MODERN AVIATION AND SPACE TECHNOLOGY

UDC 621.356; 621.372(045)

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MODELS OF CONSIDERATION OF DEGRADATION AND REGENERATIVE PROCESSES DURING THE SERVICE TECHNOLOGICAL SYSTEMS DESIGN

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Abstract. *The article explores some aspects of the performance management of designed complex polyergatic service technological systems. Dynamic state of a service technological system is considered in the context of estimation, decision making and realization.*

Keywords: decision making; design; service technological system; technology; technological process; transport system; transport system validation.

1. Introduction

Technological systems, depending on the development and operation can be divided into three main groups: industrial (manufacturers products), service (service type) and social. The main purpose of the service type systems is to provide consumers with a set of specific services with the necessary characteristics [1, 2].

Technological service system is a set of subsystems with arrivals and relevant services. Top level of the service technology system structure contains subsystems for setting and providing of services, the other subsystems are supporting structures of the system, which maintain its reliable operation. For example, in aviation and transport systems first group includes flight activity subsystems, the second group contains: air traffic control system, the formation of the passenger and cargo flow subsystem maintenance and repairing of aircraft etc.

2. Analysis of the latest research and publications

Any complex service transport system (STS) is characterized by a variety of parameters. Some of these parameters are responsible for the economic costs of the system operation, the other is related to the evaluation of functioning quality, and others. In most cases they are used for a qualitative comparison process of the systems designed, as many of them usually do not have a numeric expression. There are different approaches which can be used for system optimization, for example: mini-max criteria, linear programing and others [2,3]. However, any of them can describe process in complex with economic aspects.

3. Aim of the work

The technological service system design is a complicated and important task of system life circle. Many factors affect system design and all of these influences will result in future system performance. That is why the main aim of this article is to estimate degradation and regenerative processes influence upon technological service system at the design stage. In addition, we use the optimization approach for influences minimization.

4. STS processes description

The quality of the functioning of the projected STS has been changed during the life cycle influenced by various external and internal destabilizing factors.

The parameters values of service have a certain variation in the phase space requirements of applications because have got influence of stochastic characteristics of structural elements and destabilizing factors in general.

Relationship between vector of consumer's requirements $L_C(v)$ and characteristics of services in general can be represented as a composite functional:

$$L_{STS}(v)=\{L(v(y,t), L(v(s,t)), L(v(t))\}.$$

Request for services with the characteristics of v(y,s,t) are considered supported if the following condition is true:

$U_{STS}(v) \in D(L_{STS}(v(y,\ s\ t))),$

where $U_{STS}(v)$ – characteristics of services provided;

$D(L_{STS}(v(y,\ s\ t)))$ – phase space of admissible values of the characteristics of the requested service.

Evaluating of the effectiveness of STS at the design stage and substantiation requirements of its main characteristics is largely complicated by the presence of a priori uncertainty conditions of its functioning and stochastic parameter of internal and external destabilizing factors.

External destabilizing factors include impacts associated with the instability of the services market, changing consumer demands, more stringent environmental requirements, changes in the regulatory framework, the climatic conditions of the environment of the system and etc.

Internal factors include the processes of physical and mental aging shaping elements and services, as well as violations of technology, production and performance discipline, etc.

Quality change in the general functioning of the STS is erratic due to stochastic nature of parameter disturbances.

Prior uncertainty of conditions in which destabilizing factors characteristics change does not allow to the full extent consider their impact on the structure degradation processes and characteristics of the elements during STS design. The problem is close to the formation of a certain class of regenerative processes in the STS, adequate degradation characteristics of its elements, in order to eliminate the influence of destabilizing factors.

The common model of STS processes description can be represented in a simplified form: the estimation of STS state A, decision B and realization C [4, 5].

In this case, by condition should understand the potential ability of STS to do its functions. Depending on the STS state by solution and implementation of made decisions should be used selection processes and implement a set of control actions on the elements of the system, which are necessary and sufficient for maintain and restore (if it will be necessary) a certain level of quality of STS functioning.

The potential ability of STS to able its function at time t can be determined by double-alternative grading system by ensuring the required quality level of functioning:

$$A(x,t) = \begin{cases} A_U(x,t),\ I(A) = 1 \\ A_{\overline{U}}(x,t),\ I(A) = 0. \end{cases}$$

where $A(x,\ t)$ – elements of the state vector at time t; $A_U(x,\ t)$ – vector of the system state with the potential ability to generate and provide the requested service; $A_{\overline{U}}(x,t)$ – vector of the system state in case when request for service does not supported or "production output" of STS does not comply with the requests; $I(A)$ – marker function.

Marker function is represented by:

$$I(A) = \begin{cases} 1,\ x_i \in D(x_i),\ i = \overline{1,n} \\ 0,\ x_i \notin D(x_i),\ i = \overline{1,n}, \end{cases}$$

where $D(x_i)$ – range of possible values of the parameter vector of the ith-element STS during ensuring of the necessary level of the system quality.

Let's use function $B(A,\ t)$ to describe the processes of solution formation and function $C(B,\ t)$ for realization of made decisions:

$$B(A,t) = \begin{cases} B_T(A,t),\ A(x,t) = A_U(x,t) \\ B_S(A,t),\ A(x,t) = A_{\overline{U}}(x,t), \end{cases}$$

$$C(B,t) = \begin{cases} C_T(B,t),\ B(A,t) = B_U(A,t) \\ C_S(B,t),\ B(A,t) = B_{\overline{U}}(A,t), \end{cases},$$

where $B_T(A,\ t)$, $C_T(B,\ t)$ – function that describes the processes of selection and implementation of technology formation and provision of the requested service; $B_S(A,\ t)$, $C_S(B,\ t)$ – function that describes the functioning and implementation of control actions on STS elements to restore the potential ability of the system to do its function.

Dynamics of STS processes are possible to be described in terms of the processes of change the current values of its generalized characteristics in the phase space of interconnected regions $A\Omega$, $B\Omega$ and $C\Omega$.

Let's represent dynamics of STS processes in scale of Cartesian coordinate with the axes of A, B, C. Also let's mark specific areas $D(A\Omega)$, $D(B\Omega)$, $D(C\Omega)$ into planes where STS provided the required level of formation and provide requested services (fig. 1).

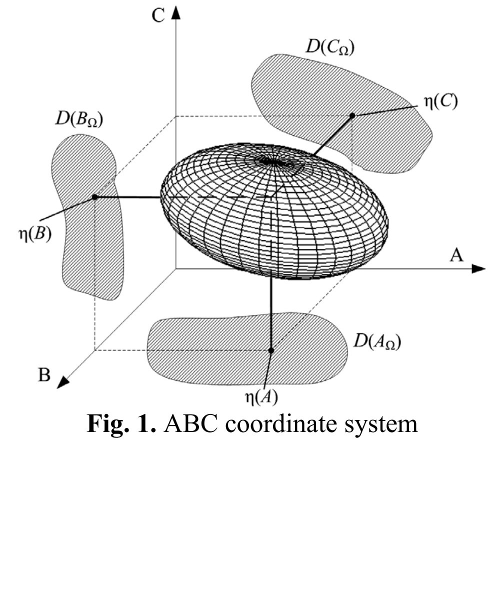

Fig. 1. ABC coordinate system

If one of the output values of the generalized characteristics of STS will be outside of the fixed area, the system becomes incapable to operate functions.

In three-dimensional space is possible to detect a point $\eta(A, B, C)$ which characterizes the current state of the dynamics of the processes in the STS. Also it is possible to use projection of this point into planes A_Ω, B_Ω and C_Ω. In this case each point $\eta(A_i)$ inside of $D(A_\Omega)$ will correspond to $\eta(B_i)$ and $\eta(C_i)$ inside the areas of $D(B_\Omega)$ and $D(C_\Omega)$.

Dynamic state of STS according to the adopted coordinate system can be described by the next function:

$$\eta(A, B, C, t) = \eta(\eta(A, t), \eta(B, t), \eta(C, t)).$$

According to specificity of the description of the dynamic STS state functioning $\eta_0(A, B, C, t)$ it is be represented in common matrix-type:

$$\eta_0(A, B, C, t) = \left| \begin{array}{l} \eta_1(\eta(A) \in D(A_\Omega), \eta(B) \in D(B_\Omega), \eta(C) \in D(C_\Omega)),\ P_1(t) \\ \eta_2(\eta(A) \notin D(A_\Omega), \eta(B) \in D(B_\Omega), \eta(C) \in D(C_\Omega)),\ P_2(t) \\ \eta_3(\eta(A) \in D(A_\Omega), \eta(B) \notin D(B_\Omega), \eta(C) \in D(C_\Omega)), P_3(t) \\ \eta_4(\eta(A) \in D(A_\Omega), \eta(B) \in D(B_\Omega), \eta(C) \notin D(C_\Omega)), P_4(t) \\ \eta_5(\eta(A) \notin D(A_\Omega), \eta(B) \in \eta_y(B_\Omega), \eta(C) \in \eta_y(C_\Omega)), P_5(t) \\ \eta_6(\eta(A) \notin D(A_\Omega), \eta(B) \in \eta_B(B_\Omega), \eta(C) \in \eta_B(C_\Omega)), P_6(t) \end{array} \right.$$

Dynamic state $\eta_1(A, B, C, t)$ of STS with probability $P_1(t)$ provides a quality of operation in case if characteristics of services provided $U(A, B, C, t)$ compliment with the requirements to requested services.

States $\eta_2(A, B, C, t) - \eta_4(A, B, C, t)$ lead to an out of characteristic values of services provided in case when it is higher than the necessary quality level of system η(A) or making wrong decisions $\eta(B)$ or in case of violation of technologies formation and (or) the provision of the requested service $\eta(C)$. Condition $\eta_5(A, B, C, t)$ characterizes process restore of the required level of functioning quality $\eta_1(A, B, \mathrm{C}, t)$ by formation and implementation of an appropriate set of control actions.

In case of $\eta_6(A, B, C, t)$, when restoration of a system state $\eta_1(A, B, C, t)$ is impossible or inexpedient, the system stops the further functioning of $\eta_1(A, B, C, t)$, or will be restructured, i.e. change of coordinate ABC system is required.

The prior uncertainty of measurement of characteristics conditions of destabilizing factors doesn't allow to consider fully their influence on processes of degradation in case STS design. Therefore the taking note task on these factors during its functioning becomes an important problem in case STS creation.

The task is consolidated to formation of a certain class of regeneration processes in STS, adequate to a level of characteristics degradation of its elements for the purpose of influence elimination of destabilizing factors.

The generic description of functioning process of STS taking into account the destabilizing and regenerating processes can be provided in a look:

$$\eta(A, B, C, t) = \eta(\eta(A, t), \eta(B, t), \eta(C, t), \\ Y_P(\eta_Y(A, t), \eta_Y(B, t), \eta_Y(C, t)/\xi(t)),$$

where Y_P – vector of controlling influences, which creates process of necessary regeneration level of STS functioning in case of its characteristics deterioration;

$\xi(t)$ – functional of the description of change dynamic of destabilizing factors.

The study of processes of characteristics origin and estimation, external and internal destabilizing factors belongs to separate area of researches. We will be reviewed of regeneration questions of the necessary quality level of STS function.

In this case sets of points in the phase state space of STS $D(A_\Omega)$, $D(B_\Omega)$ and $D(C_\Omega)$ can be considered as area of restrictions or admissible values of algorithms characteristics of a state assessment $S(y, t)$, decision-making $B(A, t)$ and implementations $C(B, t)$, which necessary and optimum from efficiency of managing directors of influences.

The set of sequentially connected algorithms of $A(y, t)$, $B(A, t)$ and $C(B, t)$ are created and implemented in links of STS-B model of system structure. Taking into account a matrix of states and its elements as the generalized index of elimination processes of destabilizing factors can be accepted:

$$P_\eta(t) = \prod_{j=1}^{n-2} P(\eta_1(t) / \eta_j(t)),$$

where $P_\eta(t)$ – probability of the STS task execution (the generalized quality index of its functioning);

$P(\eta_1(t)/\eta_j(t))$ – the conditional transition probability of STS from j state, under the influence of controlling influences in a state, with necessary level of potential possibility of execution of requests for services.

The conditional transition probability of STS state can be provided in the form of function indexes, structural elements:

$$P(\eta_1(t)/\eta_j(t)) = \varphi(P_A(t)\, P_B(t)\, P_C(t)),$$

where $P_A(t)$, $P_B(t)$, $P_C(t)$ – characteristics of execution quality of functions by a link of an assessment, formation and implementation of controlling influences respectively.

$P_A(t)$ is understood as probability of a value assessment of a incoordination of the current values of defining parameters of system from the set tolerances in phase space of possible values:

$$P_A(t) = \sum_{i=1}^{N} \sum_{i=1}^{M} P_{\text{extraction}} \left(Q_i(\tau + j) \geq V / Q_i(t) < V_{ij}\right)$$

where $P_{\text{extraction}}$ – the conditional probability of that detection of incoordination will take place on $\tau+j$ monitoring from the moment of its appearance;

N, M – quantity of elements and their characteristics in respectively;

$V_{i,j}$ – admissible area of the i values of parameter of the j element.

For n-dimensional probability density function of statistics $Q(n)$ separate components can be provided:

$$P_{\text{extraction}}() = \int_{\Omega\tau} \int_{\Omega\tau+1} .. \int_{\Omega_{\tau+j-1}} \omega_n(Q(\tau)Q(\tau+1)..Q(\tau+j))dQ(\tau)dQ(\tau+1)..dQ(\tau+j)$$

where ω_n – n-dimensional probability density function of statistic sample;

$\Omega_\tau \ldots \Omega_{\tau+j-1}$ – area of $Q_i(.)$ values, where the decision is made on a degree of quality conformity of system function to the set level.

Decision-making process generally can be multialternative from the point of view of a choice of a necessary and sufficient set of controlling influences. Thus it is necessary to consider a row of restrictions of the temporal, economic and technical character connected to specifics of decision-making in STS of this class [5].

As the generalized characteristic of a link of decision-making it is possible to use probability of formation of the optimum decision on implementation of controlling influences which meet requirements of restrictions of temporal t_{BD}, and technical and economic H_{BD}, character necessary and sufficient for transfer of system from state $A_y\ (x, t)$ in state $A_1\ (x, t)$ taking into account external conditions of $D(\chi)$:

$$P_B(A, t) = P(t_B < t_{BD}, H_B < H_{BD}, A_1(x,t),$$
$$A_Y(x,t) / D(\chi)\ ))$$

Functions of a link of implementation of the made decisions consist in carrying out recovery actions.

Achievement of the purpose of held events qualifications of staff, level of technological discipline in many respects depend on a level of fitness of elements of system to control and recovery to procedures, existence of necessary resources, etc.

For n-dimensional frequency curve of probability of statistics of $Q(n)$ separate components can be provided in a formula:

$$P_C(B, t) = P(t_C \in t_{CD}, H_C \in H_{CD},$$
$$S_0(x, t) / S_Y(x, t) / D(\chi)),$$

where t_{CD}, H_{CD} – admissible area of set time of maintenance of system and technical and economic restrictions respectively.

The considered approaches of probable estimates of STS characteristics into account stochasticity of destabilizing factors in practice not always are effective owing to inevitable in the absence of the sufficient volume of statistical data of assumptions and restrictions.

It is frequent leads to inadequate real situations, decision-making. In such cases in case of reasons for characteristics of designed system and methods of influence elimination the degradation processes on quality of STS functioning refer to intuition, common sense, experience of creation and maintenance of similar systems and etc.

The description of STS operating conditions is thus obvious to have a certain fuzziness.

In the fuzzy set is rather widely used theory of Bellmana-Zade [6].

The fuzzy decision, or the decision under fuzzy conditions, is submitted in the form of a fuzzy set in space of alternatives and restrictions. Intersection of fuzzy sets of the purposes J and G restrictions is accepted by the decision D:

$$D = J \cap G,\ \mu_D = \mu_J \wedge \mu_G. \quad (1)$$

In the presence of n purposes and m of restrictions:

$$D = J_1 \cap J_2 \cap \ldots \cap J_n \cap G_1 \cap G_2 \cap \ldots \cap G_m,$$
$$\mu_D = \mu_{J1} \wedge \ldots \wedge \mu_{Jn} \wedge \mu_{G1} \ldots \wedge \mu_{gm} \quad (2)$$

In practice application of expressions (1) and (2) often leads to big difficulties because of requirements of Bellmana-Zade approach to reduce the purposes and restrictions to one phase space that not always it is possible to realize in case of the solution of a row of application-oriented tasks.

In STS design process with the determined structure usually are restricted to a certain set of characteristics (parameters) according to which system effectiveness is estimated.

The set of the destabilizing factors significantly influencing operating conditions of system is defined, and also the appropriate methods of their elimination are provided and technical and economic expenses are evaluated when using this or that method of elimination.

Taking into account specifics of considered area of research, we will formulate the task so.

Let characteristics of system $x \in X$, change during maintenance under the influence of destabilizing factors of $\xi \in \Theta$. It is necessary to select the effective $f \in F$ methods of influence elimination of destabilizing factors probably minimum technical and economic expenses of $h \in H$.

We will consider the following statements.

Statement 1. The subset of the $x \in X$ parameters of designed system is considered the most subject to influence of destabilizing factors $\xi \in \Theta$, if

$$\forall x, \xi \to \xi Cx : \mu_C(\xi, x) \to |0,1| :$$
$$: \exists x_A : \mu_C(\xi, x_A) \ge \sup_{\xi} \mu_C(\xi, x).$$

Statement 2. Subset of $f \in F$ methods of elimination of destabilizing factors $\xi \in \Theta$ it is rather effective, if

$$\forall f, \xi \to fG\xi : \mu_G(f, \xi) \to |0,1| :$$
$$: \exists f_B : \mu_G(f_B, \xi) \ge \sup_{\xi} \mu_G(f, \xi).$$

For the proof of these statements of an assessment of a level of influence of destabilizing factors on characteristics (parameters) of system and efficiency of elimination of influence of destabilizing factors the selected methods, we will provide in the form of the appropriate fuzzy relations of $\xi\, R\, x$ and $f\, G\, \xi$.

$$C = \begin{vmatrix} \mu_R(\xi_1, x_1) & \mu_R(\xi_1, x_2) & \mu_R(\xi_1, x_3) & \ldots\ldots\ldots & \mu_R(\xi_1, x_n) \\ \mu_R(\xi_2, x_1) & \mu_R(\xi_2, x_2) & \mu_R(\xi_2, x_3) & \ldots\ldots\ldots & \mu_R(\xi_2, x_n) \\ \mu_R(\xi_3, x_1) & \mu_R(\xi_3, x_2) & \mu_R(\xi_3, x_3) & \ldots\ldots\ldots & \mu_R(\xi_3, x_n) \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots \\ \mu_R(\xi_m, x_1) & \mu_R(\xi_m, x_2) & \mu_R(\xi_m, x_3) & \ldots\ldots\ldots & \mu_R(\xi_m, x_n) \end{vmatrix} \quad (3)$$

$$G = \begin{vmatrix} \mu_G(f_1, \xi_1) & \mu_G(f_1, \xi_2) & \mu_G(f_1, \xi_3) & \ldots\ldots\ldots & \mu_G(f_1, \xi_n) \\ \mu_G(f_2, \xi_1) & \mu_G(f_2, \xi_2) & \mu_G(f_2, \xi_3) & \ldots\ldots\ldots & \mu_G(f_2, \xi_n) \\ \mu_G(f_3, \xi_1) & \mu_G(f_3, \xi_2) & \mu_G(f_3, \xi_3) & \ldots\ldots\ldots & \mu_G(f_3, \xi_n) \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots \\ \mu_G(f_p, \xi)_1 & \mu_G(f_p, \xi_2) & \mu_G(f_m, \xi_p) & \ldots\ldots\ldots & \mu_G(f_p, \xi_n) \end{vmatrix} \quad (4)$$

Membership function in (3) can be interpreted linguistic variables of type "strongly", "poorly", "don't influence", and in (4) it is possible to interpret linguistic variables of type "more", "less", "very much", "poorly", "not effective".

We will lower from columns of a matrix (3) and lines of a matrix (4) subsets of characteristics of $x_A \in X$ and the $f_B \in F$ methods of influence elimination of destabilizing factors and beforehand having defined x_A and f_B values.

$$x_A = \{\mu_C(\xi, x_{A1}) x_{A1}, \mu_C(\xi, x_{A2}) x_{A2}, .., \mu_C(\xi_1, x_{AL}) x_{AL}\}, \quad (5)$$

$$f_B = \{\mu_G(f_{B1}, \xi) f_1, \mu_G(f_{B2}, \xi) f_{B2}, .., \mu_G(f_{Bk}, \xi) f_{Bk}\}. \quad (6)$$

Really, x_A value dominates concerning the subsets created from other columns of a matrix of the relations ξCx. In turn ξCx value dominates concerning other lines of a matrix of the relations $fG\xi$.

So, subsets (5) and (6) respectively, can be read the most subject to impact of destabilizing factors on parameters of system and a subset of effective methods of influences elimination of destabilizing factors.

From elements of a subset (6) methods of elimination of those destabilizing factors significantly influencing parameters of system are selected, i.e.

$$f_{Bi} = \begin{vmatrix} f_{BHi}, \xi_j \in x_A, \xi_j \in f_B, j = \overline{1, V} \\ 0, \xi_j \notin x_A, \quad \xi_j \in f_B, j = \overline{1, V} \end{vmatrix}. \quad (7)$$

The subset of methods of the elimination, corresponding to a condition (7), takes a form

$$f_{BH} = \{\mu_G(f_{BH1}, \xi) f_{BH1}, \mu_G(f_{BH2}, \xi) f_{BH2}, \mu_G(f_{BH3}, \xi) f_{BH3}, .., \mu_G(f_{BHN}, \xi) f_{BHN}\}.$$

In practice quite often there are some methods of elimination of influence of the same destabilizing factors. In such cases the choice of a method is carried out taking into account technical and economic costs of its implementation

Statement 3. If for elimination of influence destabilizing factor ξ_j there is a subset $f_k \in f_B$ of methods of their elimination, and the assessment of technical and economic expenses is provided in the form of the fuzzy relation $h \in H$, it is considered by optimum f_{opt} an elimination method which meets conditions

$$f_{ki} = \begin{vmatrix} f_{opt}, \mu_S(c, f_{ki}) \le \inf_C \min \mu_S(c, f_k) \\ 0, \quad \mu_S(c,, f_{ki}) > \inf_C \min \ \mu_S(c, f_k). \end{vmatrix} \quad (8)$$

If under $\inf_C \min \mu_S(c, f_k)$ to understand an assessment of the allowed level of technical and economic expenses for implementation of the selected method, justice of the statement in expression (8) becomes obvious and doesn't require the proof.

The given principles shall be transformed taking into account specifics of purpose and features of functioning of designed service technological systems.

5. Conclusions

Represented approach of degradation and regeneration factors at the stage of STS design includes estimation of STS state, decision and realization but in different purposes and more strict requirements will better improve the number of characteristics of STS

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Received 10 June 2014.

В. Г. Мелкумян[1], Т. Л. Малютенко[2], І. В. Остроумов[3]. Моделі врахування деградаційних та регенераційних процесів на етапі проектування сервісних технологічних систем
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Розглянуто деякі аспекти проблем забезпечення якості функціонування проектованих складних, поліергатичних сервісних технологічних систем. Динамічний стан сервісної технологічної системи розглядається в просторі оцінки, прийняття рішень і реалізації.

Ключові слова: перевірка транспортної системи; прийняття рішень; проектування; сервісна технологічна система; технологія; технологічний процес; транспортна система.

В. Г. Мелкумян[1], Т. Л. Малютенко[2], И. В. Остроумов[3]. Модели учета деградационных и регенерирующих процессов на этапе проектирования сервисных технологических систем
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Рассматриваются некоторые аспекты проблем поддержания качества функционирования проектируемых сложных, полиэргатических сервисных технологических систем. Динамическое состояние сервисной технологической системы рассматривается в пространстве оценки, принятия решений и реализации.

Ключевые слова: проверка транспортной системы; проектирование; принятие решений; сервисная технологическая система; технология; технологический процесс; транспортная система.

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