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MAINTENANCE AND EFFECT OF MACHINES WORKED ON CONSTRUCTION SITE

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Abstract: The paper explained meaning and importance of the impact of construction machinery due to the specifics of their use. Describes how organization of maintenance activities of machines on construction sites and points to the impact this has on their performance. Accent was placed on possibilities of improving existing practice of building contractors and emphasized need for monitoring of achieved results, development and continuous updating of internal databases which are basis for planning and decision-making on implementation of mechanized work.
Key words: construction machinery, costs, maintenance, planning, effect

1. SPECIFICS OF USE AND MAINTENANCE OF MACHINES WORKED ON CONSTRUCTION SITES

Machine performed processes are often critical for deadlines and have a lot participation in implementation of construction projects, especially in engineering and new construction (up by earth and concrete works). Construction machinery has a number of important special features in relation to use and maintenance of machines in industrial plants, and there are certain similarities with machines in other industries (e.g. mining, forestry and shipbuilding). Usage of machines on building sites most is characterized by:

- Various characteristics of completed tasks over lifetime of a variable operating conditions (each project is unique);
- Work in workplaces temporary (change of work - from site to site, and at one site often more places of work);
- Use of machines that are not always optimal choice for a type of tasks (because of existing amount of work is not worth bringing another machine);
- Work mostly outdoors (exposure to different weather conditions);
- Disparity amount for implementation over a long operating time (often and downtime);
- Dislocation of works of the central places of machines, and consequently need for transport to any construction site (sometimes requires assembly and disassembly) and organization of maintenance activities of machines at each site.

For reliable cost planning work and for scheduling implementation is necessary to know impact of machines intended to be used, and that effect of specific site conditions of work. Unit labour costs of machines are direct costs and are calculated in the unit price analysis as the product cost hours of work a particular machine (how much contractor) and the norms of time, which should be inversely proportional to size of average realized performance. The duration of each activity expressed in working days deterministic is calculated as the quotient of product of amount of work and norms of time and the product of number of planned resources and number of working hours per day. Similarly it can be for a given operating time determined by required number of machines for a particular activity. Knowledge of effect it is necessary to realistically determine tasks to be implemented with available resources, in particular conditions at a given time, and to be able to harmonize the work of machines that work related.

2. PLANNING PERFORMANCE AND RELIABILITY OF CONSTRUCTION MACHINERY

Effect of one or more machines can be defined as amount of work satisfactory quality, or product, expressed in adequate accounting units (m^3, m^2, m, pc, t), which is performed per unit time, which is

usually one hour. In construction practice more common problem are lack of knowledge on impact needed for planning costs and time, or lack of appropriate norms. Before 30-40 years there are general, national norms for construction machinery (e.g. [12]), but today – the state is not interested in making such norms, and considering a lot of different machines used, it would be an extremely extensive venture. Therefore, every company should create their own, internal norms for work performed by machines that use and/or have relevant data for calculation of their planned performance.

Because of the introductory mentioned reasons, planning the impact of construction machinery is not easy. Usually there are some data from the manufacturer of the basic technical effect, i.e. theoretical effect (E_t), but not on the performance that can be achieved in concrete terms on a construction site, so-called planned or practical effect (E_p). The theoretical effect arises from the structural characteristics of machine, such as power, speed in operation, capacity and size of tool. However, this effect can actually be achieved only with a new machine, in almost ideal conditions and for a short time (up to 1 hour).

Planning effect depends on technical characteristics of each machine (i.e. E_t), but also of various specifics of working conditions at each site. Studies have shown that greatest impact on performance are technical parameters of machines, organization and experience, fatigue, health status and motivation of workers, but at least weather conditions [13]. If plan was good and there were no unforeseen impact on execution of work, then they realized effect should be approximately equal to the planned effect.

Although there are stochastic models for determining size of the impact of construction machinery (based on principle of equilibrium statistical series relating to quantitative characterization of random events over random variables) [7] [8], they are applied only to the various theoretical, and in civil engineering practice "maximum range" is a deterministic calculation of impact. Stochastic models are more specific, but give almost identical results and are quite complicated [8]. Deterministic calculation implies multiplication hour theoretical effect (for machines that run cyclically this effect is calculated as product of the number of cycles per hour with the amount of work to be done on average in one cycle) with a series of correction coefficients ($E_p = E_t \times k_1 \times k_2 \times to \times .... k_n$) whose dependent of machine type and of application characteristics. [4] [6] [9] [10] [14] [15].

There are more similar methodology for calculating performance machines (with different coefficients of correction and their value), of which those of known machine manufacturers give greater effect sizes calculated. For example, in relation to article presented procedure, budget *Fiatallis* for excavator with bucket of 1.0 m^3 gives 20%, 36% of budget of *Komatsu*, *Caterpillar*'s 48%, a *Liebherr* 53% more performance, while *Handubuch BML* gives 11% lower calculation impact. [9]

The usual correction coefficients to determine the impact of construction machinery are listed in Table 1, according to limits of their range in size can be seen that up can be more than ten times smaller than Tues. The maximum number of coefficients and largest reduction effect is at earthmoving. When calculated effect of operating time is longer than one hour is necessary to take into account higher percentage of unused working hours in these long periods of use of the machines. As amount normally expressed without taking account of material plus soils (clay material in a fused state) effect should be even cheaper by multiplying coefficient of friability whose size is inversely proportional to percentage of soils.

For all machines for safety may not always be in perfect condition (vehicle travelling on public roads, cranes) calculated effect is reduced due to anticipated failure or deterioration of k_{dm}. As seen in Table 1 of this reduction can be up to 29% of theoretical performance and amount of impairment effect may be even larger than size at the end of calculated planned effect. However, such a calculation was arbitrary because it is based solely on the current number of operating hours. In general, if machines have not had extraordinary damage new are those with up to 2000 hours and for them there is no impairment effect, machines with 2000-4000 hours of operation are considered to be preserved and their effect is reduced by 9% due to deterioration, machines with 4000 - 6000 hours of operation are considered worn out and their effect is reduced 20%, and machines with more than 6000 hours of some of literature [12] declared as "totally worn out" and their effect is reduced by 29% - correction coefficient k_{dm} includes assumption of age or condition, and of maintenance of machines and allows planning values individual performance of machine in terms of assumption of reliability. Reliability, depending on the use of machines and operating conditions, can have multiple meanings and

characteristics, for example, trouble-free operation, durability, flexibility and others. Reliability single machine as a technical system depends on reliability of functioning of its assemblies, subassemblies and parts, and determination of their interactions and relationships between them, and this is a direct effect of preservation. [9]

Failures in machines are often the result of wear, tear or aging, but their performance declining constantly and gradually. Only numerical assessment of damage degree in worn parts solves the issue of evaluating and calculating reliability of parts, and this requires knowledge of the law to wear and tear. External factors (nature of body rubbing, initial play, kind of friction, at partial load on surface friction velocity, environment, and in particular oil and ambient temperature) significantly affect interaction of internal (plastic deformation and release of heat exchange surface roughness, structure, mechanical properties and properties film, accumulation of energy in material under cyclic load may) and output factors (rate of removal, intensity of spending, linear wear). However, this relationship is very difficult to express in analytical form, but on basis of empirical data defined range limits for certain types of damage, under certain conditions. [6]

Table 1. The most commonly used ratios to correct the theoretical impact of construction machinery with the usual border sizes. [9] [12] [14] [15]

Coefficients of correction - kind of influence on effect	Limit size	Remark
k_{ut} – utilization of working time	0,75 – 0,92	Taken into account in all machines
k_{ow} – organization of work on construction site and management	0,5 – 0,83	
k_{dm} – deterioration (according to the previous number of worked hours)	0,71 – 1,00	
k_{ft} – average filling of working tools	0,40 – 1,20	The effect of working conditions and the task (characteristics of the material, terrain, etc.) on the amount work performed in one cycle of work, or the work speed - for machines that run continuously.
k_{km} – knife of machine (for machines with a knife no k_{ft})	0,40 – 1,20	
k_{ak} – blade pitch angle to direction of machine movement	0,60 – 1,00	
k_{lm} – loss of material sliding along section (dozers)	0,50 – 0,95	
k_{st} – slope of terrain travelled by it full machine (dozers)	0,40 – 2,20	
k_{at} – altitude	0,90 – 1,00	
k_{mm} – moisture of material (earth) with which to manipulate	0,30 – 0,95	
k_{ws} – convenience of working space for maneuvering of machine	0,95 – 1,00	
k_{ar} – angle rotation about an axis in working cycle (only a crawler)	0,71 – 1,26	
k_{hf} – average height of working face at work	0,80 – 1,00	
k_{lv} – suitability of transport vehicle loading (1.00 if unloading on pile addition processing machine)	0,83 – 0,91	

Because of many influences it is difficult to predict exact border between state of work and dismissal. More realistic solution provides introduction degree of belonging to state of the elements in work or dismissal. These balances represent Fuzzy events that describe the elements Fuzzy sets. Failures happen by accident, but are probabilistic events for which applies probability theory Fuzzy events. Several authors have in their papers applied this theory to determine reliability and maintenance management of technical systems [11] what are considered construction equipment.

3. MAINTENANCE MACHINES ON CONSTRUCTION SITES

In the 21st century, developed advanced strategies maintenance of technical systems, but they are as yet not applied in machinery on construction sites.

In relation to occurrence of faults, maintenance of construction machinery could be corrective and preventive. Corrective maintenance is intervening in order to eliminate unexpected failures. It is always important to remove causes that led to their creation. It can be by replacing individual parts of machine or repairs (adjustment, lubrication, cleaning and other processes).

Preventive maintenance works according to an established plan. Planning maintenance of machines based on knowledge of all relevant data about them (on application, functioning and management, carried out repairs, mode of transport, preservation, accessories and spare parts, instructions for setup,

maintenance and lubrication, test records machinery, norms for maintenance, etc.). They plan to check-ups, cleaning and lubrication, search and elimination of weak points and small, medium and major repairs and capital repairs.

One-shift maintenance procedures (e.g., visual inspection and lubrication performed alone machine operator) are performed before or after each work shift, periodic maintenance is carried out by manufacturer of the machine (checks without disassembly, cleaning and small repairs, lubrication, replacement and amendment of certain elements and settings in which along with machine operator and mechanic participate and associate - usually after 50, 100 or 200 or 250, 500 and 1000 or 2000, or 3000 hours of operation, and always includes all necessary actions to maintain for a short period containing) [16] and seasonal maintenance is usually performed twice a year (preparing machine for work in autumn-winter and spring-summer). Before storing machine needs to be carefully cleaned, paint the affected area, etched metal parts protect corrosion protection, rinse system and fill it with new operating fluids, and conduct regular operations of periodic maintenance and preservation. Greater complexity of machines and higher intensity of use in severe operating conditions (harder materials) requires more maintenance time, greater expertise and procedures that are performed in specialized workshops. Capital repair involves completely dismantling machine, review and selection of elements to those that can still be used, those who repair and those that must be replaced; significant savings with using modular units that were previously taken from other machines and renovated. [6] The decision on repair of such high returns are based on technical commission (established state machine) and economic indicators.

Preventive activities can be undertaken on basis of the time limit (where spending alike when it comes and when it does not work) or a specified number of hours worked mileage or consumed kWh. Studies have shown that the wear parts 37% more correlated with energy consumption than with hours of driving or km [6] or as early warning indicators of possible errors and delays. Such indicators are obtained by checking the current situation and the working performance of the machine which is characterized by predictive maintenance. Regular maintenance activities while there has been no failures in work of reducing cost of ownership and operating costs, [5], since it avoids damage that occurs when work is interrupted due to a malfunction. Preventive and predictive maintenance, especially in various activities showed that leads to a significant reduction in required quantity of spare parts and reducing downtime and increasing productivity and profits. [1] Possible ways of organization of the maintenance of machines in construction companies (according to [16]) and their characteristics are listed in Table 2.

Table 2. Models of organization maintaining machinery on construction sites

Org. model	Characteristics of maintenance and suitable cases for application
Centralized	Only one maintenance department with workshop and tool room (usually in the central drive companies) that operates very well (good equipment, quality experts, facilitated the collection and processing of data), but the problem is worse in connection with all sites and places of machines on them (poor monitoring and responding to sudden failures).
Individually (decentralized)	At each site with machines is service maintenance with a workshop, appropriate to the type and number of used machines. Problem is that construction companies rarely have enough for professionals, but multiplied equipment is generally less utilized. Therefore, such maintenance, generally, organized only for larger, separate site.
Combined (centralized with remote groups to maintain)	Small maintenance services are organized at each site (well aware of the condition of machines and react quickly), but in the case of complicated interventions work experts from the central departments. Current maintenance is carried out on the site (with mobile workshop), and investment maintenance is usually performed in the central workshop or service.
Cooperative (outsourcing)	Maintenance is partially or totally outsourced to specialized services, which may be the manufacturer of the machines. The situation is similar when it hired the machines, but on their maintenance care owner. This is good for small companies that do not have the specialists and equipment.

The organization of maintenance should always be consistent with - number, type and arrangement of machines and need to be flexible because of frequent changes of tasks to be fulfilled. Organization of

maintenance should include planning and implementation of technology to link maintenance, planning, supply of spare parts and equipment, training of service and user machines, and organization of warehouses and workshops to support on high and low level of maintenance, all accompanying documents. In planning cost of using machines, as well as the cost-benefit analysis of their purchase, must be, to include maintenance costs. Quite simply rough guidelines determine size of maintenance activities on construction machine on annual basis in relation to accounting cost C (factory price plus the cost of procurement and delivery) according to the model: [10]

- For basic maintenance 0.06 x C in stationary machines, 0.09 x C at transport machines
- For medium maintenance 0.08 x C in stationary machines, 0.11 x C at transport machines
- To maintain a large 0.10 x C in stationary machines, 0.13 x C at transport machines

With this should be taken into account and the cost of the test run, which can be assumed in the amount of approximately 2% of the ex-works price of the machine and costs of procurement and replacement of wearing parts (proportional to the amount and heaviness of working conditions). [10] Orienteering can be assumed that total cost of hours of construction machinery cost of their maintenance is 9-10% [3]. In the opinion of Assakkafa [2] even up to 35% of the costs of construction machinery should focus on maintenance and repairs, because savings on it can only be short-term as it will lead to bad technical condition of machine, reducing impact of low-quality work and increased risk of injury and environmental disasters, protracted downtime due to failures on machines, etc. [8]

3.1. Possibility for Improved Performance and Reliability of Construction Machinery

It is important to know the usual time losses occurring in the implementation of construction projects in order to know to plan those to whom it cannot act, and to minimize or avoid (almost never completely) the negative effect on those who are in some way can act. Losses time that according to natural causes (most weather conditions) and technological nature (changes jobs at the site, changes haulage roads, uneven and partly of load, etc.) Cannot be avoided, but only good planning and organization (adaptation) reduced . Delays that can be avoided with better preparation, management and monitoring arise due to lack of materials, spare parts and driving energy, poor distribution on the construction site, inconsistent workflows, poor choice of machines and tools, machine failures, lack of training, lack of motivation and discipline employees etc.

It is difficult to act on the working conditions (characteristics of materials, space and time, and the availability of certain resources in company and in market), but it is always possible to have a positive effect on other factors that influence effect achieved. Such measures are listed in Table 3:

Table 3. Effect of possible measures on increase the impact of construction machinery

Measures to increase the impact	Action over:
- Selection of optimal machine (between available) for required tasks (in order to give maxim. effect)	T_C, speed
- Preparation and planning of work - number and spatial distribution of machines, compliance effects machines that work-related, path of action moving machine at work, backup in effect in accordance with the severity of working conditions (10 - 30%)	T_C , speed , k_{ow} , k_{ws} , k_{lv} , k_{hf} , k_{ar} and k_{ws}
- Appropriate preparing ground for the operation of machines (e.g. in earthworks optimum moisture)	T_C , v and k_{mm}
- Ensuring regular supply of necessary energy and auxiliary materials for machinery	k_{ow}
- Selection and training of workers who work with machines, and their motivation (duly rewarding and communication) in order to take advantage of more and kept machines	T_C , k_{ut} , k_{ft} and k_{dm}
- Timely preventive maintenance and rapid response in case of corrective action (with help of technical diagnostics, machine operators and maintenance of specialized mechanics)	k_{dm}
- Monitoring of work - to ensure discipline and collection of data on realized and actual operating conditions (for planning future work assignments)	K_{ut} & *reliability*

Based on analysis of the costs and impact on performance of machines should choose the most appropriate way of maintenance. You should also consider feasibility of investing in purchase of new, better machines, which provide opportunity to achieve greater effects, more suitable for maintenance (easier maintenance and self-maintenance, and embedded devices for technical diagnostics) and use IT to monitor job performance.

Monitoring work is important for performance evaluation work (reward - motivation of workers) and to determine the norms and weather data for planning effect machines (working cycle - T_C or speed, and correction coefficients). The coefficient of deterioration should be defined according to the actual situation and the reliability of maintenance of each machine at the construction site. To create norms uptime of machines operating in repeating cycles of shorter duration is the most suitable chronometer method (measured only productive time, but subsequently has to add other average spending of time), and, as a supplementary method, it is good to use the working reports in uniform patterns the water anyway due to the normal course of business sites and companies. It is vital to establish a rational system of storage and supply with spare parts, because it has a huge impact on the reliability and cost. Planning is always a process and the process for construction machinery shown in Figure 1;

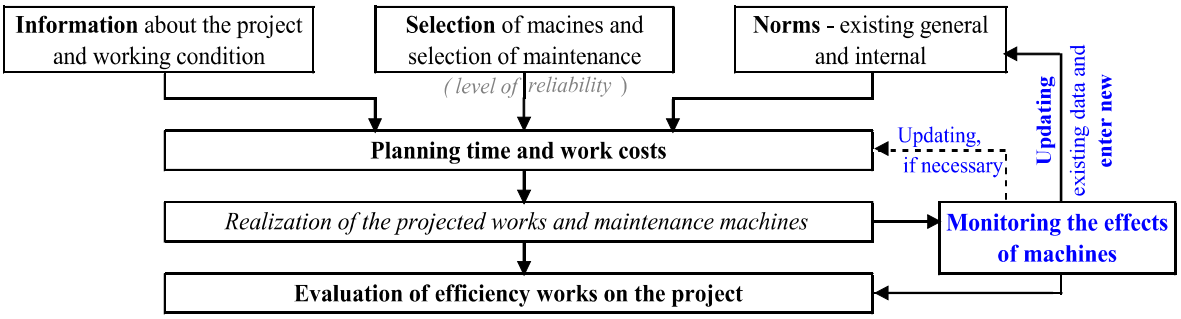

Figure 1. The process of planning the use of construction machinery

4. CONCLUSION

Achieving greater impact machines generally for contractors means lower costs and shorter deadlines. Data listed in article see importance of maintaining performance of construction machinery and share cost of maintaining - total cost of using machine. Maintenance affects safety of workers, and safety is one of factors of motivation. For all these reasons, economically works machines on site require prior well organize and plan their use and maintenance. Optimal choice of machines, as well as their use and maintenance, are among crucial problems and tasks of construction project management and organization of construction production. [12]

To plan a performance of machines recommended parallel use norms (primarily internal, and if there are adequate general norms and they should be taken into account) and budget provided for under influence of position and machine, calculated from actual sizes of correction coefficients.

Knowing positive and negative impact on performance of construction machinery in particular operating conditions it is important to be able to act on them in order to achieve higher productivity and that could be more realistically planned term and costs.

Positively can act from a position of leadership and the position of the machine operator and other workers, which is in the spirit of the totally productive maintenance (TPM).

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