On the question of the rational behavior of firms in the market of technical services in the field of the autogas system

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Abstract. The article presents new approaches to formalizing and evaluating the actions of market participants in technical services in the field of installation and maintenance of the autogas system in order to determine the rational boundaries of a number of characteristics of the behavior of these firms-players in the market. Currently, a wide range of gas equipment is produced for installation on cars, which has a wide range of consumer properties. This diversity makes it difficult for consumers to choose these products, being faced with the task of determining the nomenclature of models of autogas kits, their required number depending on various input parameters – the market environment in which the considered service station operates, the power of the service station focused on the gas market segment, etc. To solve the above problems, it is proposed to evaluate the market potential of a particular kit of AGS, goods offered to the consumer-owner of the car, which is an essential characteristic that determines the priority of inclusion (or exclusion) of a set in the gas equipment nomenclature at a particular service station. To determine the predicted effectiveness of certain decisions, the article proposes the formalization of the described market processes and the construction of a mathematical model of the market participants’ behavior depending on different influence factors, the behavior of the components included in the complex objective function and the creation of an algorithm and software for finding rational solutions.

Keywords: car, autogas system, market potential, objective function, market behavior, vehicles.

1. Introduction
In recent years, in many countries of the world gas motor fuel (GMF) is gaining more and more popularity. The fleet of gas tank vehicles (GTV) is replenished with vehicles in which the autogas system (AGS) is installed directly at the vehicle manufacturing plant. But in most cases, AGS is installed after the vehicle is put into operation. This type of replenishment of the GTV fleet will be the main one for a long time [2].

A wide range of AGS is produced, which has a big set of consumer properties [1, 4]. Historically, two production strategies have developed on the global AGS market.

1) Plants produce the entire set of equipment.

The following manufacturers can be mentioned as an example:

- BRC, Lovato (Italy), A C (Poland)

In the case of this strategy, the manufacturer makes a profit from each element of the AGS system, however, the plant needs to invest in the development and modernization of equipment, as well as to store and deliver products.
2) Suppliers of sets of AGS place the production of most components at third-party manufacturing plants, and from the resulting components assemble a certified set [3]. The following companies can be mentioned as an example:

- Digitronic, Poletron, LGTech, Elpigaz.

This strategy allows companies to diversify their risks, which depend both on the company’s dependence on one supplier and on the loss of “dead” capital invested in the development and adjustment of the technology for the production of many components, if changes are necessary in the product line.

Often during the life of a product on the market there are periods when ups and downs of quality occur. Plants of the first type, working on a full production cycle, have to pass all periods of release of goods. But suppliers of the second type, such as Digitronic, can create a kit by choosing components from a wide range of elements, selecting them at the peak (on the rise) of quality. Thus elements on decline of quality are excluded from a kit.

Also, there is a tendency in the modern AGS market in which companies and plants merge under the leadership of one large concern. At the same time, companies retain a certain functional independence and do not lose their technical uniqueness (Fig. 1).

![Figure 1. The scheme of merging companies in the Westport concern](image)

As a result, several dozen manufacturers of AGS and its components operate on the European market. This diversity makes it difficult for consumers to choose these products. Under the consumer we can understand a large range of both legal entities and individuals. In general, they can be divided into two groups. The first includes installers (as part of service stations) who buy kits or components from a manufacturer or distributor, perform both installation of gas equipment, and maintenance and repair. The second group includes directly the owners of vehicles converted to work on the GMF. Both of these groups of consumers are customers, although at different levels.

All of the above shows the relevance of the question of determining the nomenclature of models of AGS kits, the required amount depending on various input parameters – the market environment in which the considered automobile service station (ASS) operates (or will operate), on the power of the service station (or service station units focused on the gas market segment), etc. [5].

2. Approach to construction a mathematical model of effective resource management

The purchase or market potential of a particular set of gas equipment, the goods offered to the consumer-owner of the car, is a significant characteristic that determines the priority of including the kit in a set operated by a particular service station, or, conversely, excluded from the supported nomenclature [3]. The analysis of opinions, behavior of market participants gives the chance to predict
not only whether or not there will be sales in this direction in the surveyed region, but the economic efficiency of forming one or another package of offers from the service station to customers – car owners [4]. To determine the predicted effectiveness of certain solutions to the above problem, it is necessary to formalize the described market processes and build a mathematical model of market participants' behavior depending on the identified influence factors, the behavior of the components included in the complex objective function and the creation of an algorithm and software for finding rational solutions.

As a result of creating a mathematical model for making a decision on optimizing the AGS nomenclature, which one or another service station supports, a so-called objective function is prepared that takes into account various cost components, both plus and minus.

The objective function determines some financial indicators. Trying to determine the rational set of sets of AGS (products) that will be stored, installed, repaired at the automobile service station (and the ability to work with these sets will be supported), apparently, it is necessary to consider the funds remaining as a result at the service station, i.e. profit. This may be, for example, specific profit per unit of time (day, year ...), and, possibly, per one post. At the same time, it should be borne in mind that the developed rational set of kits will depend not only on the distribution of interests of the customer’s market base for those factors that are selected as basic (in our case: reliability, functionality, engine power serviced by AGS, price – are considered as basic), but also on the power of the ASS (or the element of the ASS that deals with AGS). And therefore, obviously, different recommendations can be developed for different capacities of ASS. /customer’s gain in costs per 1 km. in this approach can be manifested and taken into account as the degree of the client’s desire to switch to gas (and, accordingly, in the probability that the client will do this)/.

What components should be taken into account in the full objective function of the model?

First, this is the income from the installation of AGS sets on automobiles, then – the income from the repair of AGS, from the maintenance of AGS, as well as the expenses spent on the storage of all sets of kits (and their components) at service stations, installation, and periodic training of personnel, associated with a change in the produced nomenclature of AGS, with a change in software, advertising costs, etc.

However, in this article we consider the formation of only the first component-revenues from the installation of AGS. /This is the basic component, since both the current fleet of gas equipment already in operation in the surrounding region will need to be maintained and repaired, and increasingly those cars that we (the service station under consideration, together with competitors, of course) will saturate with gas equipment in the course of our work/.

When determining income, it is necessary to understand from whom we receive it, i.e. to determine the market base of consumers of the considered type of work, which can become our customers.

We accept the following conditions.

1) Our clients are mainly those who live, work, i.e. are mainly located in some adjacent region. Transients, of course, can call in, especially if repairs are necessary, and this is taken into account in the full model.

2) Our (considered) service station is not unique, so there are other stations in the region that operate to intercept our client in the event of our mistakes – insufficient production capacity, reduced quality, etc. Work in a competitive environment, in market conditions, is taken into account by probabilities of various kinds.

3) We accept that all the functional dependencies mentioned below are known to us.

So, we will analyze the “behavior” of the client base in order to determine the “market potential”, i.e. the number of customers who can contact us.

Let’s assume that there is a probability G0 that the client generally wants to install AGS on his car, and a probability G1 that he wants to install HBO or repair it at our station. These two probabilities depend on the region, on (i.e. the development of the situation in time), on advertising, on the breadth of options presented for the client (the more options we have, the sets of AGS, the more likely the client will reach us, – all other things being equal or almost equal conditions), etc. These probabilities
are included in the expressions of the objective function after formalizing each of the components separately.

In the meantime, we consider how the probabilities of a “customer reaction” are formed depending on the parameters characterizing a particular set of AGS.

We assume that the parameter of the supported engine power is not further considered in conjunction with the others, because according to this parameter, customers were initially separated, having cars with different engines and require different (on this parameter) gas equipment.

Let us know the following probability distribution (or, more simply, the distribution of the number of customers) according to their requirements by two parameters, the meaning of which – for any combination (x, y) probability \( \rho(x, y) \) dx dy is the proportion of customers who, starting with this parameter value and higher/better (on each axis), allow themselves to purchase (and install) a kit of AGS (hereinafter – the product, goods). At the same time, we do not consider the cost at this stage, putting in this function the sense that with the worst quality in terms of the parameters the client does not want to purchase the goods (although, maybe, he will take it at a bargain price, see below).

Let this distribution look like this:

**Figure 2.** Example of the distribution of customers according to the level of requirements for the quality of goods by 2 parameters

/ Hereinafter the figures – with conditional parameters and conditional values /

Here, along the X axis (in front of us) is parameter A, along the Y axis (away from us) is parameter B, and along the Z axis is probability (number of customers).

Further, for the convenience of visual presentation and explanation, we will consider the dependence on only one factor.

To get distributions separately for each factor, we simply take the integral separately along each axis.

As a result of integration along the X axis, we obtain the distribution of the parameter B (from Y):
As a result of integration along the Y axis, we obtain the distribution of the parameter A (from X):

Figure 4. Distribution of customers on the parameter A

With this distribution of clients N(A) we will continue to work – again, for the convenience of visualization (let's assume, for example, that these are the client's requirements for one of the main components of quality – reliability, mean time between failures on a certain scale).

Let's ask a question how to describe client behavior depending on values of the considered parameters?

First, there are claims of the client, or his requirements to goods (further on all figures this axis will be denoted by the letter "W"). The approximate meaning of this – the quality below the $W_X$ I (the client) do not consider. (The variant of distribution together by two parameters of this value is shown in Fig. 2, separately – in Fig. 3, 4). However, this is quite conditional, the customer can say it to himself, in fact, the customer can purchase goods below the $W_Y$ border, if the price is low, or in the mood – with a certain probability. So, the probability of making a decision is also affected by the price. In a survey of customers, they can specify as boundary two prices – one at which I will definitely buy goods of such and such quality, and the other, above which I definitely will not buy goods of such and such quality. Such deterministic customer behavior is shown in Fig. 5a. Here on axes: W-claims of the client, K – quality of goods, C – the price of goods. The green surface is the upper allowable price for a customer with $W_Y$ claims for a product with $K_x$ quality. The lower violet surface is the boundary of the 100 % acquisition decision. All this is subject to the availability of only one product offered by our (or some other) service station.
Figure 5. A discrete and probabilistic graphical description of the client’s behavior when deciding on the purchase of goods (installation of a kit of gas equipment)

However, as already mentioned, the behavior of the client mass is not strictly determined, and is more correctly described by probabilistic functions. The representation of such a function is given in Fig. 5b, 5c and 5d. These functionals are based on the same functions that are shown in Fig. 5a, but with the distribution of the probability of making a decision between the green and purple surfaces (also above and below them). In Fig. 5b, the probability value is determined by the transparency of the corresponding point (it looks like a more or less faded blue color, the lighter the lower the probability), in Fig. 5c – from another point of view, color across the palette of the visible rainbow – from violet (highest value) to red (lowest value) and with graduation transparency. Figure 5d shows a complete representation of the behavior of the probability of making a decision on the level of claims, on the quality of the product and its price – with the addition of a zone of almost 100% probability (bottom blue part).

Fig. 6a – 6c show sections of the obtained object P (K,W, C) by different planes. The intersection of planes with a 3D object-graph represents the behavior of the probability of a decision:

a) for a given quality of goods, the dependence of the price boundaries on the level of customer complaints, and the behavior of the probability of making a decision on the combination of the level of claims and the value of the price (cross section by the green plane, Fig. 6a);

b) for a given level of the client's claims, the dependence of price boundaries on the quality of the goods, and the behavior of the probability of decision-making on the combination of the quality of the goods and the value of the price (cross section with a raspberry plane, Fig. 6b);

c) at a given price level, the dependence of the boundaries of acceptable product quality level on customer's claims and behavior of the probability of the decision from a combination of quality of product and level of customer's claims (the yellow section of the plane, Fig. 6c).

/The named dependencies are visible by the behavior of the grid lines and by the slight darkening of the section planes./
Figure 6. Cross-sections of the function $P(K, W, C)$ by planes of constant quality (A), constant level of quality requirements (B) and constant price (C)

Figure 7. The possible behavior of the probability of making a decision to purchase a product at a fixed level of quality, depending on the level of customer requirements at different fixed prices
Separately (Fig. 7) determine the behavior of the probability of making a decision to buy a product of const. quality (here K=12 in the selected conditional scale), and with different fixed price of the goods (conditionally from 3 to 6, lower price – the graph above), when the abscissa axis is set to increase the customer's quality requirements, i.e. the minimum quality (or so), which client admits for himself by the parameter under consideration.

**Figure 8.** Composition of functionals $P(K, W, C)$ and $N(W)$

**Figure 9.** The position of the integration path (determined by the properties of the product) of the function $P(C, W, P)$ with the weight $N(W)$ along the claim axis $W$
It is evident that for a very low price for a product of this quality (not very bad), they will take it until the customer’s claims for quality increase significantly, and even then there is probability that the customer will take the product for a low price. At a higher price, a client with low quality requirements (and, accordingly, with a lower upper and lower price acceptable for himself) will not take such a product at all, but with an increase in quality requirements (and the corresponding acceptable price limits for the client), there is a probability of taking the goods. It rises until the quality requirements from the client exceed the quality of this product (at a specific price), and then falls down with increasing customer requirements. For some price (here ~ 6) for such price of such quality nobody will buy goods – the probability goes to 0 regardless of the level of customer requirements.

Next, we proceed to determine the market potential of the product, taking into account the distribution of opinions, the behavior of the customer mass, expressed in terms of the probabilities that have just been considered (Figs. 5–7), and the distribution of the mass of customers by the quantity—how many of these or those we have customers by the level of claims (shown in Fig. 4). Together, the functionals \( P(K, W, C) \) and \( N(W) \) are shown in Fig. 8 in a different color representation. At the same time, the distribution function of clients by the parameter “\( P \)” is given by a red ribbon.

Figure 9 gives an idea of a representation of the probability of making a purchase decision, indicating here the axis (rod) that defines a particular product. This is the axis, the fixed coordinates of which are the cost and quality of the goods, along which this probability function is integrated along the “\( W \)” axis with a weight of \( N(W) \).

Carrying out such integration along the axis of the customer's claims level "\( W \)" for different combinations of the cost of \( C \) and the quality of the goods, we obtain the dependence function shown in Fig. 10. It represents the market potential \( R \) (on a conditional scale, as mentioned above) for the goods of value \( C \) and quality \( K \), i.e. how many customers from the considered area, the region may well purchase such goods. / It should be said that the potential is an opportunity stretched over time, but using the average time that client makes a decision on the purchase of goods, we can reach the flow of applications for work per unit time, which will allow us to further represent the generated objective function completely in the form of time-specific revenues and costs and optimize the desired solution./

Also in Fig. 10 added (for illustration) approximate boundaries within which a combination of product characteristics \( \{K, C\} \) can be real. Borders are crimson (lower price) and yellow translucent (upper price) color. To all this is added a green label-cylinder, marking the position of a particular product (here the product with the same coordinates as in Fig. 9).
So, let the service station have several types of goods (kits of AGS) offered to customers. In Fig. 11 they are shown in the same environment as in Fig. 10, several labels-cylinders (given in different colors). However, the total market potential in this case will not be equal to just the sum of the potentials of these four, taken separately.

**Figure 11.** The combination of images of several products on the function of market potential

**Figure 12.** Illustration of a combination of probability functions for several products depending on the level of customer claims and the formed correction factor
We consider the behavior of the probability of a positive decision on the purchase of goods by the customer of the product “No. i” depending on the level of customer claims. For the example of the four products in Fig. 12 graphs of these probabilities are given, shown in the corresponding colors. It is seen that for some values of “W” the sum of these graphs exceeds 1. However, this amount is the probability that the customer will buy something from us. It cannot be higher than 1, because according to the terms of the task, the client will install no more than one set on one of his vehicles.

Where the sum of the probabilities is less than 1, we accept that the interest of customers is distributed between different goods, and thus the probability that some kind of purchase will happen is increased and taken equal to the sum of the individual probabilities.

And where the sum of probabilities is greater than 1, we correct all incoming functions in such a way as to reduce the value of the sum of probabilities to 1, i.e. the correction coefficient, by which we will divide the functions included in the consideration, is equal to the sum of these functions if this sum is greater than one, or is equal to 1 if the sum is less than 1. In Fig. 12, the color of the correction factor $K_c$ is shown in black.

The correction performed affects the probability values only for specific goods and for each combination of goods (kits of AGS) it is considered separately, and after correction, the obtained market potentials can be correctly added. In the table 1 the values of the market potential for the considered 4 products before and after the correction are given.

| Table 1. Calculation of individual and total market potential for the selected example |
|---------------------------------|----------------|----------------|----------------|
|                                  | quality | cost | market potential expressed in objects | market potential expressed in money |
| data before correction           |         |      |                                    |                                |
| 6                               | 3       | 122.3| 366.8                                |
| 11                              | 3.9     | 104.3| 406.7                                |
| 16                              | 4.2     | 116.0| 487.3                                |
| 25                              | 6.9     | 1.5  | 10.3                                 |
| Total                           |         | 344.1| 1271.1                               |
| data with correction            |         |      |                                    |                                |
| 6                               | 3.0     | 69.3 | 207.7                                |
| 11                              | 3.9     | 56.0 | 218.3                                |
| 16                              | 4.2     | 64.3 | 270.0                                |
| 25                              | 6.9     | 0.8  | 5.2                                  |
| Total                           |         | 190.4| 701.2                                |

Thus, the market potential of 4 goods represented at one service station is higher than that of any one of the components of this group, but lower than the sum of the potentials of any two separate goods (except for the most expensive and therefore with very low potential – within the framework of the above functions).

Going through the various options for sets of goods (kits), we calculate the resulting total market potential, and then the income received from this. When constructing the full model, it is also taken into account that the probability that the client will choose a specific reporting station increases with the number of types of products offered, at the same time, this increases the cost of storage, personnel training, etc. In addition, in the course of a full analysis, it is expected that recommendations will be formed on a rational set of AGS kits depending on the power (size) of the service station. For example, if the station is of low power, then it is not necessary to cover all groups / types of customers – the market potential of a small range of installed AGS, working for any one group, may be quite enough.

Thus, depending on the size of the station, you can give different sets of recommendations depended on number and type of sets of goods/kits.
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