Mechanics Transport Communications

Academic journal http://www.mtc-aj.com

ISSN 1312-3823 (print)
ISSN 2367-6620 (online)
volume 17, issue 3, 2019
article № 1777

THE HIERARCHY OF EFFICIENCY INDEXES FOR USING OF EARTHMOVING MACHINES AT VARIOUS LEVELS OF MANAGEMENT DECISIONS

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Key words: *Efficiency, monitoring, road-construction machines, unit cost of production.*

Annotation: *Methods of technical and economic evaluation of road-construction machines are highly developed but their operation requires a wide list of initial data which is very difficult to obtain without monitoring systems. In modern conditions, economic factors determine the possibility of machines' operation and the technical excellence of the machine is viewed by considering the cost of ownership and operation. This determines the relevance of the application of technical and economic assessments. In order to ensure the feasibility of applying of such technical and economic indexes towards the efficiency evaluation, they need to be adapted for use in monitoring systems. Modern monitoring systems allow you to monitor the technical and operational characteristics without a comparison with the indexes of the economic sphere. There is almost complete uncertainty in the methods of selection and evaluation of equipment that could be used in practice in modern conditions characterized by the presence in the market of equipment of the same purpose from different manufacturers. In such conditions, a system for collecting and processing the information with feedback would be convenient - a monitoring system for effectiveness evaluation. Feedback is necessary for creating the control actions in order to increase the efficiency or maintain it at satisfactory level - performance management. The development of methods of both technical and economic assessment which are suitable for using for road-construction machines and adapted for implementation in monitoring systems is a relevant topic of scientific research.*

The concept of efficiency applies not only to machines but also to enterprises which determines the hierarchy of efficiency indexes for different decision-making levels. Indexes of this hierarchy can be applied to the evaluation of the technical and economic efficiency of a certain road-construction machine [1].

Natural indexes (length, time, area, volume, mass, etc.) that occur at the driver's level, form more complex, intermediate indexes (metal consumption, productivity, energy intensity, etc.), which determine, in turn, indexes of the next level (for example, the full unit cost of production) [2; 3].

There may be the following hierarchy of indexes presented in real time by monitoring (actual), related to different decision-making levels:

• level of operator and/or on-board computer: efficiency indexes; indexes of the functional state of the aggregates; indexes of stock sufficiency of materials (technological, fuel and lubricants);

• level of the work supervisor at the facility: indexes of the integrated productivity of the unit (or group) of the machines; performance schedule, indexes (alarming) of the operability; indexes (alarming) of the position or direction of movement of the self-propelled machine; indexes of the physiological state of the driver or operator, indexes (alarming) of the quality of work of the machines;

• level of the Head of the enterprise: integrated indexes of the implementation of the schedule; quality indexes (emergency) of operation; indexes (emergency) of machine operability; indexes (emergency) of the schedule;

• level of regional and sectoral leader: indexes of risk to the life or health of the population of the region, indexes of the threat to the environmental situation; generalized indexes of the implementation of the schedule of works on the objects by contractors.

The efficiency of equipment exploitation may depend on decisions which the implementation is mandatory directly in the process of work as well as on strategic decisions that are appropriate for further using of equipment. Due to the fact that the collection and processing of data in automated systems may take some time, to simplify data processing it is advisable to separate the indexes obtained during the monitoring which need to be processed in real time, and the indexes that can be processed with a delay.

To simplify the separation of indexes into the two considered groups, it is advisable to distinguish such generalizing features as spatial position, state of internal systems, and product quality. For the spatial position, the following subgroups can be distinguished (real-time mode): maintaining a given trajectory of the working body in a local coordinate system tied to the object of impact; tracking the position and speed of movement of machines in the global coordinate system. The following subgroups can be distinguished for the state of the internal systems (real-time mode): registration of operator state indexes; registration of efficiency indexes of machines. For product quality, the following subgroups can be distinguished (real-time mode): measurement of machine's efficiency indexes (deviation from design parameters of the surface, degree of compaction, etc.) moving in field with the global coordinate system; measurement of the efficiency of stationary machines in the local coordinate system.

A natural index of the effectiveness of machines must be available for instrumental control in order to enable automated accumulation of the index values in processing and decision making. Among the physiological parameters of the operator there are may be: blood pressure level; heart rate; body temperature.

Among the natural indexes of the efficiency of moving machines there are the following:

• indexes characterizing the work of machine units: independent timer; the crankshaft rotational speed, rotational speed of the driving element of the propulsion unit (sprocket or wheel); fuel consumption, frequency of pressure pulsations in the hydraulic system; consumption of technological materials (if provided by the type of machine); CO and NOx content in engine exhaust;

• indexes of the scope of work performed by the machine: the volume of load carried by the machine with the moldboard; the distance of material movement dragged by moldboard; the time of material movement; the volume of material moved by the machine with a bucket; the distance of material movement by bucket; material transfer time by bucket; the volume of the excavation (pit, trench, well, ditch, etc.) dug by the machine; the time to create a notch; the volume of material transported by the machine; material transportation

distance; material transportation time; surface area processed by the machine; surface processing time;

• indexes characterizing the quality of work of machines: the discrepancy between the actual and designed marks of surfaces; the discrepancy between the actual and designed degrees of compaction; the discrepancy between the actual and standard distribution densities of reagents; the discrepancy between the actual and regulatory conditions of the surface of the artificial coating.

Indexes of the work quality can be controlled by modern monitoring systems, but there are no systems that allow to obtain the integrated technical and economic indexes [4–11], i.e. this direction does not need a development.

When reaching to higher decision-making levels the natural indexes stop to be relevant but are included in (i.e. define) more complex calculated indexes.

The calculated indexes at the level of the facility manager allow an operational assessment of the effectiveness, allowing to determine the machines or groups of machines that need attention with the following formation of a control action. These indexes include:

• shift time utilization rate (determined by the duration of the engine with a nominal power or close to the last);

• productivity of machine (determined by the volume and range of the transferred material; the volume of laid material; the amount of laid material; theoretical speed; slipping; resistance to displacement; soil strength; size of the tool, working time in traction mode, etc.);

• resource capacity of production unit (for example, fuel consumption per unit volume of extracted, displaced or compacted soil, laid cement or asphalt concrete, distributed reagent, etc.).

As for the Head's level of the enterprise, in addition to indexes of the direct assignment of the created object, it is necessary to form an idea of the work efficiency at the facility, the efficiency of the enterprise and the industry. It is also necessary to have an idea about the possible environmental consequences of working activity (for example, transport construction). Thus, for this level there are technical, economic and sanitary-environmental indexes. Technical and economic indexes are important for all interested groups - both for the work producer (contractor), and for the customer, who may be presented as an administrative organizations (authorities) and private organizations. Sanitary and environmental indexes in the context of a well-established relationship with a relatively low responsibility can be considered as significant only for the customer who belongs to the administrative structures.

These two groups of indexes essentially contradict with each other, since the process of any construction is accompanied by environmental degradation. Sanitary and environmental indexes, as a rule, are transferred to the category of restrictions consisting in establishing standards for harmful effects on the environment and humans. In case of going beyond the limits of the norm, legal proceedings are initiated against the responsible persons (physical, legal) and end in fines. Thus, restrictions on sanitary and environmental indexes are ultimately reduced to indexes of the economic sphere.

A significant index of the work's manufacturer (the contractor) is the profit p_i for the reporting period [12]:

$$\boldsymbol{p_i = \frac{D_\Sigma - Z_\Sigma}{T_1}},$$

where D_Σ is the sum of all (gross and other) incomes for the period T_1; Z_Σ - current expenses and losses for the period T_1; T_1 - the duration of the construction of the object of transport construction.

The value D_Σ may define the sum of the contract fixed during the tender won by the manufacturer (contractor). The value Z_Σ consists of the operating costs Z_1 and losses Z_2 on eliminating of negative effects of the construction such as changing of hydrogeological conditions [12]:

$$\boldsymbol{Z_\Sigma = Z_1 + Z_2}.$$

The value T_1 is usually fixed by the contract and depends on the amount of work Q_Σ on the object stipulated by the contract and the productivity $P_1$of the machines provided by the contractor [12]:

$$\boldsymbol{T_1 = \frac{Q_\Sigma}{P_1}}.$$

The contractor's profit p_i being a possible criterion of its effectiveness depends on external factors (D_Σ, Q_Σ, Z_2) which the contractor cannot influence and factors determined by the contractor (P_1, Z_1) [12]:

$$\mathbf{p_i = \frac{P_1(D_\Sigma - Z_1 - Z_2)}{Q_\Sigma}}.$$

Thus, operating costs and efficiency can be attributed to the largest indexes of the contractor's self-control. If these indexes are combined, then the unit cost of production will be obtained.

As the main criterion for assessing the technical and economic efficiency it is advisable to choose the unit cost of production including the cost of ownership (SEPV):

$$\mathbf{SEPV} = \frac{C_1}{P_2} + \frac{1}{T_2 \cdot T_3 \cdot n_1 \cdot P_2} \cdot C_0, \textit{ (thousand rubles / production unit)}$$

where C_1 is the cost of machine-shift with reduced costs of ownership (thousand rubles); P_2 - operational replacement performance (production unit / shift); T_2- the life of the machine (years); T_3 - the number of days in a year (days); n_1 - the number of shifts per day; C_0 - the cost of the machine (thousand rubles).

At the regional and federal level, it is necessary to guide by higher level indexes in order to assess the effectiveness of the implementation of budgetary funds and to assess the sanitary and environmental safety of the region. To do this, you can use the following indexes: the timing of the construction of the object; the expected profit of other economic entities from the commissioning of the object; socio-economic consequences of the facility commissioning; budget expenditures on control compliance with the rules of construction and eliminate its negative consequences.

Conclusion. Thus, by depending on the level of decision making there is a significant number of indexes. Some of these indexes are used for direct control on the machines, so they must be available in real time. The other part can be obtained with some delay. To assess the effectiveness of road-construction machines, the decision-making levels of the Head of the company and the work manager at the facility are important, whose operating costs and productivity can be attributed to the largest indexes of self-control, i.e. there is the owner's possibility to correct these indexes.

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ЙЕРАРХИЧНОСТ НА ИНДЕКСИТЕ ЗА ЕФЕКТИВНОСТ ПРИ ИЗПОЛЗВАНЕТО НА ЗЕМЕКОПНИ МАШИНИ ПРИ ВЗЕМАНЕТО НА УПРАВЛЕНСКИ РЕШЕНИЯ

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Ключови думи: *ефективност, наблюдение, пътно-строителни машини, единица разходи за производство.*

Резюме: *Методите за техническа и икономическа оценка на пътно-строителните машини са добре развити, но тяхното приложение изисква широка гама от първоначални данни, които трудно могат да бъдат получени без наличието на системи за наблюдение. При съвременните условия, икономическите фактори определят възможността за използване на машините, а техническото състояние на машините се определя предимно от разходите за поддържане и експлоатация. Това определя необходимостта от извършване на икономически и технически оценки. За да се осигури съответствие между приложението на подобни технически и икономически индекси за оценка на ефективността, е необходимо да се използват системи за наблюдение. Съвременните системи за мониторинг позволяват да се наблюдават техническите и експлоатационни характеристики на машините без да се извършва сравнение от икономическа гл. т. Съществува, обаче известна несигурност при избора на методи за измерване и оценка, които се използват в практиката при съвременните условия, поради наличието на пазарна икономика и възможност друг производител да предлага същия продукт при по-добре условия. При такива условия, внедряването на система за събиране и обработване на информация с обратна връзка от клиентите ще бъде от полза – система за наблюдение за оценка на ефективността. Обратната връзка с клиентите е необходима за създаването на контрол, така че да се повиши ефективността и поддръжката на системата на едно задоволително равнище. Развитието на методите за техническа и икономическа оценка, които могат да се приложат и при пътно-строителните машини и да се адаптират за внедряване в системата за наблюдение е основна цел на настоящия доклад.*