Perfection of Technical Service of Manufacturing Plants Equipment

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Abstract: in the context of significant ware of manufacturing plants machines and equipment a big role belongs to coordination of technical service. Chief mechanical departments of industrial plants, engineering services of agricultural companies are not able to provide the whole range of high quality technical service. In the same time, the domestic market of industrial services which includes of aggregate of specialized companies providing industrial equipment repair services has necessary resources for providing quality repair and maintenance. Technical capacity of repair and maintenance companies also can be involved in maintaining operability of machines and equipment. But in case of outsourcing some volume of works, it is necessary to define what type of repair and maintenance works and what type of equipment can be outsourced. Finding decision to optimization task which consists in distributing repair and maintenance works of different complexity among existing levels of technical service can help distribute the volume of works in the best way. Possible losses of companies from underproduction during the time an outsourcing company performs services need to be taken into consideration. However, sometimes at some ratio of expenses on technical services and volume of expected losses the task does not have one decision. In this case, an additional criterion should be applied which is evaluating outsourcer’s service engineers qualification. The qualification can be defined by estimating the competence level according to a complex criteria which considers three aspects of this competence. Firstly, the degree of competence correspondence to the construction of machines and equipment under service. Secondly, the degree of competence correspondence to the technologies of technical service. Thirdly, the degree applied technical service techniques correspond to machines and equipment under service. This method of service engineers’ competence estimation can be used both by client and outsourcer companies.

1. Introduction

Analysis of industrial companies operation helped us to discover high level of industrial equipment deterioration including machines fleet which, depending on the region, comprises from 40 to 80 % [1]. This results in heavy expenses on maintenance and repair. As a rule process of equipment renewal takes much time which makes it necessary to use equipment which service life has ended. The same situation is in the agricultural sector. More than 60 % of the machinery fleet has run out their service life. Machines and tractors fleet of agricultural companies consists of tractors and agricultural machinery of Russian (Soviet and CIS) production and only a small quantity of tractors and machines which provide high productivity and promised high reliability are of foreign production. The agricultural sector is characterized by underdeveloped infrastructure of maintenance and repair with dealers offering warranty repair and spare parts sale [2, 3].
According to data of regional agriculture ministries, companies possess 45 years old tractors and 33 years old combines. The average age of tractors comprises 17.5 years, and combines – 10.5 years (figure 1–2)[4, 5].

**Figure 1.** Age composition of tractors of Omsk and Chelyabinsk region agricultural companies.

**Figure 2.** Age composition of harvester combines and forage combine harvesters of Omsk and Chelyabinsk region agricultural companies.
At present the domestic market of industrial services which includes the aggregate of specializing companies providing industrial equipment repair services has resources necessary for providing quality repair including technologies, equipment, and highly qualified personnel with needed competence and experience.

Over the period of existence of State Committee for Agricultural Equipment the Engineering Service had accumulated big experience of centralized maintenance of cars, “Kirovets” tractors, machines for livestock breeding, irrigation equipment. Optimal combination of centralization when organizing maintenance and repair works with rational concentration of maintenance and repair means can provide significant improvement of agricultural machines operation. For example, according to data of Ministry of Agriculture and Food Products of Omsk region [4], in 2016 eight out of 24 major dealer centers organized work of 45 mobile teams providing agricultural machines warranty maintenance (table 1).

| Item № | Company name                          | Equipment type                        | Number of warranty maintenance teams |
|--------|--------------------------------------|---------------------------------------|-------------------------------------|
| 1.     | OAO “Semirechensk supply base”       | Tractors, combine harvesters, mowers, | 13                                  |
| 2.     | OAO «Sibirskaya Base»                | Tractors, combine harvester, mowers,   | 5                                   |
|        |                                      | trailed reapers                        |                                     |
| 3.     | OOO PSC “OmkDizel»                   | Seeding machinery                      | 8                                   |
| 4.     | ZAO Agrokomplekt base                | Tractors, mowers, grain seeders, grain| 4                                   |
|        |                                      | cleaners                               |                                     |
| 5.     | OAO “Kalachinsky mechanical plant”   | Trailed reapers, grain seeders         | 1                                   |
| 6.     | OOO “ASM”                            | Tractors, mowers, seeding machinery,   | 10                                  |
|        |                                      | grain seeders                          |                                     |
| 7.     | OOO “Omskagrilizin”                  | Tractors                              | 2                                   |
| 8.     | OOO «Agrocentre Zakharovo»           | Seeding machinery                      | 2                                   |

Besides, existing repair companies of various specialization can be involved for providing technical services.

Involvement of these companies will make it possible to use advantages of existing labor division forms [6]:
- technical (dividing full procedure in separate ones);
- functional (dividing different types of works and specialization of separate groups of workers depending on their operation functions);
- professional (dividing workers according to their profession and disciplines);
- qualification based (dividing workers inside of each professional group according to their qualification and categories).

2. Results

Outsourcing is one of the most modern and successful business models which makes it possible to achieve real competitive advantages. Advantages of outsourcing are: concentration on profile activity, application of the best methods and experience, improvement of competitiveness, cutting expenditures, application of cutting-edge technologies, improvement of service, improving production process flexibility and achieving synergy effect, strategic considerations, etc. In the result of outsourcing need of investments decreases and product quality rises as a supplier is a specializing company, also concentration of management resources takes place as the number of managed objects reduces [7].
However, outsourcing of repair and maintenance works to an external organization is viable under condition of receiving services quality guarantees and high qualification of servicing personnel. Besides, economic feasibility of outsourced volumes considering works complexity is important.

2.1 Technical service tasks distribution
Customarily, the technical service structure includes three complexity levels of machines and equipment repair and maintenance:
- daily (on shift basis) machines and equipment maintenance by operating personnel;
- different types of maintenance defined by numbers, uncomplicated repair of machines and production equipment requiring involvement of chief mechanic department services or repair companies;
- repair and overhaul, instrumental assessment of technical state of machines complex subsystems and units requiring involvement of dealer companies experts, specializing repair companies (table 2) [8].

Table 2. Technical service structure

| Components of machines and equipment technical service | Levels of technical service |
|------------------------------------------------------|----------------------------|
| Regional level                                       |                           |
| Inter-zonal level                                    |                           |
| Zonal level                                          | level of holdings and unities |
| Company level                                        |                           |

| Repair and maintenance technologies                  | Technologies of maintaining and recovering of technical state parameters, including in-place technologies |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                                                     | Technologies of machinery and equipment units, components and subsystems maintenance |
|                                                     | Technologies of performing separate maintenance operations |

| Maintenance and repair aims                         | Providing machines and equipment long-term functioning reliability |
|-----------------------------------------------------|--------------------------------------------------------------------|
|                                                     | Providing machines and equipment mid-term functioning reliability |
|                                                     | Operational support of machines and equipment operability |

| Maintenance and repair performers                    | Machines and equipment maintenance experts who have knowledge of technical state parameters adjusting and their maintenance and recovery |
|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
|                                                     | Machines and equipment units, components and subsystems maintenance experts: engines, transmission, hydraulic systems, electrical equipment, working parts |
|                                                     | Machines and equipment maintenance experts who have skills of maintenance operations performance using special technical tools |

| Processes in machines and equipment as in systems   | Process of implementation/realization of the TS main function and auxiliary functions which maintain sub-processes |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
|                                                     | Ware, lubrication, thermal regulation, dynamic load process in TS components |
|                                                     | Processes in separate units, components, and systems of machines and equipment which lead to technical state parameters adjustment |

Thus, during formation of technical service the task arises of rational distribution of machines and equipment maintenance works which differ in level of influence the units and subsystems across different level subjects of technical service (figure 3).
The task relates to resources distribution or transportation tasks. One of the possible effective methods of solving these tasks is the simplex method (table 3) [9].

It is necessary to perform the necessary volume of machines and equipment maintenance works distributing it across the levels of technical service

\[ Q_{i,j} = \sum_{j=1}^{3} x_{i,j} \]  

The amount of expenditures and losses from production loss must be minimal:

\[ \sum_{i=1}^{3} \sum_{j=1}^{3} C_{ij} x_{ij} a_y b_y d_y e_y g_j \rightarrow \min \]  

It is better to perform the dimensionless number minimization contracting the previous equation taking outside the summation symbol the cost of first level maintenance \( C_i \)

\[ \sum_{i=1}^{3} \sum_{j=1}^{3} K_{ij} x_{ij} a_y b_y d_y e_y g_j \rightarrow \min \]

where \( K_{ij} \) is technical services cost index.

Minimization makes it possible to define values of the technical service cost index which correspond to transferring from this or that level of technical service.

However, entering symbols \( a_y b_y d_y e_y g_j = K_n^p \) – generalized index of expenses and losses, it can be noticed that it can be equal for different technical service levels at different values of partial indices \( a_y b_y d_y e_y g_j \). In this case the task can have innumerable number of solutions meaning variants of works distribution across levels of technical service.

Absence of one (or preferred) solution according to economical criterion supposes presence of other criteria determining distribution of different complexity maintenance volume across the technical service levels (technical-economical, technological, operational, etc.). One of the most important criterion is the level of service engineers’ qualification.

\[ 2.2 \text{ Estimation of service engineers qualification} \]

Qualification can be estimated according to the following properties:

- degree of competence correspondence to serviced machines and equipment construction
• degree of competence correspondence to technical service technologies
In its turn service engineers competence can be taken as aggregate of their knowledge, skills, and experience.
After finding common units and subsystems in the machines and equipment construction, one variant of qualification estimation per first property can be suggested (Table 3).

Table 3. Correspondence of service engineers competence to machines and equipment units and subsystems construction (for a group consisting of four people)

| Maintenance and repair performers competence elements | N, People. | Knowledge | Skills | Experience | TOTAL Possible |
|--------------------------------------------------------|------------|-----------|--------|------------|---------------|
| Engine transmission Drive system Hydraulic system Electrical equipment Control system Working parts |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 63 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| 84 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |

The table is drawn for a group consisting of four service engineers. Maximum number of points cannot exceed 84. However, we suppose that 63 points are enough for providing correspondence according to parameter under consideration: all performers are familiar with machine units, no more than one performer is not trained to service any one of the units, at least two performers have skills of performing technical servicing of any unit.

For estimating qualification according to the second property it is necessary to define what kinds and types of works are performed during machines and equipment technical service.

There are several classifications of technical service works. According to the ways of repair performance: welding works, mechanical and bench-work, welding deposit, galvanic operations, heat treatment, under pressure recovery, hydraulic system parts replacement, electrical systems replacement. According to the works’ aim: workability recovery, object modernization, diagnosing, lubrication, adjustment, calibration, examinations. Repair and maintenance operations are classified as: cleaning and washing, installation and de-installation, control and adjustment, lubrication.

In compliance with reliability management standard, customarily the following types of technical service works are distinguished: cleaning, lubrication, adjustment, calibration, repair, recovery, replacement [10]. Taking the standard’s recommendations as the basis let us estimate service engineers qualification according to the second property (table 4).

Table 4. Correspondence of performers competence to repair and maintenance technologies (for a group consisting of four people)

| Maintenance and repair performers competence elements | N, people | Cleaning | Lubrication | Adjustment | Calibration | Repair | Recovery | Replacement |
|--------------------------------------------------------|-----------|----------|-------------|------------|-------------|--------|----------|-------------|
| Engine transmission Drive system Hydraulic system Electrical equipment Control system Working parts |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 63 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| 84 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |

Similar to the previous estimation, we consider that 63 points are enough for ensuring correspondence of competence according of considered property: all performers are familiar with machine units,
no more than one performer is not trained to service any one of the units, at least two performers have skills of performing technical servicing of any unit.

Besides the considered properties the estimation of competence is possible according to one more property which makes it possible to estimate the degree applied technical service techniques correspond to machines and equipment under service (table 5).

**Table 5.** Correspondence of technical service technologies to machines and equipment under service

| Technical service technologies | Machines and equipment units and subsystems |
|-------------------------------|---------------------------------------------|
|                               | Engine | Transmission | Drive system | Hydraul. system | Electrical equipment | Control system | Machines working parts |
| Cleaning                      | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Lubrication                   | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Adjustment                    | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Calibration                   | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Repair                        | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Recovery                      | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| Replacement                   | 2      | 2            | 2            | 2              | 2                 | 2              | 2                     |
| **TOTAL** 98                  | 14     | 14           | 14           | 14             | 14                | 14             | 14                    |

Suggested correspondence estimations:
- 2 – fully corresponds
- 1 – partially corresponds
- 0 – does not correspond

Preliminarily, let us take at least 80 % which corresponds to 78 points as allowable estimation level. Numerically the qualification estimation will be derived from equation:

\[ K = K_1K_2K_3 \]  \hspace{1cm} (4)

where

\[ K_1 = \sum_{i=1}^{84} K_{i1} \] – estimation of performers competence correspondence to processes running in machines and equipment units and subsystem,

\[ K_2 = \sum_{i=2i}^{84} K_{2i} \] – estimation of performers competence correspondence to repair and maintenance technologies

\[ K_3 = \sum_{i=3i}^{98} K_{3i} \] – estimation of correspondence of applied technical service technologies to machines and equipment under service.

According to the presumptions offered by us the allowable estimation level of service engineers competence, who are repair and maintenance performers, comprises \[ K \geq \frac{63}{84} \cdot \frac{63}{84} \cdot \frac{78}{98} \approx 0.45 \] provided that \[ K_1 \geq 0.75, \ K_2 \geq 0.75, \ K_3 \geq 0.80 \]

3. Conclusions

The service engineers competence estimation developed by us is necessary when choosing an outsourcer in cases economic criteria does not bring to an unambiguous solution. In practice, there is not always possibility to consult an expert estimation of service engineers, and in this case the suggested method can be used. To do this it is necessary to develop questionnaires and tests taking into account company’s machines fleet and equipment. The method can be applied by repair- and maintenance and...
service companies for personnel rating and certification, as well as for estimation of competence after personnel has taken staff development and retraining courses. The tables given here for example can be simplified or developed further according to requirements of both outsourcer and producing companies. Worthy of separate attention is the issue of switching from determined to probabilistic estimates in future.

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