Criteria for assessing the results of production activities of automobile gas filling compressor stations

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Abstract
Within the framework of this paper, the performance indicators of the automotive gas filling compressor stations for 2014 - 2016 are considered. As a result of the analysis of the indicators of more than two hundred stations owned by PJSC Gazprom and transmitting information in the form of corporate statistical reporting forms criteria of estimation of efficiency of results of industrial activity of stations have been generated. The application of these performance evaluation criteria will allow to provide information to decision-makers about problematic entities of the organization in an automated mode.

Keywords: ***CNG stations, process of automated monitoring, the efficiency of production processes, the efficiency of design solution***

1 Conceptual bases of research

A key factor in the concept of the analysis of the production and economic activities of CNG stations is the dynamically forming criterion [1, 2] for assessing the organizational and technical decisions made in the production and economic activities of CNG refueling stations.

Fundamental principles of the concept

The concept is based on a set of principles, the system of which is complete, sufficient to solve the analysis of the results of production and economic activities of CNG stations. This system covers: principles reflecting the decision-making process in accordance with the initial provisions: with technical and technological, theoretical, methodological and organizational fundamentals; principles of interaction of the foundations, linking them into a single whole for making decisions; principles that take into account the specifics of the basic tasks of decision-making, which consists of a limited set of steps to address them.

Basis bases

To eliminate the existing uncertainty in the terminology used and in the conceptual apparatus, the principles reflected through the basic framework are developed: theoretical and methodological basis - allows you to observe, predict and analyze the current state of the solution of the decision-making problem; technical and technological basis - allow to substantiate the technical and technical feasibility of the main tasks of decision making; organizational bases - allow to identify the data, assess the state of the solution of problems, control and manage the decision-making process as a whole.

The basic principles reproduce the knowledge of the proposed concept of decision-making. To represent knowledge, multiparameter and multifunctional sets are used.

The development of aggregates is based on the principles of P1 - cost, P2 - convertibility, P3 - productivity, P4 - systemic principle. The implementation of the P4 systemic principle presupposes the availability and application of technology for the representation of knowledge in the form of models. The main elements of the basics are concepts, methods and operations.

The concept assumes a general scheme of the work of the basic principles.

$X=\{x\}$ – is the set of initial data,

$S=\{s_k\}$ – is the set of problems, $\Pi=\{\pi_\lambda\}$ – is the set of solutions,

$\Lambda=\{\lambda\}$ – is a set and $\Lambda^* \subseteq \Lambda$ – is a subset of decision procedures,

$Y=\{y\}$ – is a set and $Y_\lambda=\{y^1_\lambda,..,y^n_\lambda\}$ – is a subset of the outcomes of the solutions.

Let the operators be defined:

- f_I, operator of identification on the set of problems $S=\{s_k\}$:

$s_k \in S \rightarrow \pi_\lambda \in \Pi$, such that $f_I(s_k)=\pi_\lambda$, (1)

- f_S, operator of realizations on the set of solutions $\Pi=\{\pi_\lambda\}$:

$\pi_\lambda \in \Pi \rightarrow y^i_\lambda$, such that $f_S(\pi_\lambda)=y^i_\lambda$, (2)

- f_C, operator of choice (esimation) on a subset of outcomes of the solution $Y' \subseteq Y$:

$y \in Y' \rightarrow X_y = f_C(Y) \subset Y$, such that:

$\forall U \subset Y\, f_C(U)=U \cap X_y = U \backslash V_y$, where $V_y = X \setminus X'_y$. (3)

Then, based on the basic sets f_I, f_S and f_C (according to expressions 1-3), the set of initial data is truncated and the maximal $X' \subset X$ is defined, the data set that is invariant under $\Lambda^* \subseteq \Lambda$, the sets $\Lambda=\{\lambda\}$ of the procedures for solving the problem: $\forall \lambda \in \Lambda^*$,

$$f_I f_S f_C(X')=X'.$$

Using the generally accepted concepts of decision theory, we will talk about a multicriteria problem, which in general is represented:

$$z = V(A),$$

where $A=\{A_q\}$ is the set of known technical solutions, V is the function of selection of the solution.

To solve the problem we construct a function of selection V - a criterion, which includes components that depend on regulatory, legal and technical requirements with agreed values of indicators. Selection of solutions is performed in the process of solving the last two problems on the basis of the formed multicomponent criterion.

The solution of the problem is represented in the form of a mapping P, having a domain of definition on the corresponding set of estimates, as a composition of concepts, methods and operations:

$$P = f_{STPR} f_I f_S f_C, \quad (4)$$

where f_{STPR} is the function of standard production technical requirements. The values of this function represent regulatory requirements (in fact - restrictions on standards).

2 Structure and methods of research

The evaluation of the efficiency of production activities is carried out in the context of each CNG filling station separately according to the following procedure.

At the first step of formationing of criteria the set of components that are identified with the technical characteristics of known and manufactured equipment samples is considered as the domain of the mapping *P* (4). Due to a number of requirements of normative and technical documentation, the initial truncation of the total set of technical solutions is made, which makes it possible to improve the efficiency of the station equipment. Further on the truncated set using basic concepts, methods and operations, various available sets of components are formed, each of which is considered as a variant of the criterion, and truncated sets must provide different criteria. After the evaluation of the completeness and the minimum power of the criterion, the most appropriate is chosen by calculating the significance of its components. This problem is subject to algorithmization and can be implemented using a combinatorial model of discrete problems.

Since the task of choosing a technical solution and a set of measures to improve the efficiency of the production process at a plant is a multi-criteria task of making large-scale decisions, in the process of solving problems from a variety of possible solutions all wittingly unefficient solutions are removed, thereby corresponding truncations are performed.

Solutions to internal tasks may not contain global ones and consist of local solutions. To compare the results, a measure of information loss of solving problems is introduced. Since all the parameters of the target decision functions have different dimensions, a transformation is performed in which objective functions are converted into dimensionless quantities. Rules of rationing take into account the nature of the parameters to be regulated, by using the information measure on Hartley. Due to the normalization with reduction to a single measure, the problem turns into a multicriteria decision-making problem under conditions of certainty.

However, there are separate efficiency criteria, which are not desirable to be integrated within the framework of solution *P*. One of them is responsible for the efficiency of spending resources in the production process, and the second - for technological effectiveness of design solutions . When designing new objects, it makes sense to compare the obtained values of *P* with the efficiency criteria of existing enterprises. Consider these criteria.

Evaluation Criteria

1. Criterion for assessing the effectiveness of the production activity of CNG stations

The criterion for assessing the effectiveness of production activity f_{E} is based on a comparison of specific actual production indicators with specific regulatory performance indicators for the applied technical solution of the station [2]. The main components in the criterion include: - electricity consumption at the station; - natural gas consumption for own needs; - oil consumption in the lubrication system of the cylinders of compressors of the station; - consumption of adsorbent for the gas drying system; - coolant flow rate.

$$f_{\mathrm{E}} = \left(W/P_1\right)\left(Q/P_2\right)\left(L/P_3\right)\left(M/P_4\right)\left(N/P_5\right),$$

where W - the specific actual power consumption at the station, kW·h/m^3; Q - specific actual consumption of natural gas for own technological needs and losses for the station, m^3/m^3; L - specific actual oil consumption, kg/m^3; M - specific actual consumption of adsorbent, kg/m^3; N is the specific actual flow rate of the cooling liquid, l/m^3; P_1 - specific normative power consumption for the station according to project documentation, kW·h/m^3; P_2 - specific normative consumption of natural gas for own technological needs and losses for the station according to the project documentation, m^3/m^3; P_3 - specific oil consumption according to the project documentation, kg/m^3; P_4 - specific standard consumption of adsorbent according to the project documentation, kg/m^3; P_5 - specific standard flow of cooling liquid according to the project documentation, l/m^3.

2. Criterion for assessing the technological effectiveness of design solutions of CNG stations

The criterion for assessing the technological effectiveness of design solutions of the CNG stations f_D is based on the comparison of actual requirements in the main production equipment, functioning stations and design parameters of the initial technical solution of the station [3-4]. The main elements of the CNG stations are: - the scheme of the organization of the compression process; - Number of compressor units; - number and volume of gas accumulators; - availability of automatic control system and its technical characteristics; - availability and technical characteristics of natural gas drying and purification systems; - number of high pressure lines; - Number of gas filling columns; - design productivity; - peak design productivity. All of the above indicators are part of the three main ones:

$$f_{\text{D}} = \left(Q_1 / Q_2\right)\left(N_1 / N_2\right)\left(P_1 / P_2\right),$$

where Q_1 is the actual volume of produced compressed natural gas, m^3 / year; Q_2 - design capacity of the station, m^3 / year; N_1 - the actual time of operation of the compressor facilities of the station, hour / year; N_2 - design time of operation of compressor facilities of the station, hour / year; P_1 - the actual number of refueled vehicles, units / year; P_2 - design number of refueled vehicles, units / year.

3 Results of the study

Dynamics of prices

Gas motor fuel, entering the market of motor fuels in a market economy, faced price competition with traditional liquid motor fuels. At the beginning of 2014, the average level of the price of compressed natural gas in the Russian Federation was about 30% of the cost of diesel fuel, which was one of the key indicators that stimulate vehicle owners to use gas engine fuel, to buy new (or to retrofit existing) equipment. The increase in the consumption of compressed natural gas from the point of view of the work of a number of scientific teams [1, 2] should have led for profitability of CNG stations by increasing the degree of loading of the main production equipment of the stations. However, operating stations, taking advantage of the absence of other manufacturers of gas motor fuel in a specific locality and their own uncontestedness to existing Vehicles with gas cylinder equipment, along with increasing the station load, are actively increasing the cost of CNG. The dynamics of changes in average selling prices for diesel and gas motor fuel in the Russian Federation is given in Table 1.

Table 1: The dynamics of changes in average selling prices for diesel and gas motor fuel

	Gas motor fuel, rubles, m^3			Diesel fuel, rubles, L		
	2014	2016	%	2014	2016	%
Russian Federation	9,32	13,12	**+28,96**	32,17	37,65	**+17,02**

Despite the absence of the need for special additives and components used in the production of gas motor fuel and components used in the production of liquid motor fuel and partially purchased for foreign currency from foreign companies, the selling price for gas motor fuel is growing 1.7 times faster than the price of diesel fuel. It should be noted that the price of natural gas supplied through main gas pipelines to CNG refueling stations increased by 10.1% over the period 2014-2016. In the conditions of the existing trends and the conditionally established target efficient price for the use of gas motor fuel as 50% of the cost of diesel fuel (at the current price level of 18.82 rubles per m^3), the price of gas motor fuel will be unattractive 7-8 years later.

In a number of subjects of the Russian Federation, such as the Bryansk, Belgorod, Voronezh, Kaluga, Kursk, Lipetsk, Orel, Ryazan and Tula regions, in three years the selling price increased by 45% and reached 15.60 rubles per m^3 of CNG. If the current trend persists in the areas listed above, in 2 to 3 years the price for compressed natural gas will exceed 50% of the cost of diesel fuel.

Assessment of the effectiveness of the production of CNG stations

Examples of generalized calculations by the given criteria for the three of the hundred and seventy-seven stations studied monthly in PJSC Gazprom [5] are shown in Table 2. Figure 1 shows the dynamics of the change in the average annual energy consumption, and Figure 2 are graphs of the energy consumption factor in the context of the months of the year.

Table 2: Examples of generalized calculations by the criteria

Name of CNG station	2014		2015		2016	
	f_E	f_D	f_E	f_D	f_E	f_D
CNG station Perm-1	1,213	0,084	0,953	0,148	0,984	0,272
CNG station Kaluga-1	1,394	0,250	0,884	0,238	0,995	0,231
CNG station Saratov-1	1,141	0,197	0,989	0,190	1,028	0,222

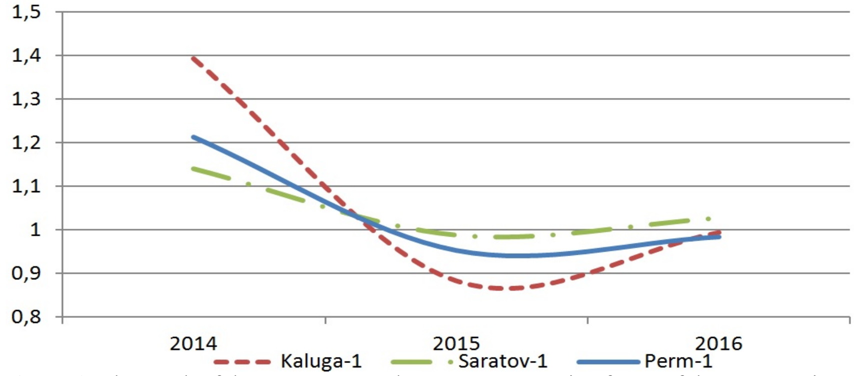

Figure 1: The graph of the average annual energy consumption factor of the CNG stations

The criteria given in this study can be used to analyze the efficiency of the operation and design divisions of large companies owning CNG stations.

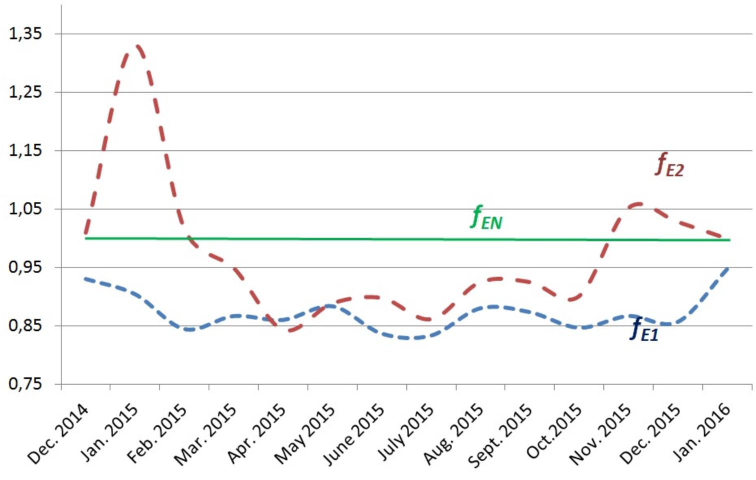

Figure 2: The graph of the energy consumption factor of the stations: f_{E1} – CNG station Perm-1; f_{E2} – CNG station of Kaluga-1; f_{EN} is the normative level

When $f > 1$ - the object and production units operate ineffectively, exceeding the norms of consumption of fuel and energy resources and materials; when $0.8 < f_E \leq 1$ - the object and production units work efficiently; when $0,01 < f_E \leq 0,8$ - the object and production units work with a clear violation of the technology of the production facility and technological regulations; $f_E = 0$ - the object does not work. When $f_D > 1$ - the object is designed with errors or does not cope with the load; when $0.8 < f_D < 1$ - the object is designed without errors, correctly placed and copes with the load; when $0,2 < f_D \leq 0,8$ - the object is designed with errors, incorrectly placed, the load is insufficient (corrective measures are possible); when $0 \leq f_D \leq 0,2$ - the object is designed with an explicit excess of the power of the main production equipment, it is incorrectly placed, there is no load (corrective measures are ineffective).

4 Conclusions

All stations analyzed in the study have excess production capacity, the f_D coefficient only in eleven of the surveyed stations exceeded 0.5, and all others - at the level of 0.15-0.3. Based on the results of the assessment of the quality of operation of the operating personnel, the stations were divided into three groups: - operating in accordance with technological regulations and meeting the standards of costs of fuel and energy resources and materials; - work with technological regulations and non-compliance with the standard; - work in violation of technological regulations.

In addition, the above evaluation criteria can be used to prepare proposals for decision-makers regarding the motivation of the personnel serving the facility by preparing in the automated mode the lists of personnel subject to incentive payments, as well as incentives and fines.

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