Methodology for assessing the impact of transport accessibility on the competitiveness of residential facilities

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Abstract. The purpose of this study is to develop a methodology for assessing the impact of various factors of consumer choice on the competitiveness of residential facilities. One of the key factors in the work is the presence of a developed transport infrastructure. As a result of the study, their functional interdependencies were determined, an algorithm for assessing and analyzing the competitiveness indicator of the construction object from the point of view of the consumer was developed.

1. Introduction

Existing scientific approaches to determining the competitiveness of construction products are based on a combination of a number of its properties and market position. However, they do not reflect the influence of the totality of its properties on the possibility of maximizing the utility received by the consumer from the acquisition of housing [1-3].

2. Materials and Methods

Based on the identified shortcomings of existing scientific approaches to determining the factors of competitiveness of housing products [4,5], it is proposed to clarify and supplement quality indicators, price characteristics, a description of the ready time of products, and to structure these groups of parameters into a classification of factors of competitiveness of housing products (table. 1).

The application of this classification allows taking into account the totality of competitiveness factors, including clarifying and supplementing the quality indicators of housing construction products, using the elements that form the payment structure, and specifying the description of the ready time of products.

The developed classification is based on the conceptual functional dependence of demand for a product $D$ on the totality of its quality indicators $OC$, price characteristics $Z_f$, and ready time of products $T$:

$$D = f(OC, Z_f, T) = f(Q_f, Q_w, Q_n, R_f, Z_f, T)$$
### Table 1. Classification of factors of competitiveness.

| Groups of factors | Designation | Factors |
|-------------------|-------------|---------|
| Apartment characteristics | $S_G$ | Size of the total area with balconies |
| | $S_R$ | Living rooms |
| | $S_{LIV}$ | Size of the living space |
| | $S_{DR}$ | Dining rooms |
| | $S_{BR}$ | Bedrooms |
| | $S_{LAV}$ | Bathrooms |
| | $S_{NRI}$ | Size of non-residential area |
| | $S_{KIF}$ | Kitchen |
| | $S_{COR}$ | Corridors |
| | $S_{STOR}$ | Storerooms |
| General characteristics | $Q_p$ | Planning factor |
| | $K_I$ | Sizes of a loggia, balconies |
| | $S_{BAL}$ | View characteristics from windows |
| | $K_{STR}$ | Floor of an apartment in question |
| | $H_G$ | Apartment height |
| | $Z_V$ | Combination of kitchen and living room in one room |
| | $Z_N$ | Influence on the sound comfort of neighboring rooms |
| Interior parameters | $Z_I$ | Quality and availability of finishes, fittings of sanitary equipment, features of engineering systems |
| | | Parameters of water supply, sanitation, heating, air conditioning, ventilation, electricity, gas supply, waste collection systems. |
| Engineering systems | $Z_{EN}$ | Home management organization |
| Operational | $Z_M$ | Technologies and typification of construction parameters |
| | | Stationary Height and number of storeys |
| | | Decoration of facades |
| General technical | $Q_B$ | Proximity of coastal and forest zones, kindergartens and schools, health facilities, cultural and sports centers, harmful enterprises; building density. |
| Building characteristics | | Seismological activity, climatic features, the presence of aggressive and homogeneous fields, social equality and cultural harmony |
| | | Parking parameters |
| Surroundings | $L$ | Quality of intra-quarter roads, the availability of bicycle and pedestrian roads |
| Neighborhood | $Q_N$ | Presence and parameters of landscaping elements |
| Road infrastructure | $Z_L$ | Cost of an apartment |
| | | Unit cost of an apartment |
| | | Loan amount |
| | | Cost of production, taking into account the overpayment |
| Landscape | $Z_S$ | Final cost of the loan |
| | | Initial fee |
Qualitative indicators $OC$ of housing construction products are divided by the author into four groups of parameters considered within the apartment $Q_r$, the entire building $Q_s$, the surroundings of the house $Q_z$, as well as the transport accessibility of the facility $R_T$, and are caused by their constituent elements - competitiveness factors, and, taking into account the dependencies of the constituent elements, have the following form:

$$Q_r = f(S_G, S_{LV}, K_1, K_{ST}, H_G, Z_N, Z_N, Z_N)$$  \hspace{1cm} (2)

$$Q_s = f(Z_{EN}, Z_{AF}, Y_{GF}, Y_{AF})$$  \hspace{1cm} (3)

$$Q_z = f(Z_N, Z_N, Z_N, L)$$  \hspace{1cm} (4)

$$R_T = f(R_T, R_0)$$  \hspace{1cm} (5)

Price characteristics $Z_p$ consist of the absolute $P$ and relative $P_{rel}$ cost of the product, the elements that form the payment structure $Y_r$ and depend on the financial capabilities of the consumer (current and future savings - $P_0$ and $P_n$) and credit conditions (duration $N$ and interest rate $I$) and, taking into account the dependencies of the constituent elements, are formed as follows:

$$Z_p = f(P, P_0, P_{rel}, P_n, I, N)$$  \hspace{1cm} (6)

Using the conceptual relationship between demand for a product (1) and a combination of its quality indicators (2;3;4;5), cost characteristics (6) and the availability period, it is possible to bring the factors of competitiveness of housing construction products to a single functional dependence.

Based on the restrictions imposed on the compared objects and their influence on the assessment and analysis of competitiveness, the author proposes to clarify the developed classification of factors, taking into account those that affect consumer choice (Table 2) [6].

**Table 2. Classification of factors of competitiveness of housing products affecting consumer choice.**

| No. | Factors                                      | Designation | Dimension            |
|-----|---------------------------------------------|-------------|----------------------|
| 1   | Size of the total area with balconies       | $S_G$       | square meters        |
| 2   | Living space size                           | $S_{LV}$    |                      |
| 3   | Planning factor                             | $K_1$       |                      |
| 4   | Group indicator of transport accessibility  | $R_G$       | minutes              |
| 5   | Individual indicator of transport accessibility | $R_p$   |                      |
| 6   | Cost of an apartment                        | $P$         |                      |
| 7   | Initial fee                                 | $P_0$       | rubles               |
| 8   | Monthly payment                             | $P_n$       |                      |
| 9   | Unit cost of an apartment                   | $P_{rel}$   | ruble/square meter   |
| 10  | Credit rate                                 | $I$         | percent              |
| 11  | Loan terms                                  | $N$         | months               |
| 12  | Time to completion of construction          | $T$         |                      |
The use of this classification allows clarifying the relationship between demand for products \( D_i \) depending on the quality parameters \( Q'_i \) that can be recognized by the consumer in accordance with the restrictions imposed on the compared objects. The author proposes to use an indicator of the competitiveness of housing products \( CIC \), based on factors of consumer choice, as follows:

\[
CIC = D_i = f(Q'_i, R_i, Z_r, T) = f(S_c, S_{LV}, K_i, R_i, R_o, P, P_o, P_n, P_a, I, N, T)
\]  

(7)

The competitiveness indicator \( CIC \), in accordance with the indicated dependence (7) and given restrictions, is identified with the level of demand, is determined individually for each object and characterizes it at the time of assessment, based on the competitiveness factors of housing construction products that affect consumer choice.

The application of this approach allows clarifying the principle of the influence of factors of product competitiveness on consumer choice [7, 8].

3. Results

The problems of applying existing approaches to determining the competitiveness of products are associated with the peculiarity of using the method of expert assessments, which does not give complete objectivity, the lack of universal indicators that take into account the specifics of construction in progress, for comparison, the methodological difficulties of quantifying and bringing the results to financial indicators.

The developed algorithm for assessing and analyzing the competitiveness of housing products is based on a comparative approach to real estate assessment and is reduced to the following eight stages.

First stage. Determining the value of existing consumer savings \( P_0 \) and its ability to make monthly payments \( P_n. \)

Second stage. Definition of objects acceptable for assessment and analysis, terms \( T \) to completion of their construction. Consideration of affordable mortgage programs and setting the size of the interest rate on the loan \( I \), as well as the maximum possible loan period \( N_{\text{max}}. \)

Third stage. The choice of specific apartments in available objects, the determination of the sizes of their general \( S_c \) and living \( S_{LV} \) areas, the declared price \( P \) of the apartments of interest and their planning coefficients \( K_i. \):

\[
K_i = \frac{S_{LV}}{S_c}
\]

(8)

Fourth stage. Calculation of the loan term \( N. \) based on annuity payments, the ability to make payments during this period with the specified parameters \( P, P_o, P_n, I. \)

\[
N = \frac{100 \times (P - P_o)}{100 \times P_n - I \times (P - P_o) + 12}
\]

(9)

Comparison of the calculated value \( N \) with a given value \( N_{\text{max}}. \)

Fifth stage. Clarification of the number of objects allowed for evaluation and analysis. Calculation of the unit cost of the apartment \( P_{\text{m}}. \):

\[
P_{\text{m}} = \frac{P}{S_c}
\]

(10)

Sixth stage. Definition of group \( R_o \) and individual indicators \( R_i \) of transport accessibility based on the location of the place of work of the consumer or the logistics center of the city. Calculation of the
daily difference in transit $t_\Delta$ and the cost of time $TC$ required to determine the amount of additional transport costs $TP$.

The daily difference in transit $t_\Delta$ characterizes the additional time costs for moving the consumer from the logistics center to the selected object. With an equal ratio of cases of using personal and public transport, the daily difference in transit is formalized as follows:

$$t_\Delta = R_P + R_G$$ (11)

The calculation of the cost of time costs $TC$ is necessary to bring the daily difference in transit to the financial equivalent during the calendar month (consists of 21 working days, 8 hours per day), calculated on the basis of the borrower’s income (adopted as $2.5\ P_n$).

$$TC = \frac{2.5P_n}{21*8*60} = \frac{P_n}{4032}$$ (12)

This formula involves the average number of working days in a month – 21, and hours per day - 8, a coefficient of 0.4 characterizes the size of the monthly payment of the level of the estimated monthly income.

The amount of additional transport costs $TP$ is determined by the cost of time costs $TC$ and the daily difference in transit $t_\Delta$ during $N - T$ months (average number of days - 21):

$$TP = TC * t_\Delta * 21 * (N - T) = P_n * t_\Delta * (N - T)$$ (13)

When considering an object with a minimum daily difference in transit $t_\Delta$, in case of coincidence of the places of residence and location of the compared objects, or coincidence of the terms of lending and completion of construction $N = T$, the additional current transport costs $TP$ are zero.

Seventh stage. Calculation of the competitiveness indicator of housing products by the specific value method $CIC_v$.

It is proposed to calculate this indicator by the ratio of the sum of all current and future costs - $P_0$ and $P_{MT}$ related to the purchase of the selected housing, as well as possible additional costs for transportation $TP$ to the total area $S_G$ of the object in question:

$$CIC_v = \frac{P_0 + P_{MT} + TP}{S_G}$$ (14)

$$= \frac{P_0 + (P - P_0) * \left(\frac{100 + I \cdot \frac{N}{12}}{100} \right) + P_n * (R_P + R_G) * (N - T)}{S_G}$$

Eighth stage. Prioritization of $CIC_v$, $K$, and $P_{w^*}$. Analysis and assessment of the results. Choosing the most competitive facility.

The proposed algorithm for assessing and analyzing the competitiveness of housing construction products (Fig. 1) on the basis of calculation of the competitiveness indicator by the specific value method $CIC_v$ is based on the ratio of the sum of multidirectional parameters $P_0$, $P_{MT}$, $TP$, the increase of which decreases $CIC_v$ to a unidirectional indicator $S_G$, the increase of which contributes to its growth. Thus, products with a minimum value of the indicator $CIC_v$ will be the most competitive.

Table 3 presents the proposed summary sheet of parameters for calculating the competitiveness indicator of housing products using the specific value method. These parameters are determined by the capabilities of the consumer - $P_0$ and $P_\alpha$, by the characteristics of the object - $S_G$, $S_{av}$, $P$, $T$, $R_\alpha$, and $R_\gamma$, by the loan conditions - $I$ and $N$.
Table 3. Summary sheet of parameters for calculating the competitiveness index using the specific value method.

| No. | $S_{LIV}$ | $S_G$ | $R_G$ | $R_P$ | $T$ | $N$ | $I$ | $P_0$ | $P_N$ | $P$ |
|-----|-----------|-------|-------|-------|-----|-----|-----|-------|-------|-----|
|     | square meters | minutes | months | percent |      |      |      | thousand rubles |
| 1   |           |       |       |       |     |     |     |                      |
| 2   |           |       |       |       |     |     |     |                      |
| ... |           |       |       |       |     |     |     |                      |
| $n$ |           |       |       |       |     |     |     |                      |

**Figure 1.** The algorithm for assessing and analyzing the competitiveness of housing products.

The indicated parameters (Table 3) are used to calculate the competitiveness indicator $CIC_U$, unit cost $P_m$, and planning coefficient $K_1$, which are used to compare selected objects.

Table 4 presents the proposed summary sheet of parameters for assessing and analyzing the competitiveness of housing products based on the competitiveness indicator calculated using the specific value method and relative values - $K_1$ and $P_m'$. 
Table 4. Summary sheet of parameters for assessing and analyzing the competitiveness of housing products.

| No. | Object name | Building | $CIC_{uc}$ | $P_{m^2}$ | $K_1$ |
|-----|-------------|----------|------------|----------|------|
|     |             |          | (thousand rubles/square meter) |         |      |

The selection of the most competitive object is carried out in accordance with the selected priority for indicators $CIC_{uc}$, $P_{m^2}$, and $K_1$.

4. Conclusion
The proposed algorithm for assessing and analyzing the competitiveness of housing products on the basis of calculation of the competitiveness indicator by the specific value method as the ratio of the sum of all current and future costs associated with the purchase of selected housing, as well as subsequent additional transportation costs to the total area of the facility in question, allows one to: take into account in the assessment the time until completion of the construction of the objects under consideration; avoid using the method of expert assessments when comparing them; identify universal indicators for the analysis; reduce the result of the assessment of competitiveness to a financial indicator.

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