland [13], in Chapter 4, puts a special attention to the integration of quality into the policy and strategy, and in Chapter 7 to the performance measurement frameworks. Bahrami and Evans [14] point out the characteristics of the term super-flexibility as the arc of agility, versatility, malleability, robustness and resilience. To achieve that, organizations need to incorporate more knowledge into their processes and so increase the capacity for novel situation and susceptibility of modification. Lin and Hsu [15] put a special attention to the forms of agility in services and the fuzzy view of new service development.

In [16], the authors analyze the effect of the improvement of the quality of maintenance process using information technology and, by the analysis of a case study, found that it significantly reduces the throughput time (18 to 25 percent), enhances the maintenance process quality about 4.6 percent and so on.

Arsovski et al. [17] analyze the impact of usage of the equipment of a higher level of automation and flexibility (Flexible Manufacturing Systems) on the production costs and productivity and found that for each level of automation there is the optimal area of production factors.

Maskel [18] gives approach to measure performance in World Class Manufacturing (WCM) with emphasis on maintenance and production performances. Soković and Pavletić [19] analyze synergy effect of six sigma approaches in which maintenance influence is incorporated. Effectiveness of production processes is analyzed in [20], and Cost of Quality (CoQ) was used as a measure of effectiveness.

Pun et al. [21] analyzed the effectiveness centered maintenance (ECM) model and determined phases in ECM implementation (people participation and training, quality improvement diagnosis, maintenance strategy development, performance measurement). Liyanage and Kumar [22] analyzed maintenance and operations performance management in value-based view. They pointed to the value creation process through value modeling. Besides pointing to the different concepts of operations management, they also described the concept of implementation of Balanced Score Cards in the process of value creation.

Yam et al. [23] point to benchmarking as a performance management tool and process, consisted of the following steps: (1) identifying the key performance variables that need to be benchmarked, (2) selecting good information sources for benchmarking, (3) collecting and measuring data maintenance, (4) normalizing and adjusting the collected and measured maintenance information to a meaningful database, (5) analyzing the maintenance data against other organizations that are known to be a leader in the world, (6) changing and improving the maintenance performances. In [24] authors presented multi-criteria hierarchical framework for maintenance performance measurement (MPM). They determined seven criteria, each of which contains a number of performance indicators. Criteria include: (1) equipment-related indicators, (2) maintenance task related indicators, (3) cost-related indicators, (4) impact on customer satisfaction, (5) learning and growth, (6) health, safety, security and the environment, and (7) employee satisfaction.

Ip et al. [25] point out to the problem of production scheduling i.e. the role of maintenance in capacity planning. At the end of the study they suggest the concept of SCADA (Supervisory Control and Data Acquisition) integrated maintenance management system and its role in increasing the effectiveness of maintenance. In [26] authors analyze MRPII system as an environment in which maintenance activities are taking place. This requires the design of appropriate maintenance system within MRPII functions, with the following models: (1) data capture system, (2) work card system, (3) maintenance planning system and (4) job progress system. Tong and Liang [27] analyzed the problem of product reliability, the problems related to accurate forecasting and methods for it. Authors, trough case study, presented the results of the application of neural network and SARIMA model.

Grünig and Kuhn [28], in chapter 14, specified business strategies at the level of the market offer and in chapter 15 of the resources through value chain model. Neely [29] gives an overview of problems and different approaches in performance measurement, starting from the accounting perspective, via marketing perspective to the integrated performance measurement system. He particularly emphasizes the focus on strategic effectiveness, anomalies of high performance and problems of loosely coupled performance measurement systems. Finally, in chapter 18, the fundamentals of the approach of linking financial performance to employee and customer satisfaction are shown. Scheer [30] presents ARIS characteristics as a house of business engineering, models and practical procedures in which process management and performance management are integrated.

Kaplan and Norton [31], in chapter 2, analyzed corporate strategy and structure, in chapter 3 aligning financial and customer strategies, in chapter 4 interval aligning process and learning and growth strategies. At the same time, they pointed out the importance to provide adequate equipment and technology and operation processes, related to customer and financial strategies. The same authors [32] pointed out to the possibilities and advantages of linking the strategy operations for competitive advantage. The starting point was the strategy formulation process plan. In [33], authors point out the opportunities of balanced scorecard for translating strategy into action. They particularly emphasize the importance of internal business-process perspective, where in chapter 5, appendix they analyze the methods of measurement of time, quality and costs.

Alsyouf [34] presents the approach of measuring maintenance performance using balanced scorecard approach, starting from business process analysis. Particularly interesting are modified balanced scorecard (BSC) model, presented in Part 2: Operations with connections between quality, maintenance and logistics (p. 139) and separate maintenance perspective (p. 140). The author has changed the impact of the maintenance performance of one paper machine on ROI in amount of 9%. Wang et al. [35] point to the possibility of the integration of hierarchical BSC with non additive fuzzy integral in case of the application of high technology in organizations. Perspective importance ranks were analyzed for eight organizations, separately. Roux et al. [36] stress the importance of simulation of preventive maintenance activities and their relationship with production. The simulation is performed using Petri nets, taking into account the impact of maintenance period on availability of production equipment, expressed in percent. In [37], authors present the results of sensitivity analysis of an optimal Gantt charting maintenance scheduling model, taking into account the following criteria: (1) preventive maintenance cost minimization, (2) operational time maximization with constraint: limited maintenance capacity and variables: (1) machine idle time, and (2) operation periods. Sensitivity analysis is based on gradient theory applied on cost function.

Fernandez and Marquez [38] analyzed the case of implementation of maintenance management in distribution network service providers with emphasis on information flow between the maintenance function with other entities. Authors define a set of generic maintenance systems: (1) inventory system, (2) monitoring system, (3) management system, (4) geographic information system, (5) balanced scorecards system, and (6) export decision support system. Weinstein et al. [39] analyzed maintenance function and related maintenance costs and quality costs in four case studies.

Based on previous results of investigation, purpose of this paper is to connect maintenance and other processes (internal perspective) with other perspectives in strategic map, and more, to define model of impact of maintenance on strategic level, expressed by product price and competitiveness of enterprises. Based of analysis of the previous investigation results, the following hypotheses were defined:

H1: Efficiency and costs of maintenance process have an impact on the quality of production process,

H2: Quality of products, as a result of production process, has an impact on financial performance (mostly price) and competitiveness, and

H3: Price of the product has an impact on competitiveness.

In addition to the description of the developed methodology, the paper describes the structure of simulation model and the results of the verification in the case of a medium-size company in the automotive industry. In this case, it was found that with changes of the perspective of learning and development of 10 %, 20% and 30 %, with improvement of maintenance processes

by 10 %, 20 % or 30 %, performances in the customer perspective are increased, namely for the quality for 3, 5 and 7 %, and for the delivery time for 1, 3 and 4 %. It affects the financial perspective (on price by 6%, on average), and thus on the competitiveness by 4 %. These results confirm the possibility of improvement, which are slightly lower than expected, due to low equipment efficiency (65 %). This approach is based on strategic approach of Kaplan and Norton.

The practical implications of the proposed approach are numerous. It can serve as a basis for alternatives rating when investing in the improvement of maintenance, cost assessment, improvement of the quality of basic (primary) process, evaluation of the effects of maintenance training, etc. Presented methodology can also be used for the definition of impact of internal and external processes on the competitiveness, by addition of new performances and appropriate relations. Also, it can be used to connect with resilience model of the whole company, where, instead of the equipment maintenance, recovery processes would be used.

The originality of the paper is based on in the fact that this approach is applied for the first time in the field of maintenance, with the inclusion of relations between the different perspectives and their simulation. In this way, maintenance is no longer viewed only as an expense, but as a generator of new value and competitive advantage in the long run, and thus sustainable development.

2. The fundamentals of developed methodology

The subject of this paper is a methodology for strategic impact of maintenance management. The methodology is based on the approach of Kaplan and Norton, with focus on the processes of maintenance and other processes in the organization (internal perspective) and performances that directly affect the maintenance management (Figure 1).

In this model, in the perspective of growth and learning, based on maintenance process performance analysis, for this study the following performances were selected:

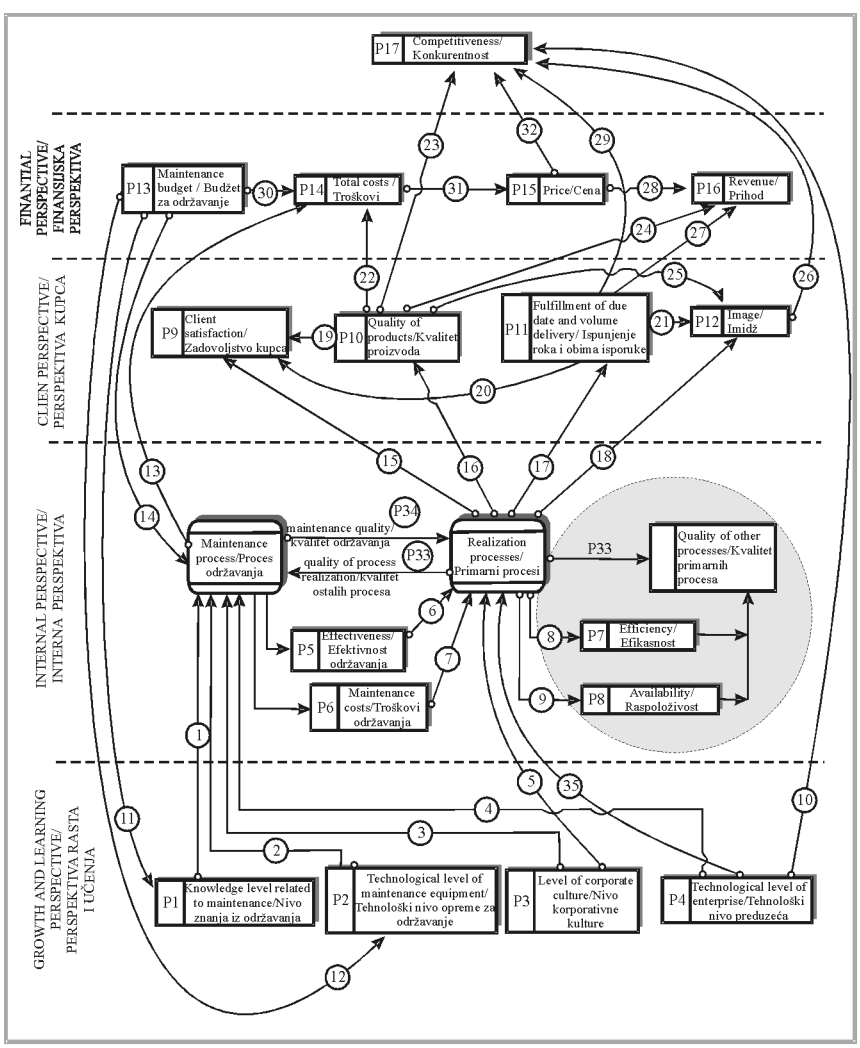

Figure 1. Basic model structure
Slika 1. Struktura osnovnog modela

- the level of knowledge related to maintenance,
- technological level of the maintenance equipment,
- the level of technological knowledge,
- the level of corporate culture.

Beside these performances, in any particular company other performances could be selected, depending on the importance of maintenance on the competitiveness.

In the internal perspective, two processes were selected:

- maintenance process and
- primary processes, especially the basic production processes.

Figure 2 shows the decomposed model of maintenance process with corresponding process performances stored in database for each component sub-process. It should be noted that in every company different network of maintenance sub-processes and their links with other processes in the company could be conceived.

Commonly used maintenance process performances (placed in the appropriate database) are:

- effectiveness of maintenance, shown as the achieved/ planned ratio,
- maintenance costs,
- mean maintenance time and others.

Thus, for example, within the sub-process 1: Maintenance planning, the planned time-terms are defined, and, by using appropriate simulation software, optimal sequence of maintenance activities could be determined.

Maintenance management monitors all maintenance process performances and, based on the criteria or objectives which result from the business strategy, chooses the optimal solutions and leads maintenance process to their realization.

In addition to the maintenance performances, maintenance process effects affect on the basic process through its performances, primarily:

- MTBF (Mean Time Between Failure),
- costs of downtime,
- costs of conflict of orders because of the maintenance operations and delays,

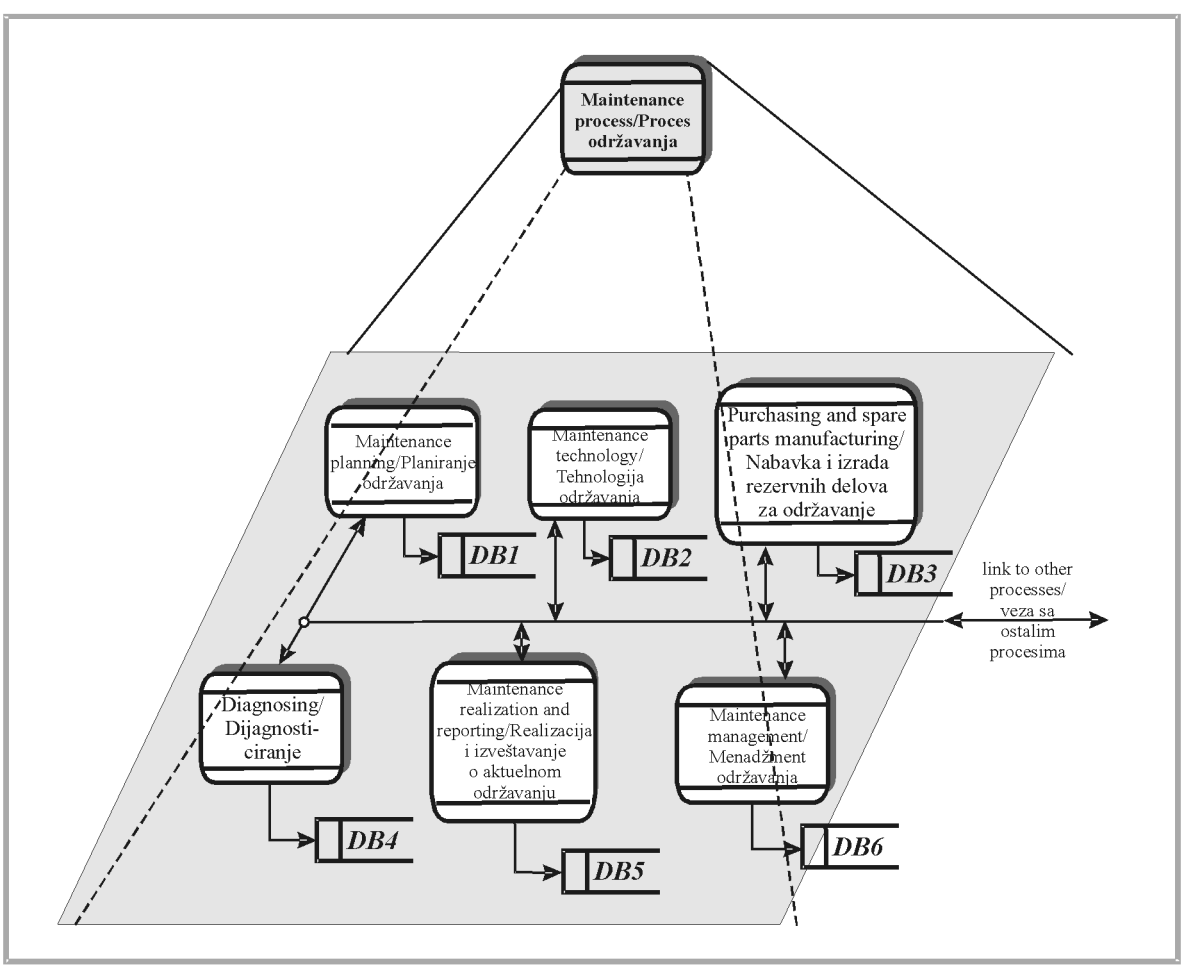

Figure 2. Maintenance process model

Slika 2. Model procesa održavanja

- costs of subsequent machines preparation, etc.

This aspect is explained in details in broad literature in the field of maintenance. The problem is that there is no appropriate model that integrates all of these performances, but only partially.

Process performances from the internal perspective have a significant impact on the customer perspective. For a typical manufacturing company, the performances related to:

- product quality,
- due date and volume of the product delivery and
- producer's image, could be selected.

Maintenance processes affect the first two groups of performances, by monitoring of performance over a longer period of time. Figure 3 shows the maintenance processes quality, which consists of maintenance performance and client perspective performances.

An example of quality metrics of an medium-size company in the automotive sector is given in Table 1.

The quality of maintenance process affects on other processes, primarily on the manufacturing process. This can be traced through the influence of P5 and P6 to P7 and P8.

The relation between P6 (maintenance costs) and P7 (the efficiency of the production process) is shown

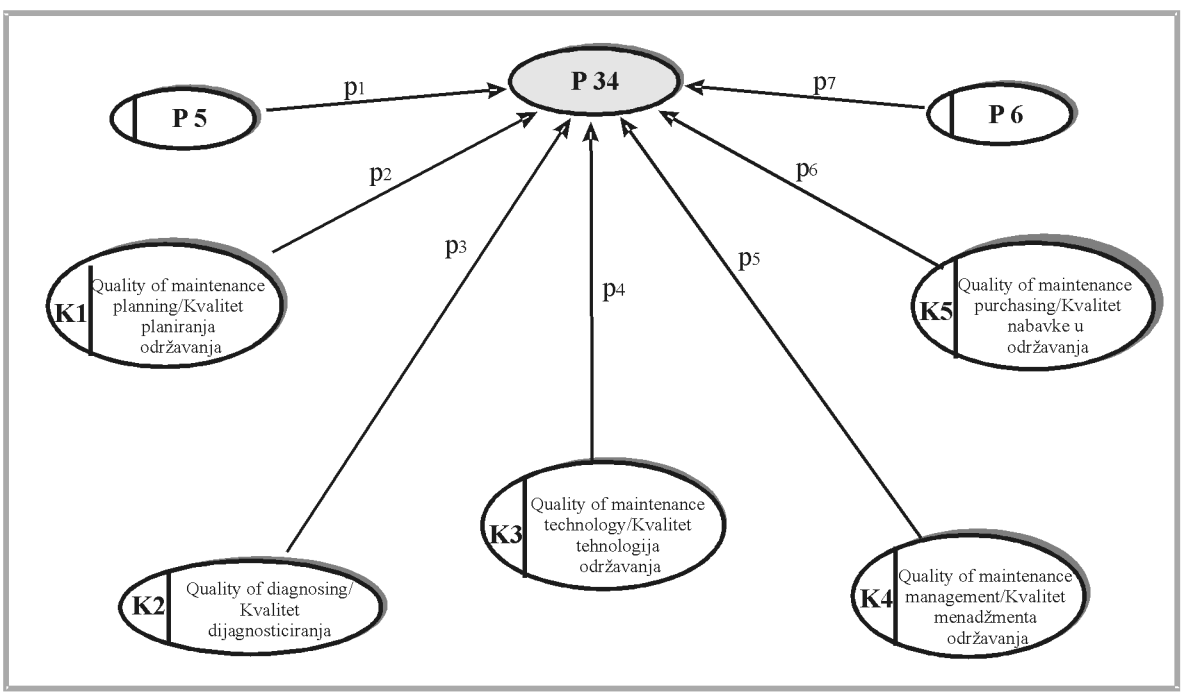

Figure 3. Relations between maintenance performances and client perspective performances

Slika 3. Veza između performansi održavanja i performansi perspektive klijenta

Table 1. Maintenance quality

Tabela 1. Kvaliteta održavanja

P5, h	P6 Cs/Cp x100	K1	K2	K3	K4	K5	Grade / Ocena
> 10	< 50	96 – 100	96 – 100	96 – 100	96 – 100	96 – 100	10
9 – 10	50 – 60	86 – 95	86 – 95	86 – 95	86 – 95	86 – 95	9
8 – 9	60 – 70	76 – 85	76 – 85	76 – 85	76 – 85	76 – 85	8
7 – 8	70 – 80	66 – 75	66 – 75	66 – 75	66 – 75	66 – 75	7
6 – 7	80 – 90	56 – 65	56 – 65	56 – 65	56 – 65	56 – 65	6
5 – 4	90 – 100	46 – 55	46 – 55	46 – 55	46 – 55	46 – 55	5
4 – 5	100 – 110	36 – 45	36 – 45	36 – 45	36 – 45	36 – 45	4
3 – 4	110 – 120	26 – 35	26 – 35	26 – 35	26 – 35	26 – 35	3
2 – 3	120 – 150	16 – 25	16 – 25	16 – 25	16 – 25	16 – 25	2
< 2	> 150	< 15	< 15	< 15	< 15	< 15	1
0.2	0.2	0.1	0.1	0.1	0.2	0.1	Weight (p) / ponder (p)

in Figure 4a, and the relation between the P6 and P9 (availability of production equipment) in a medium-size company in the automotive sector, obtained by monitoring during 3 years, for every 6 months, is shown in Figure 4b.

A typical relation between the performances of the maintenance process and maintenance costs is also different for each company. The dependence between the effectiveness of the production quality (P33) and maintenance costs (P6) in the analyzed company is shown in Figure 6.

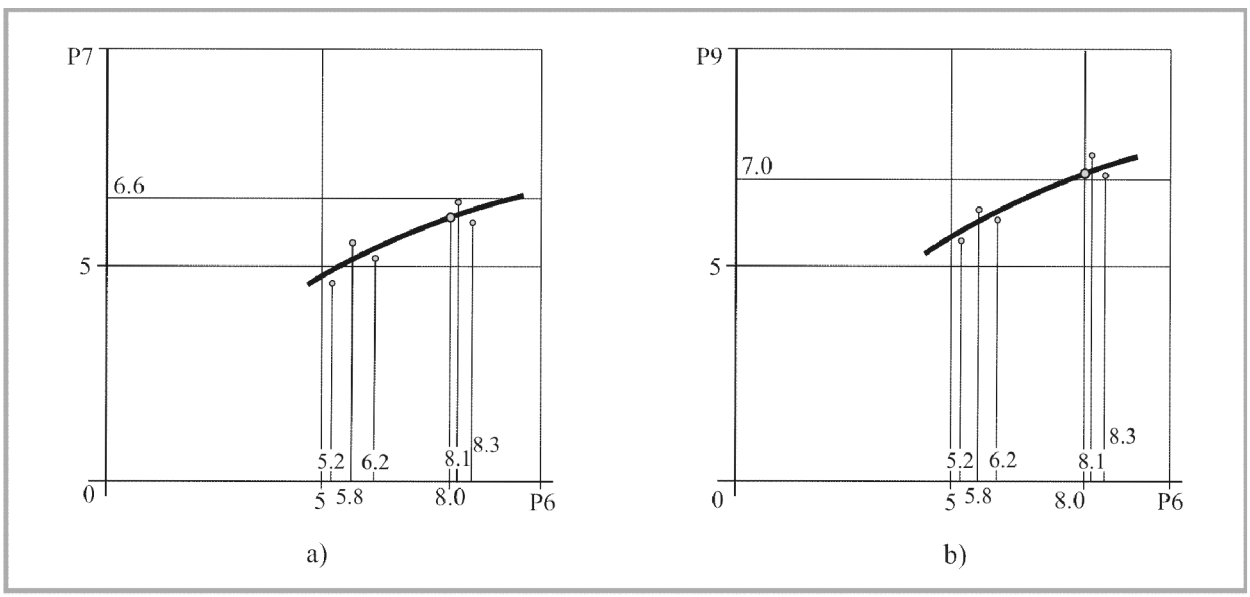

Figure 4. The influence of maintenance on production process efficiency

Slika 4. Utjecaj održavanja na efikasnost procesa proizvodnje

The influence of the effectiveness level of maintaining on the delivery due date and volume level, for each company is different, because it depends on the level of inventory in the finished products warehouse.

Figure 5 shows the relation between the production process quality (P33), obtained through the quality metrics given in Table 1, and P11 (fulfillment of delivery due date and volume).

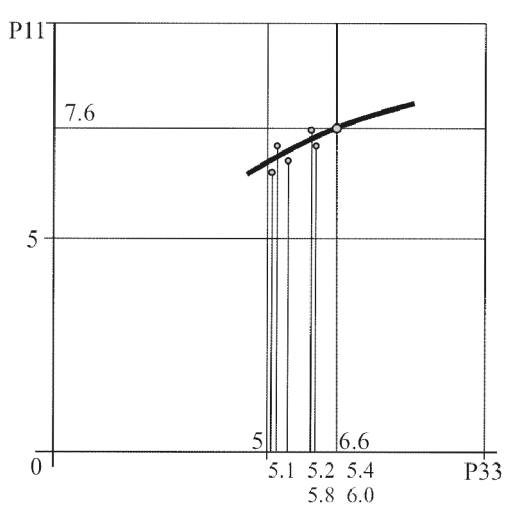

Figure 5. The relation between P33 and P11

Slika 5. Veza između P33 i P11

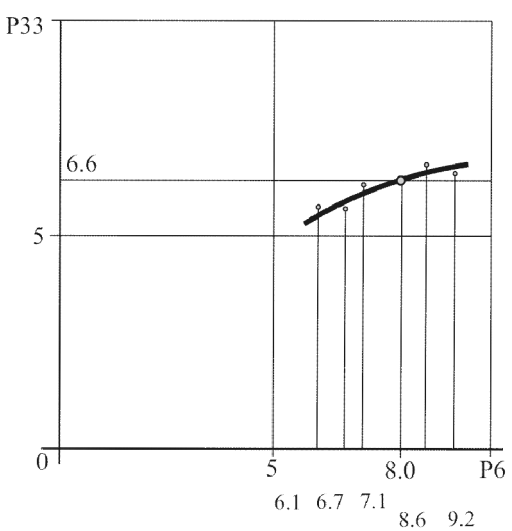

Figure 6. The relation between the effectiveness of the production and maintenance costs

Slika 6. Veza između efektivnosti proizvodnje i troškova održavanja

Through customer perspective performances, it is influenced on financial perspective performances, in particular on:

- price based on income and expenses,
- maintenance budget, as part of total costs in line with the maintenance strategy.

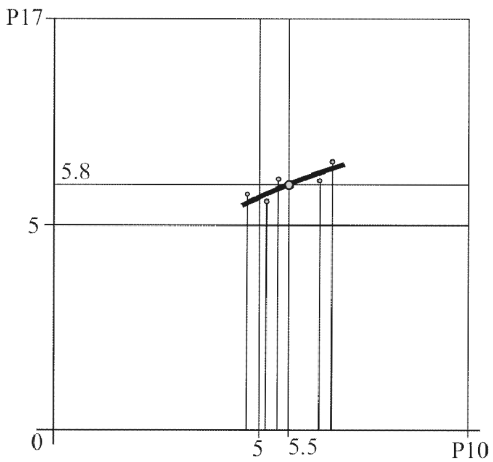

Figure 7. The influence of product quality on competitiveness
Slika 7. Utjecaj kvaliteta proizvoda na konkurentnost

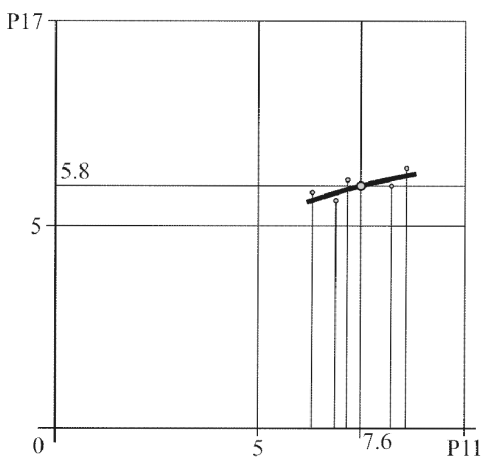

Figure 8. The influence of product quality on the competitiveness of delivery due date and volume
Slika 8. Utjecaj kvaliteta proizvoda na konkurentnost ispunjenja roka i obima isporuke

On the other hand, the client perspective performances are directly related to competitiveness, through product quality (Figure 7), and delivery due date and volume (Figure 8).

The influence of product quality on income and expenses is dependent on many factors. According to the research conducted in analyzed companies, the typical curve has a shape as shown in Figure 9.

Significant impact on the competitiveness has the product price. Depending on the type of product and existing competitors, this dependence has higher or lower trend.

3. The results of investigation

Based on previous results of Alsiouf [34], assessed on machine level, the impact of maintenance on ROI is very high. In analysis of maintenance practice in Swedish institutes [40], he found that 7% of companies use key performance measures and ranked important factors for maintenance selection in orders: machine availability, lost production costs, machine reliability, smooth production, product quality, cost effectiveness, on time delivery, replacement costs, investment cost. In this investigation predictive approach using performing maintenance tasks is highly assessed. Because of that, basic hypothesis is related to the measurable impact of maintenance on delivery (P11), efficiency (P7), client satisfaction (P9), quality of production (P33), revenue (P16), costs (P14) and competitiveness (P7).

Maintenance costs are the result of expenditure of all production resources in maintenance process. In proposed methodology, the extended model, shown on Figure 10, is used.

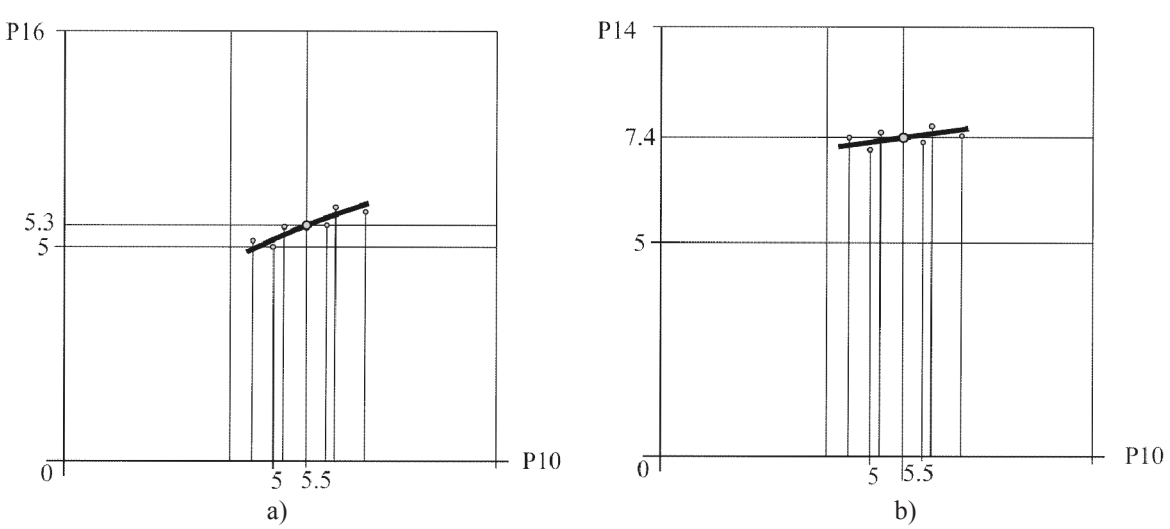

Figure 9. The influence of product quality on income and expenses
Slika 9. Utjecaj kvaliteta proizvoda na prihode i rashode

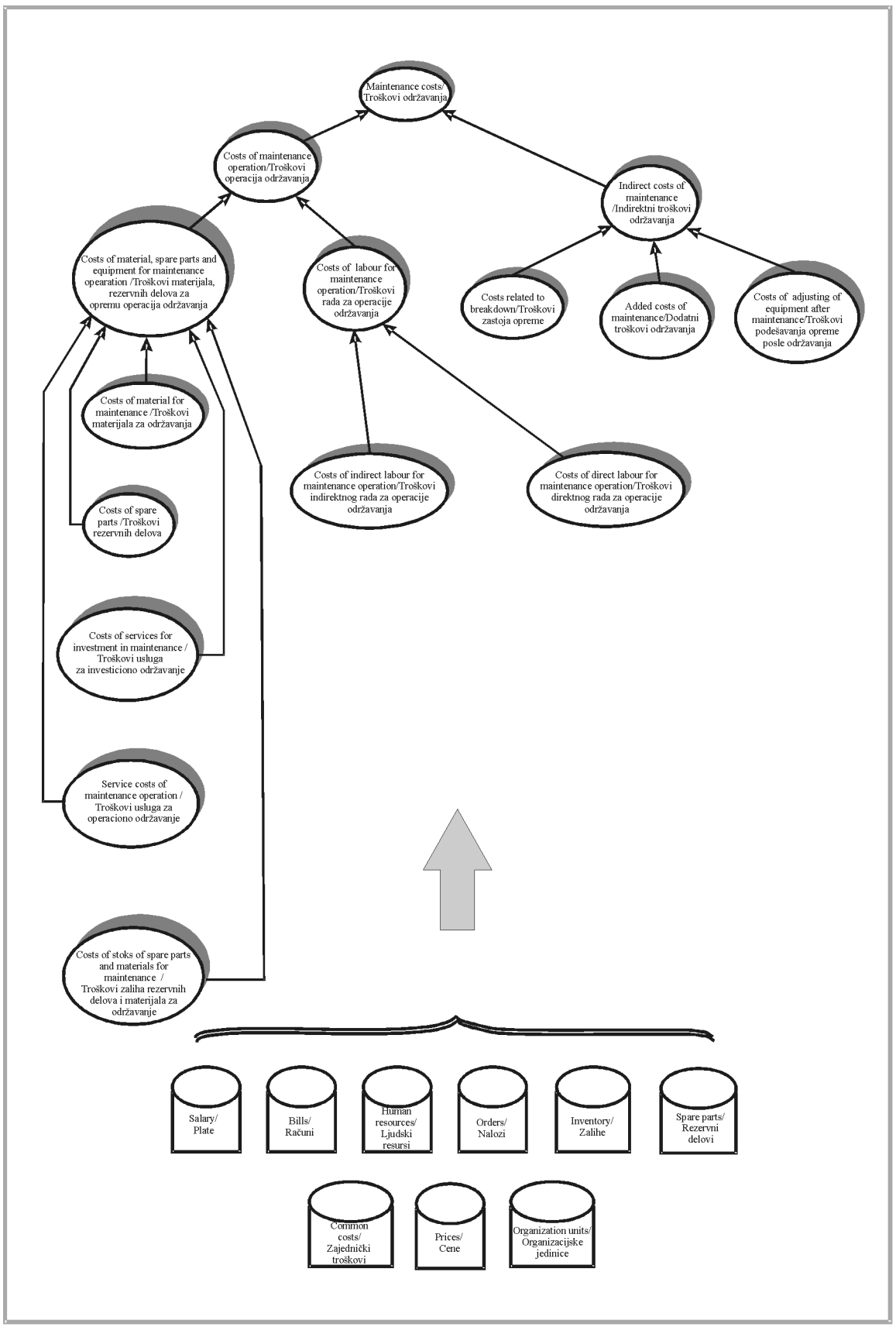

Figure 10. The model of maintenance costs

Slika 10. Model troškova održavanja

By the analysis of accounting data related to the maintenance costs of analyzed production-business systems, it was found that services for capital maintenance are dominant, followed by the services for ongoing maintenance, material spent for maintenance and spare parts consumed. From this structure, which in conditions of high inflation and the current way of keeping track of expenses has a conditional character, it can be concluded that the project of improving the maintenance system must place emphasis on reducing the cost of capital maintenance. Compared to the total maintenance cost in analyzed period, costs for services for capital maintenance were over 47%, and compared to the total spent of spare parts and material for maintenance even 27% (Figure 11).

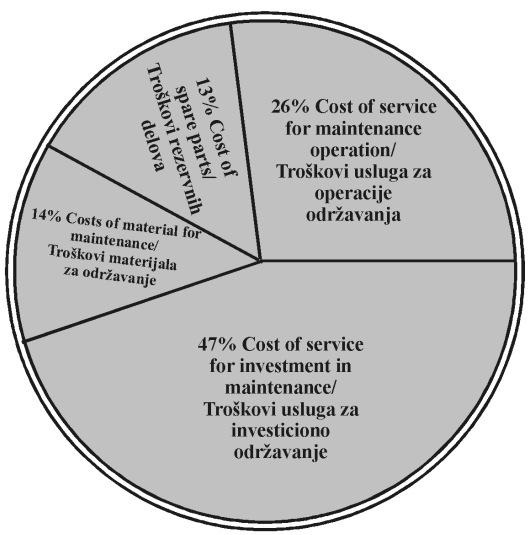

Figure 11. The structure of maintenance costs
Slika 11. Struktura troškova održavanja

Accounted amount of maintenance costs makes only 20-30% of total maintenance costs. As an example, for analyzed manufacturing system through organizational measures and while increasing production, following component maintenance costs were reduced:

- the services for ongoing maintenance,
- services for capital maintenance,
- cost of the materials for maintenance and spare parts,
- storage costs of spare parts and materials and
- costs related to equipment downtime.

Using monitoring system for maintenance costs, production efficiency and client satisfaction are defining matrix for normalization of data (Table 2).

Table 2. Basic matrix for normalization of P7 and P9
Tabela 2. Osnovna matrica za normalizaciju P7 i P9

Maintenance costs/total costs x 100% (P7) / Troškovi održavanja / ukupni troškovi x 100% (P7)	Client satisfaction (P9) / Zadovoljstvo klijenata (P9)	Grade / Ocjena
<1	10	10
1-2	9	9
2-3	8	8
3-4	7	7
4-6	6	6
6-9	5	5
9-15	4	4
15-22	3	3
22-30	2	2
>30	1	1

Although many other factors have influence on volumes of P7 and P9, correlations between P6 (maintenance costs) and P7 (production efficiency) and P6 and P9 (client satisfaction) are very high (more than 0.98).

Relation between P33 (quality level of production and other processes) and fulfilling of delivering due date and volume is also with high correlation (more than 0.95). Normalization of data is realized through matrix (Table 3).

Table 3. Normalization of P33 and P11
Tabela 3. Normalizacija P33 i P11

Quality level of production and other processes (P33) / Razine kvaliteta proizvodnje i drugih procesa (P33)	Fulfillment of delivering due date and volume (P11) in % / Ispunjenje roka i obima isporuke P(11) u %	Grade / Ocjena
10	>100	10
9	98-100	9
8	96-98	8
7	92-96	7
6	85-92	6
5	75-85	5
4	60-75	4
3	40-60	3
2	20-40	2
1	<20	1

Deep analysis shows that most influential are the processes of logistics, management, manufacturing and human resources management (HRM).

Relation between P6 (maintenance costs) and P33 (quality of production and other processes), shown in Figure 7, is characterized also by high regression coefficient (higher that 0.96). Normalization of data is realized through matrix, given in Table 4.

Table 4. Normalization of P7 and P8
Tabela 4. Normalizacija P7 i P8

Efficiency (P7) in % / Efikasnost (P7) u %	Availability (P8) in % / Dostupnost (P8) u %	Quality of other processes / Kvalitet drugih procesa	Grade / Ocjena
>98	>98	10	10
95-98	95-98	9	9
92-95	92-95	8	8
88-92	88-92	7	7
84-88	84-88	6	6
80-84	80-84	5	5
75-80	75-80	4	4
70-75	70-75	3	3
60-70	60-70	2	2
<60	<60	1	1
0.4	0.4	0.3	Weight / ponder

With these results of investigation, the basic hypothesis related to the impact of maintenance in domain of internal perspective is proved. Linking client perspective and financial perspective gives new knowledge about impact of maintenance on higher levels of decision according to competitiveness (P17), prices (P15), revenue (P16) and costs (P14).

Quality of products (P10) is a result of realization of all processes (P33). Relation between these performances is very important for designing quality policy and positioning of organization on the market. Correlation coefficient is significantly high (more than 0.90), but slope of regression curve is not high as we expected. Explanation lies in domain of high monopolistic status of organization based on supplying products for old domestic models of cars and closeness to the clients. The similar explanation is about relation between P11 and P17.

The impact of quality of products on revenue is detected, but it is smaller than in literature (up to 30%), because the price is dominantly influenced by selling those type of products in domestic market.

Quality of products theoretically has an impact on the reduction of total costs. In analyzed organization, because of investments in quality improvement, the costs were slightly higher with the increase of product quality. Regression coefficient was significantly high (more that 0.95).

At the end of analysis, the relation between price (P15) and competitiveness (P17) was analyzed and this relation was very sensitive to price changes. That means, if we define optimal plan based on previous results of investigation, organization is in position to choose trade-off between price and competitiveness, by varying performances under control in all perspectives of this model.

4. Conclusions

Equations should be written using the MS word integrated

From all above presented, the following conclusions could be drawn:

- maintenance management includes strategic, tactical and operational component,
- maintenance costs directly affect the quality and the competitiveness of company, and by approved basic hypotheses, the model of goals, which is the basis for the development of strategic map, is established,
- on the basis of research of initial performance level the model of goals enables the analysis of their interactions, sensitivity to changes and Pareto analysis of key performance indicators (objectives).
- for analyzed organization, the greatest impact have the following performances: maintenance costs (P6), production effectiveness (P7), quality of products (P10) and product price (P15) (Group A in Pareto analysis – about 67% of impact).

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