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Improving Repair Management of Bucket Wheel Excavator SRs1200 by Application of Project Management Concept

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The losses resulting from the defect or breakdown of equipment amount to incredible sums, often far higher than the cost of maintenance, repair or reconstruction. It is for this reason that a large number of methods for maintenance and repair of industrial and other plants have been developed. Elaborated in much detail, these methods nevertheless leave a lot of space for improvement. The improvement is primarily viewed in the context of the management of time, resources and costs of such enterprises. This paper presents a certain concept of project management the implementation of which may improve the maintenance and repair projects. The concept was tested in practice and confirmed in the project of revitalizing of the bucket wheel excavator SRs1200 at MB Kolubara, one of the most complex projects of the kind in the region recently, in terms of technical complexity of reconstruction, the number of participants, the number of activities, cost and time of realization, as well as other elements of the project. The application of this concept allowed for achieving significant results in the technical and financial fields, which will further be analyzed in detail.

Keywords: bucket wheel excavators, maintance management, reapair management, project management

0 INTRODUCTION

Simple consumer items such as small electronics, small appliances, and mechanical devices are expected to work without fail. For more complex items such as PCs, communications devices, and even automobiles, most consumers will tolerate very few failures. For some very complex systems such as nuclear power plants and rocket propulsion systems, failures can be disastrous and very high reliabilities are required [1].

Therefore, proper maintenance and repair in terms of time, cost and quality is of utmost importance.

The result of ineffective maintenance management in the USA only represents a loss of more than $60 billion each year. The losses of production time and product quality that result from poor or inadequate maintenance management have had a dramatic impact on the US industries' ability to compete with Japan and other countries that have implemented more advanced manufacturing and maintenance management philosophies [2].

Smaller countries have to pay even more attention to the efficient maintenance and repair management of the big industrial systems, since their competitive position is far more difficult and losses could have substantial influence on the country's economy and stability as a whole.

Traditional approaches of maintenance and repair management could give acceptable results but they have to be combined with contemporary management disciplines. Modern, specialized management approaches, such as change management, innovation management, risk management, project management are in a process of exploring and developing new possibilities and ways of application.

Various methods and techniques of project management, if adopted properly, could substantially improve processes of maintenance and repair of industrial and other big pieces of equipment.

1 THEORY REVIEW

Industrial and process plants typically employ several types of maintenance anagement [2]:

a. run-to-failure

When a machine breaks down, fix it. This is a reactive, the most expensive method of

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maintenance management. The major expenses associated with this type of maintenance management are high spare parts inventory cost, high overtime labor costs, high machine downtime, and low production availability. To minimize the impact on production created by unexpected machine failures, maintenance personnel must also be able to react immediately to all machine failures [2].

Breakdown maintenance was practiced in the early days of production technology and was reactive in nature. Equipment was allowed to run until a functional failure occurred. Secondary damage was often observed along with a primary failure [3].

b. preventive maintenance

Maintenance tasks are based on elapsed time or hours of operation. All preventive maintenance management programs assume that machines will degrade within a time frame typical of their particular classification. The normal result of using statistics to schedule maintenance is either unnecessary repairs or catastrophic failure [2].

Some of the preventive maintenance procedures have been developed; however, they lack details to make them efficient and safe, and to reinforce sound maintenance practices [4].

c. predictive maintenance

Predictive maintenance is monitoring the vibration of rotating machinery in an attempt to detect incipient problems and to prevent catastrophic failure [2].

d. Total Productive Maintenance (TPM)

The concept was developed by Deming in the late 1950s. It is a program of zero breakdowns and zero defects aimed at improving or eliminating the following six crippling shop-floor losses [2]:

- equipment breakdowns
- setup and adjustment slowdowns
- idling and short-term stoppages
- reduced capacity
- quality-related losses
- startup/restart losses

e. Reliability-Centered Maintenance

If machinery and plant systems are properly designed, installed, operated, and maintained, they will not fail, and their useful life is almost infinite. Few, if any, catastrophic failures are random, and some outside influence, such as operator error or improper repair, causes all failures [2].

These and other traditional ways of maintenance and repair management have significant drawbacks. Various issues could emerge as a reason why these strategies do not give best results in terms of objectives, costs, time and quality. If we focus on these elements: objectives, costs, time and quality, it is more than obvious that tools and techniques, as well the process of project management should be applied in order to improve repair and maintenance management as a whole [5].

Even though, many authors recognize engineering and maintenance as specific projects [6], project management methodology is not applied at all or at least not in a proper way in these areas in transition economies.

This process of project management is intended to guide project managers and project teams in effectively performing key process steps, such as identifying the true need defining the project objective, creating an execution schedule, and maintaining control throughout the entire project [7].

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements [8].

Planning and scheduling major maintenance projects using computer supported Critical Path Method (CPM) techniques was one of the earliest applications of computers in support of the maintenance function. The central idea behind development and use of such systems was to identify opportunities for parallel execution of tasks associated with a turnaround project so that available manpower and resources may be utilized as efficiently as possible to minimize equipment downtime [9].

Typically, the well-designed CPM system produces reports which show how limited resources may be used to complete a project in the shortest possible time. Alternatively, the system may show the manpower necessary for completion of a project in a given length of time [9].

In spite of the CPM system's "head start" in use by maintenance groups, this potentially profitable tool soon was abandoned by a surprisingly large number of plants and companies.

Most companies said the available CPM systems were too complex or too cumbersome for effective use in maintenance turnaround projects

or small construction jobs [9].

There are two major issues for abandoning of the CPM techniques.

First of all CPM is not a project management.

Even though project management has been in existence for more than 40 years, there are still different views and misconceptions about what project management really is. Textbooks on operations research or management science still have chapters entitled "Project management" that discuss only PERT (and CPM) scheduling techniques. A textbooks on organizational design recognized project management as simply another organizational form [10].

Every day engineers, salespeople, technicians, and countless others are thrust into the role of project manager. They're very good at what they do. In fact, they're typically the most technically knowledgeable engineers or the most successful salespeople [7].

Industrial and mechanical engineers usually posses substantial technical knowledge regarding the industry and equipment that they are involved with, but not the knowledge of project management as a process.

The art of project management relates to the fact that projects are really about people getting things done. Project management requires a keen knowledge of human behavior and the ability to skillfully apply appropriate interpersonal skills. The second aspect involves the knowledge, understanding, and skillful application of a prescribed project management process [7].

The customer satisfaction is another very important issue in project management. Customer satisfaction, connected with the criteria for successful project objectives realization, is the basic starting point for the introduction of project excellence [18].

The project management is a scientifically based and practically confirmed concept that uses appropriate methods of organization, planning and control in order to rationally coordinate all the necessary resources and activities in order that a certain project be executed in a most efficient manner [11].

There is a number of approaches to project management, the best known and the most largely accepted of which are certainly those proposed by the International Project Management Association (IPMA) and the Project Management Institute (PMI).

To the purpose of the maintenance and repair of industrial equipment project in Serbia, we propose the project devised by Jovanović [11], which in turn sublimes the elements of other proposed project management models. According to this concept, it is necessary to primarily identify the basic elements of the execution of any project to be planned, monitored and controlled, and these are: time, resources and costs. Therefore this concept of project management includes three basic modules – time management, resources management and project execution costs management, as shown in Figure 1. Planning, monitoring and control over time, resources and costs of the project execution help achieve the basic objectives of the project, i.e., meeting the planned deadlines for the project completion within the planned costs [11].

According to all previously mentioned, we have come to the following hypothesis: the application of project management and the general concept mentioned above, with specific procedures adjusted for this purpose, could substantially contribute to the time and cost reduction in maintenance and repair projects.

In order to prove the above stated hypothesis, we applied the project management concept to one of the biggest repair projects in Serbia.

2 CONCEPT APPLICATION

After the breakdown of the bucket wheel excavator SRs 1200x 24/4 at the surface excavation area "Field D" in the Mining Basin Kolubara, Serbia, which burned away and was cut off from exploitation, which has in years caused a significant delay in the production at strip mines, and consequently the coal tailings, the Electric Power Industry of Serbia decided to reerect - revitalize the excavator to which aim they announced an international tender for the bucket wheel excavator revitalizing project realization, to be funded by a cheap credit provided by the Government of the Federal Republic of Germany through the "Kreditanstalt für Wiederaufbau" bank for reconstruction of Frankfurt.

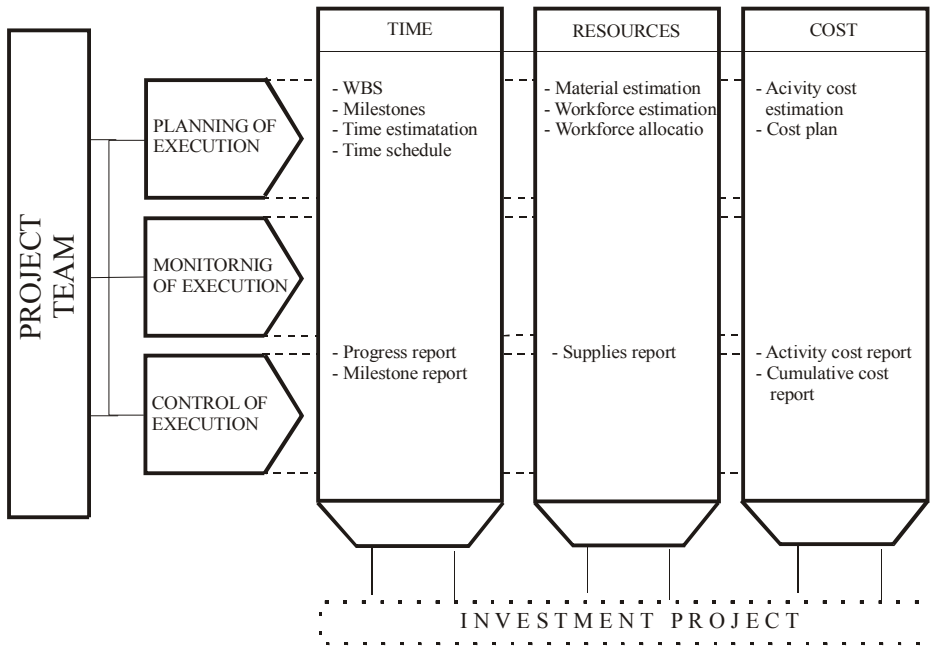

Fig. 1. *A General project management concept*

The tender was announced and carried out aided and conveyed by the consultants VEAG Power Consult of Cottbus, Germany. The tender was won by a German company FAM of Magdeburg, representing the consortium including Kolubara Metal (hereinafter KM) of Vreoci, Serbia, as main subcontractor for machinery equipment and a complete assembly and installment and ABB of Cottbus, Germany, as main subcontractor for electric equipment.

The basic objective of the project was to reduce the lagging in the strip mines in the Mining Basin of Kolubara, which will directly affect the coal stock balance to be delivered by the MB Kolubara to the Steam Power Plant "Nikola Tesla" at Obrenovac. In order to achieve this basic objective, it was the obligation of the FAM/ABB/KM consortium with their subcontractors and suppliers in the realization of the scope of deliveries and services in the contracted period and for the anticipated – contracted (fixed) value of the transaction, to complete the revitalizing and launch the bucket wheel excavator SRs 1201 destroyed in the fire.

The resulting sub objectives are the following:

- The realization of the first revitalizing of the bucket wheel excavator in the MB Kolubara, which in turn will serve as example for the future revitalizations in terms of the method and scope of modernization;
- The modernization from the aspect of the solutions applied both in the machine and in the electric sections, as regards the fact that the original solutions date back to 1968 and that manifold changes meanwhile occurred in the regulations regarding this matter as well as in the applied multidisciplinary technical solutions, so that the constructive and designing measures undertaken in the revitalizing of the bucket wheel excavator resulted in the increase in the excavator capacity from 3450 m^3/h to 4100 m^3/h of loose soil;
- Allowing for further revitalizing by providing a reliable large capacity excavator;
- Technology transfer from German firms to the national ones.

The contracted liability of the KM towards the FAM as the consortium representative includes the following:

- designing (designing detailed engineering for machine equipment);
- malfunction detection (including special purpose tests) and revitalization of

machine equipment and steel structure;
- manufacturing, transport and assembly of the entire revitalizing and new equipment at the assembly site at Zeoke - "Field D"
- participation in functional trials of the assembled tool in the free mode of operation;
- participation in the launching of the excavator in the full load mode of operation.

The contracted value of the transaction of the Kolubara Metal was stipulated at 3,095,000.00 EUR.

Bearing in mind that the key elements of the bucket wheel excavator SRs 1201 revitalizing were the deadline, the budget and the participation in the consortium, the general management of the KM made a firm decision to apply the project management approach with all its elements in this job, primarily on the basis of the proposed project management concept, as well as the project management procedure adapted to the projects of overhauling and revitalizing of heavy machinery equipment as given in [11].

To the purpose of increasing the capacity of the KM in the field of project management the experts from the University of Belgrade and the Serbian Project Management Association (YUPMA), member of the International Project Management Association (IPMA) were recruited.

In accordance with the concept, the project organization structure and the KM project team were formed first, to be engaged in revitalizing work. As there is a large number of participants in the project, the project organization structure is rather complex and is shown in Figure 2.

The project itself was conducted by the KM project team consisting of a number of functionally different experts, so that a multidisciplinary approach could be achieved. The team included the project manager (the team leader), 1 mechanical engineer, an expert in the assembly/dismantling activities, 1 civil engineer, an expert in steel structures, 1 mechanical engineer of machinery equipment, 1 electrical engineer, 1 graduate process engineer for antirust protection, 2 mechanical and 1 electrical technicians, with an occasional inclusion of 1 graduate process engineer specialized in welding. In addition to the mentioned team members, the experts from the Serbian Project Management Association were engaged as consultants and provided professional support in all the phases of project management.

The given project management concept meant that the execution would be planned in detail, so that the plan of the overall project was obtained, which in turn would serve as basis for further management. Devising the project plan meant identification of all activities to be carried out as per contract, devising the WBS (Work Breakdown Structure) and determining the key events.

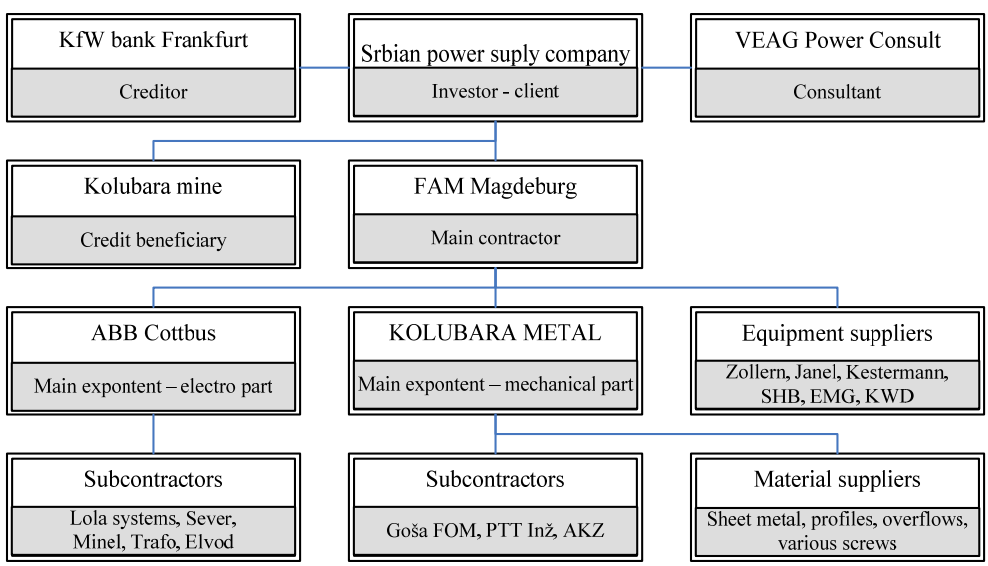

Fig. 2. *The bucket wheel excavator SRs 1201 revitalizing project organization*

A special problem in planning referred to identifying the prospective newly established activities (additional works or supplies caused by a detailed malfunction detection of equipment previously estimated as usable, possible delays in manufacturing by the subcontractors, etc…). On the basis of the detailed plan of activities a time plan and an estimation of the duration of the project were worked out.

The further structuring of the bucket wheel excavator SRs1201 x 24/4 revitalizing was worked out by coordinating individual activities to be carried out with the persons and/or sectors in charge of these activities, as well as responsibility the function bears. It was in this way that the estimate and allocations of workforce, as well as responsibility matrix on the project were determined. In accordance with the concept, the allocation of financial and other resources to particular activities, phases and the project in general was performed, on the basis of which an estimate of resources and costs of the project was accomplished [12].

All the activities related to the project plan were carried out using the project management software tools – MS Project. The master plan scheme is shown in Figure 3.

Due to the complexity of the project, the monitoring and control of the project execution was multilevel. A large number of participants, on one hand, and the demand for high quality of equipment and works performed, strict deadlines for accomplishment individual phases and the project as a whole and over all the project budget that was firmly restricted by the key-in-hand system, on the other hand, required that the approach to management, as well as control of the project execution be consequent [13]. In accordance with the concept adopted, the KM project team decided to do the monitoring of the project execution through the following elements [14]:

- the plan control,
- log,
- receipt control at the manufacturer's and on delivery,
- daily, weekly and other meetings
- various reports and protocols.

A detailed control plan was devised [15] and offered it to the FAM and to the EPS and they accepted it. The plan of control included all the activities in the project that were to be carried out in the KM head office, in the KM workshops and at the site itself.

A log was kept since the opening till the closure of the building site at the assembly site, where all the works and the daily scope were entered and verified by the supervisory board. On receipt of all supplies the receipt control was carried out upon receiving parts or equipment, while in special cases the receipt control was carried out at the manufacturer's, according to the concept adopted.

Daily briefings of the project team took place, during which the members reported what was accomplished the previous day and agreed upon what was to be done next. Also, there were weekly meetings with the representatives of the FAM or the ABB that were ever present at the building site. If necessary, the meetings were organized with all member teams. On all these meetings the official protocol was made. On two-monthly basis the Investor-client organized and the Consultant chaired status meetings, where the project management of the investor and project

ID	WBS	Task Name	Duration
0		**Revitalization project SRs 1201**	**365 days**
1	1	Basic engineering	252 days
3	2	Detailed engineering	234 days
5	3	Technical documentation	126 days
7	4	Revitalization of existing equipment	273 days
9	5	Development and purchase of new equipment	245 days
11	6	Machinery assembly	249 days
13	7	Electric assembly	154 days
15	8	Functional testing	14 days
17	9	Test work	14 days
19	10	Capacity proof	7 days
21	11	Delivery to client	7 days
23	12	Final delivery protocol	0 days

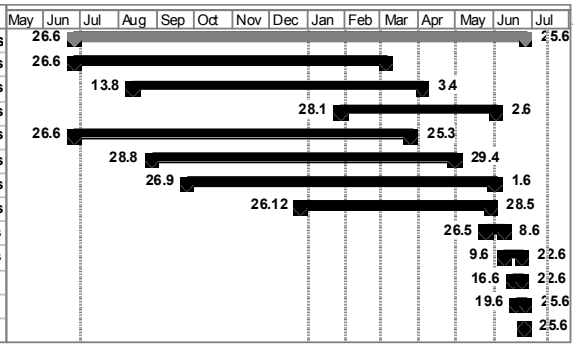

Fig 3. *The project master plan*

managers of all the project teams participated (FAM, ABB, Kolubara Metal).These status meetings were dedicated to the analyses of the progress of the project from the point of view of production, delivery and installment and the accomplished activities were compared with the time-term plan of realization; then the problems were discussed – discrepancies and the method for solving as well as the quality level of the manufactured and installed equipment. Of course, the payment rates to the main contractor were analyzed, as they further affected other payments to other participants in the project.

The project operational monitoring and control were primarily based on the software support of the MS Project. The computer work was carried out when needed, using the mentioned software primarily in the context of time, resources and cost management. The entire system, regarding the space dispersity (3 locations: head office, production and installment) was supported by an appropriate network system.

The project supervision and control were also multilevel. The Investor-client EPS, as mentioned above, formed their own supervision team consisting of the experts from the EPS, Kolubara and the *consultants* from the German firm VEAG Power Consult. On the other hand, the main contractor FAM and the main subcontractors ABB and Kolubara Metal formed their project teams that actually managed the project and controlled the execution. In view of their real position and influence upon the execution of individual phases of the project, the the main contractor's and the main subcontractors' project teams executed an in-depth control over all the elements of the project. This means that their actual impact upon the scope, quality and project realization deadlines was by far greater than that of the Investor. This was supplemented by the need that the contractors' project teams, in addition to their own capacities, were in charge of controlling the performance of their subcontractors and supliers of equipment and production material.

Throughout the execution of the project the KM project team received demands to make certain changes which proved an additional challenge. The demands for change mostly referred to the discrepancies between the EPS teams and the user, the Strip mine Polje D (Field D). The pressure was mainly of technical nature and included, on one side, the demands that larger scale modernization than contracted be made, and, on the other side, that better and more modern solutions be used, which made it impossible to remain within the contracted budget [16]. The Kolubara Metal project team was also under pressure to shorten the previously stipulated deadlines, without all aspects of the project execution being taken into account – for example, supplies, tenders, sub deliverers etc. The best method of managing such change was to keep accurate and complete documentation so as to be able to firmly prove that such demands of the Investor were not appropriately based, and that the demands were excessive.

Despite the cited problems and a striking complexity of the project, the project was successfully brought to an end in accordance with the demands of all project stakeholders. The execution time was 12 instead of the initially planned 14 months, which resulted in significant savings. The technical results and the quality of the project could also serve as an example of good results.

3 RESULTS AND DISCUSSION

Revitalizing of the bucket wheel excavator SRs is of paramount importance for the work of the KM plant and the EPS in general, since it directly affects the production of electricity, and therefore the business operations of a large number of firms in Serbia. Therefore it was of great importance that the revitalizing should be accomplished in as short a time as possible and with the lowest possible costs, so that the losses should be reduced as much as possible.

The project technical results achieved were excellent. After 12 months the project lasted, the total of 1460 t of hardware was installed (including 108 t ballast) as well as approximately 115 t electric equipment, cables (power and optical) and auxiliary structures. The result of this complex job was a bucket wheel excavator SRs 1201x24/4 with substantially improved properties which can be observed in Table 1. Besides these technical results that we can boast of as an outstanding accomplishment in modern practice, as regards their technical specification and the project quality, the financial results of the revitalizing project that are accomplished are also important.

Table 1. *Properties of averaged and reconstructed excavator*

Averaged SRs1200:	Revitalized SRs1201:
• Capacity 3465 m^3/h • Bogie wheel motive power 400 kW	• Capacity 4100 m^3/h • Bogie wheel motive power 630 kW • Circular motion tripple drive of upper construction • Container principle of electric equipment installation • Frequency regulated power

The losses resulting from the bucket wheel excavator breakdown may be classed in two groups: direct losses and indirect losses.

The direct losses refer to the reduced production of coal to be used in the steam power plant, and hence to the reduced production of electricity. The indirect losses are related to the reduced, endangered and inefficient business of numerous commercial and non-commercial organizations dependant on electricity supply. In order to stress the results achieved by the project management application in the bucket wheel excavator revitalizing, we will present the direct benefits resulting from an efficient management of this enterprise.

According to the KM statistical data, conclusion can be drawn that an annual output of the bucket wheel excavator (11 months of exploitation and 1 month routine maintenance) amounts to between 5.5 and 7 million m^3 tailings, which means approximately 550,000 m^3 tailings on monthly basis. As per normative data, the production of 1 ton of coal uses 2.5-3m^3 tailings. This means that the output of the bucket wheel excavator is 200,000 - 230,000 tons of coal monthly, i.e., 2 - 2.3 million tons of coal annually. Furthermore, if taken as an equivalent that 1.5 kg coal produces 1 kWh of electricity, then the monthly output of the bucket wheel excavator amounts to 150 million kWh of electricity, which converted into currency amounts to about 4.5 EUR million per month.

According to the KM and EPS experts estimations, and on the basis of the investigation performed, it is maintained that the indirect losses are three times larger that the direct ones, so that they amount to about 13.5 EUR million per month. On the basis of the technical documentation and the technological method, as well as on the basis of previous experience of the consortium and the YUPMA experts, the designed bucket wheel excavator revitalizing was planned to last 12 months. Experiences regarding such projects show that the usual delays are 3 – 6 months as regards the planned period.

The application of the project management concept in the planning and execution of this project, allowed for the project to be accomplished within 12 months, thus directly saving at least two months or 9 EUR million of direct costs. If direct losses be included, then the savings obtained by the application of project management are even larger and amount up to 36 EUR million.

Very good results were also achieved in the resources and cost management of the project itself, in all its phases and activities. We can freely maintain that the departure from the cost and resources plan devised with the project management methods was almost negligible.

During the one year of the project term the whole KM project team, as well as some representatives of subcontractors, suppliers and other collaborators were subject to a lot of training concerning project management and software tools used as logistic support, which resulted in raising the TM capacity, but also in creating teams of engineers capable, by changing the project management, of promptly and efficiently performing any complex maintenance or repair projects.

Therefore, it can be maintained that the analysis of the results of the revitalising project clearly proves the initial hypothesis and that the results accomplished applying the project management have had great effects in time, costs and resources management in the project, which further resulted in extraordinary savings, as the bucket wheel excavator SRs 1201 was launched again.

4 CONCLUSION

Despite numerous advantages, the traditional methods in the management of maintenance and repair of machinery equipment do have some weaknesses. These weaknesses are mostly related to the time, resources and costs management, however, in managing these enterprises not enough attention has been paid to the human aspects. The paper present a general project management concept which, combined with the traditional methods, may largely improve the existing systems of maintenance and repair management. The application of this concept to the bucket wheel excavator SRs 1201 revitalizing in the MB Kolubara, Serbia, allowed for significant direct and indirect savings resulting from an adequate resources management. These savings are, in the first place, the result of shortening the duration of project execution by two months, thus avoiding the opportunity costs of approximately 36 EUR million. The concept applied clearly achieved the set objectives, but also allowed for its further application in similar projects in this country and in the region.

Further research should certainly be directed towards the elaboration of the concept as regards specific procedures, both in routine maintenance and in emergency cases such as breakdown, thus making it possible to reduce losses and avoid other problems arising from scheduled or unscheduled equipment failure.

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Corrigendum

Product Family Modelling in Conceptual Design Based on Parallel Configuration Grammars

Eugeniu-Radu Deciu, Egon Ostrosi, Michel Ferney, Marian Gheorghe
Strojniški vestnik – Journal of Mechanical Engineering, vol. 54(2008), no.6, p.398-412

The equation 7 on page 408 of the above mentioned article has to be corrected. The corrected form of the equation :

$$P_1^{add}: \left| \begin{array}{c} \left[\langle CONICAL\_THREAD\_AREA \rangle \rightarrow \langle CYL\_THREAD\_AREA \rangle \langle CONICAL\_AREA \rangle \right] \\ \left[\langle PlaneConnection \rangle \rightarrow \langle ExtPlaneFace_1 \rangle \langle ExtPlaneFace_1 \rangle \right] \\ \left[\begin{array}{c} \langle ExtThread \rangle \rightarrow \langle ExtThread \rangle \langle 0 \rangle \\ \langle ExtPlaneFace_2 \rangle \rightarrow \langle 0 \rangle \langle ExtPlaneFace_2 \rangle \\ \langle KeyGroove \rangle \rightarrow \langle 0 \rangle \langle KeyGroove \rangle \\ \langle ConicalLatFace \rangle \rightarrow \langle 0 \rangle \langle ConicalLatFace \rangle \end{array} \right] \end{array} \right|$$

Understanding the Mechanical Properties of Self-Expandable Stents: A Key to Successful Product Development

Daisuke Yoshino - Katsumi Inoue - Yukihito Narita
Strojniški vestnik – Journal of Mechanical Engineering, vol. 54(2008), no.6, p. 471-485

In the footnotes of the above mentioned article there has been a mistake. Above there is the corrected title. The wrong form of the title appeared in the footer of the pages (473/475/477/479/481/483/485).