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An Optimal Approach to Design of Joinery for Renovation of Panel Buildings

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Abstract-The paper describes a decision support approach for optimal design of joinery work for panel buildings. The decision support approach is illustrated via proposed flowchart algorithm for optimal design of the joinery work in panel buildings renovation. The investigation shows a variety of modules for different kind of panel buildings in Bulgaria. The results show the possibility to reduce the joinery work variants in panel buildings to a set of unified modules taking into account variation of panel buildings. The usage of described approach contributes for decreasing of the price, materials and time for design of joinery work.

Keywords-*unified modules, joinery work, optimal design, decision support system.*

I. INTRODUCTION

The paper concerns the possibilities for optimal design of joinery work for multifunctional panel apartment buildings. The research is motivated by the program "Support of the Energy Efficiency of Multifamily Buildings" that is in accordance with the "Regional Development" program of the Ministry of Regional Development and Public Works (MRDPW). The object of this program is a set of 700 000 apartments in panel buildings with more than 2 million and 700 000 inhabitants. The replacement of the old woodwork by joinery work made of modern materials (plastic or aluminum), is a basic stage in the process of panel buildings renovation. The approaches for optimization of the size of the profiles and the glass, necessary for the production of different modules will be analyzed, for the goal of decreasing the wastage, as well as to optimize the additional accessories of the joinery work.

The efficiency of traditional management information systems development and implementation based on isolated technology, organization and human factor analysis has been made more effective through the integration of organization, human and technology variables over ICT platforms [1]. On the other hand, the decision support systems (DSS) are intended to enhance individual decision making by providing easier access to problem recognition, problem structure, information management, statistical tools, and the application of knowledge. Such a system is designed to enable the easier and faster generation of alternatives, and to increase the awareness of deficiencies in the decision-making process. It can help the decision maker to make more effective and efficient decisions in complex situations. In the context of decision support systems, different techniques and methods are aggregated to fulfill the function of support the decision maker. DSS structure consists of many modules depending on the flow of collecting and processing data. Different authors identify different components of DSS. Three fundamental components of DSS as database management system, model-base management system and dialog generation and management system are identified in [2]. According to [3], DSS is described by four major components: user interface, database, model and analytical tools, and DSS architecture and network. Another generalized architecture [4] has five distinct parts: data management system, model management system, knowledge engine, user interface, and user(s). Taking into account the above considerations a generalized architecture of DSS is considered as shown on Fig. 1.

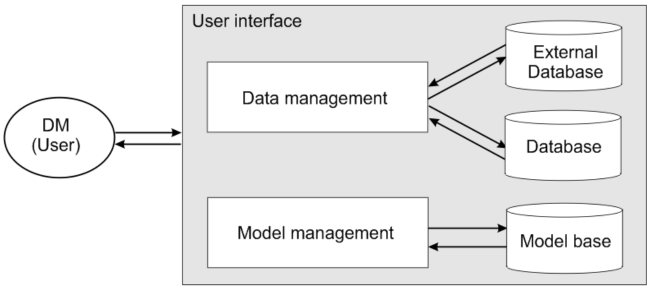

Figure 1. Generalized architecture of DSS

The DSS dialogue requires tradeoffs between simplicity and flexibility. Therefore, the user interface of DSS should facilitate decision makers to have easy access, manipulation and usage of common decision domain terms with all aspects of communication between the user and the DSS. Nevertheless, the data and models are at the core of each DSS. Therefore, a decision support approach for optimal design of joinery work for panel buildings is proposed.

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II. Problem Description

The investigations show that the panel buildings in Bulgaria are realized in four, five, six, seven, and eight floors buildings with following types of apartments and joinery work (doors and windows) as shown:

a) bachelor's apartment (Fig. 2a) – door B1 and two-wings window B2 and one-room apartment (Fig. 2b) – door O1, two-wings window O2, door O3, one-wing window O4.

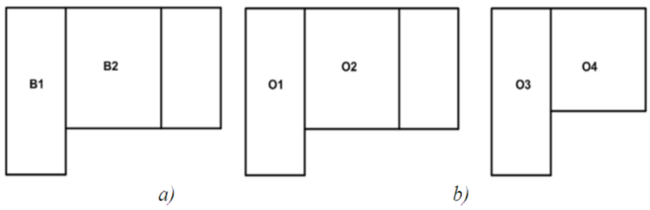

Figure 2. Joinery work of bachelor (a) and one-room apartment (b)

b) two-rooms apartment (Fig. 3) – door Tw1, two-wings window Tw2, door Tw3, one wing window Tw4, window Tw5.

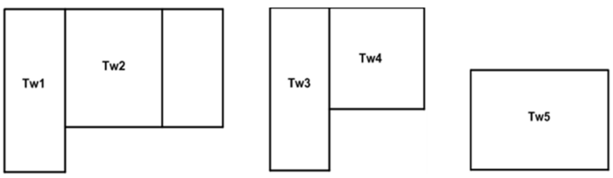

Figure 3. Joinery work of two-rooms apartment

c) three-rooms apartment (Fig. 4) – door T1, two-wings window T2, door T3, one-wing window T4, window T5, window T6.

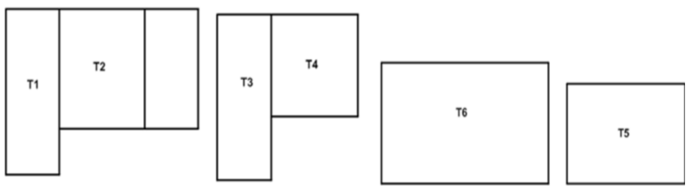

Figure 4. Joinery work of three-rooms apartment

d) four-rooms apartment (Fig. 5) – door F1, two-wings window F2, three-wings window F3, door F4, window F5, window F6, three-wings window F7 and door F8.

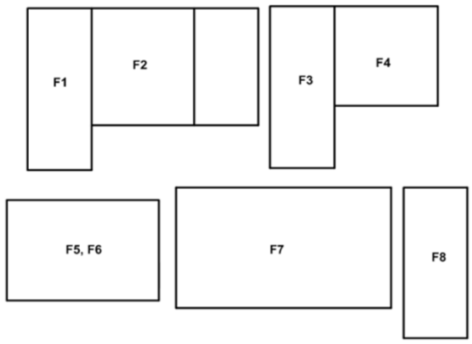

Figure 5. Joinery work of four-rooms apartment

e) entrance door and rear doors (Fig. 6a) the size is equal, but the cutting out is different for each separate case and a staircase window (Fig.6b).

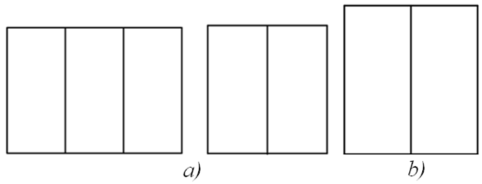

Figure 6. Joinery work of entrance door and rear doors (a) and staircase window (b)

After the elements in the panel apartments are defined, some measurements should be taken for different panel buildings in several large cities (Sofia, Plovdiv, Varna, Bourgas, Pleven, etc). The measured joinery work dimensions for height (h) and width (w) in millimeters for different apartments are shown in Table I to Table IX.

TABLE I. Building 205, Droujba

	Three-rooms						Bachelor	
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***B1***	***B2***
h	2200	1700	2200	1400	1370	1700	2200	1700
w	730	210	730	1400	2050	2800	730	2100

TABLE II. Building 19, Ovcha koupel

	Two-rooms					Bachelor's		Three-rooms					
	Tw1	***Tw2***	***Tw3***	***Tw4***	***Tw5***	***B1***	***B2***	***T1***	***T2***	***T3***	***T4***	***T5***	***T6***
h	2200	1710	2200	1405	1380	2200	1715	2200	1715	2200	1405	1380	1715
w	730	2105	730	1405	2050	730	2110	730	2110	730	1405	2055	2810

TABLE III. Table III: Building 513, Ljulin

	Three-rooms						Bachelor	
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***B1***	***B2***
h	2200	1700	2200	1400	1370	1700	2200	1700
w	730	2100	730	1400	2050	2800	730	2100

TABLE IV. Building 407, Ovcha koupel

	Two-rooms					Four-rooms							One-room			
	Tw1	***Tw2***	***Tw3***	***Tw4***	***Tw5***	***F1***	***F2***	***F3***	***F4***	***F5/6***	***F7***	***F8***	***O1***	***O2***	***O3***	***O4***
h	2200	1710	2200	1405	1380	2200	1710	2200	1405	1375	1710	2000	2200	1710	2200	1405
w	730	2105	730	1405	2055	730	2105	730	1405	2050	2810	650	730	2105	730	1405

TABLE V. BUILDING 21, DIANABAD

	Three-rooms						One-room			
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***O1***	***O2***	***O3***	***O4***
h	2210	1705	2210	1405	1370	1710	2010	1705	2210	1405
w	735	2105	735	1405	2055	2805	735	2105	735	1405

TABLE VI. BUILDING 15, DROUJBA

	Two-rooms					Two-rooms				
	Tw1	***Tw2***	***Tw3***	***Tw4***	***Tw5***	***Tw1***	***Tw2***	***Tw3***	***Tw4***	***Tw5***
h	2205	1708	2205	1408	1378	2205	1708	2205	1408	1378
w	735	2108	735	1408	2058	735	2108	735	1408	2058

TABLE VII. BUILDING 50, MLADOST 1

	Three-rooms						Bachelor		Two-rooms				
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***B1***	***B2***	***Tw1***	***Tw2***	***Tw3***	***Tw4***	***Tw5***
h	2205	1705	2205	1405	1375	1705	2205	1705	2205	1705	2205	1405	1375
w	735	2105	735	1405	2055	2805	735	2105	735	2105	735	1405	2055

TABLE VIII. BUILDING 50, SLATINA

	Two-rooms					Two-rooms					Two-rooms				
	Tw1	***Tw2***	***Tw3***	***Tw4***	***Tw5***	***Tw1***	***Tw2***	***Tw3***	***Tw4***	***Tw5***	***Tw1***	***Tw2***	***Tw3***	***Tw4***	***Tw5***
h	2207	1707	2207	1407	1377	2207	1707	2207	1407	1377	2207	1707	2207	1407	1377
w	737	2107	737	1407	2057	737	2107	737	1407	2057	737	2107	737	1407	2057

TABLE IX. FRONT AND REAR ENTRANCE DOORS, STAIRCASE WINDOW

	Front entrance door	**Rear entrance door**	**Staircase window**
height	2200	2400	2200
width	3200	2500	2000

After acquisition of sufficient data about the size of different elements (doors and windows) in the different types of the panel buildings apartments and the detailed analysis of the data collected, it was established that the dimensions of certain elements in different apartments are quite close. This gives the possibility to unify them, since the differences within the range of ±20 mm are acceptable.

III. OPTIMAL DESIGN APPROACH FOR THE PROFILES AND GLASS FOR JOINERY WORK

Cutting stock problems can be encountered at the production stage of profiles and glass for joinery work. Cutting stock problems consist in cutting large pieces (*objects*), available in stock, into a set of smaller pieces (*items*) in order to fulfill their requirements, optimizing a certain objective function, for instance, minimizing the total number of objects cut, minimizing waste, minimizing the cost of the objects cut, etc. These problems are relevant in the production planning of many industries such as the paper, glass, furniture, metallurgy, plastics and textile industries. In the last four decades cutting stock problems have been studied by an increasing number of researchers [5-8]. The interest in these problems can be explained by their practical application and the challenge they offer to academia. For despite their apparent simplicity, they are, in general, computationally difficult to solve. The continuous growth of the prices of the materials and of the energy requires minimization of the production expenses for every element. The coefficient of usage K_u [9, 10] is used as a criterion of efficiency. In order to solve similar problems, a set of mathematical methods are proposed. The cutting stock problem is an optimization problem, or more precisely an integer linear programming problem that minimizes the total waste while satisfying the given demand [11]

$$\min \rightarrow \sum_{j=1}^{n}\sum_{i=1}^{p} c_{ji} x_{ji} \tag{1}$$

$$\sum_{j=1}^{n}\sum_{i=1}^{p} a_{jik} x_{ji} = b_k,\ k = 1,\ldots,q \tag{2}$$

$$x_{ji} \geq 0,\ j = 1,\ldots,n;\ \ I = 1,\ldots,p \tag{3}$$

Where (1) is the objective function, (2) are constraints determining the number of pieces needed to complete the order and (3) are conditions of non-negativity of the variables.

One the cutting stock problems is cutting out glass surfaces and profiles in the production of glass packets for windows, shop windows, doors, roofs and other for joinery work. The dimensions of the glass are different depending on the case considered. Depending on the type of the orders/requests, rod sheets which differ in size, width and brands, are used for cutting out. That is why the portfolio of the orders is divided into groups, depending on the characteristics of the initial parameters. The cutting problem can be formulated in the following way: a number of items (glass for doors, windows, etc.) must be selected from the requests portfolio and depending on the size and type of the primary material, optimal cutting out must be done, with minimal loss of the material used. Since these losses have to be minimal, it is necessary to maximize K_u according to the formula [12]:

$$K_u = \sum_{r=1}^{n} S_r \frac{1}{S_{eb}} \tag{4}$$

where the numerator is the sum of the areas in the requests portfolio and S_{eb} is the area or length of the source material. The maximal value of K_u = 1, but in real life it is hardly reached. Knowing the value obtained for K_u and comparing it with K_u = 1, we could make a conclusion about the optimality of the cutting.

IV. STRUCTURE OF DSS FOR OPTIMAL DESIGN OF THE JOINERY WORK IN PANEL BUILDINGS RENOVATION

The analysis of realized study and the acquired database for dimensions of the elements in the windows and doors in different buildings and apartments in panel buildings show that all modules can be reduced to several unified modules. This leads to the conclusion that a project for optimal technology in the design of joinery work in panel buildings could be accomplished by the following steps: 1) definition of the unified modules of joinery in panel apartment buildings; 2) determining the size of the joinery work on the basis of the optimization problems solved; 3) formulation of the requests towards the profiles manufacturers with respect to optimal dimensions of the initial materials. The flowchart algorithm of the proposed system for optimal design of the joinery work in panel buildings renovation is shown on Fig. 7.

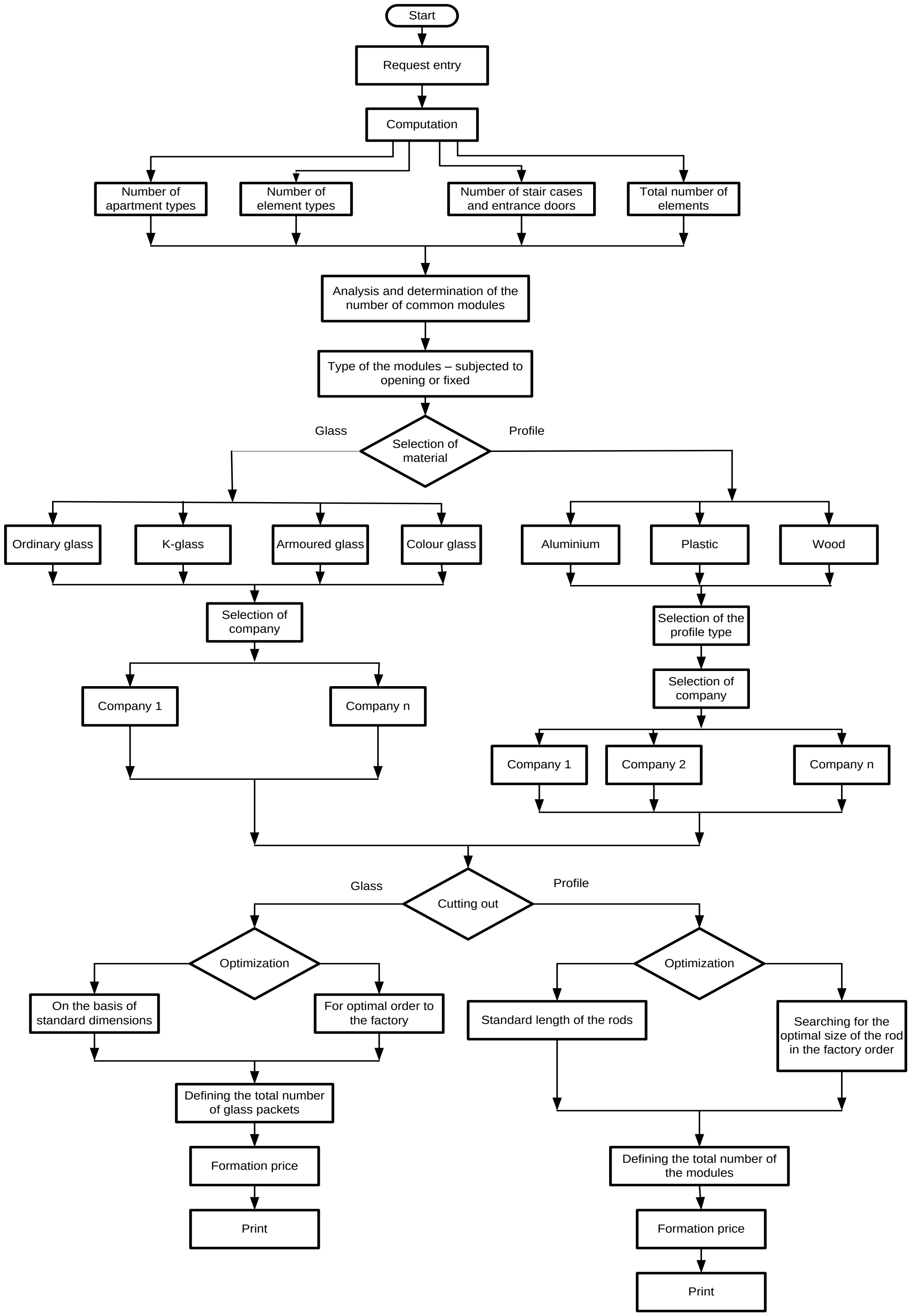

Figure 7. Flowchart diagram of DSS for optimal design of the joinery work in panel buildings renovation

The description of the proposed structure is summarized as follows: 1) entry of the request and different computations – the order parameters are given – number of the apartment buildings, number of the floors, number of the different types of apartments; and computation of the total number of the types of apartments, elements, staircase windows and entrance doors; 2) analysis and determination of the unified modules and defining the type of the unified modules – subjected to opening or fixed; 3) type of the modules – subjected to opening or fixed – depending on the requests each module is divided into two parts – subjected to opening and fixed, and their number is computed; 4) selection of the material – the algorithm divides here into two branches; 5) profile – selection of Al, PVC, wood, type of the profile and manufacturing plant; 6) glass – type of the glass – ordinary glass, K-glass, armored glass, color glass and producing company; 7) cutting out – this is a very important element in joinery production. In the modular system proposed two elements of cutting are pointed out: glass and profiles, but enhancing the system possibilities, some other elements of production could be additionally cut out – such as distancioners, persiennes, etc. As a result of the system execution an optimal design of joinery work made of contemporary materials (plastic, Al) is available. The technology is based on the formulation of models and the mathematic optimization problems, and contributes to the optimal design of unified modules of joinery work for panel apartment buildings.

Optimizing the joinery cutting out require to develop new mathematic models and methods implemented in a software system. The optimization in profiles cutting out is accomplished in a similar way: 1) with respect to the standard length of the rods – having in mind several standard lengths of the rods, made of Al and PVC, offered by the producing factories, for smaller in volume requests, the optimal cutting out of the suggested length is realized with respect to the criterion for minimal waste; 2) searching for optimal dimensions of non-standard rods in the special requests towards the manufacturing plant, when the order is large (over 50 apartment buildings).

At the end, the total number of the modules and glass packets is determined, their price is computed and the module types with their dimensions are printed.

V. NUMERICAL TESTING

Following the above conclusions, the large number of elements in the panel apartments (about 28 in number) could be reduced to the following unified modules (Fig. 8):

- Module 1 – a door with dimensions 2200/730 for elements B1, O1, O3, Tw1, Tw3, T1, T3, F1, F3
- Module 2 – two-wings window with dimensions 1700 mm/2100 mm for elements B2, O2, Tw2, T2, F2
- Module 3 – one-wing window with dimensions 1400 mm /1400 mm for elements O4, Tw4, T4, F4.
- Module 4 – two-wings window with dimensions 2050 mm /1370 mm for elements Tw5, T5, F5, F6.
- Module 5 – two-wings window with dimensions 2800 mm /1700 mm for elements T6, F4.
- Module 6 – a door 650 mm /2000 mm for element F8.
- Module 7 – a front entrance door with dimensions 2200 mm /3200 mm for element ED.
- Module 8 – a rear entrance door with dimensions 2400 mm /2500 mm for element RD.
- Module 9 – a staircase window 2200 mm /2000 mm for element SW.

The expected time of investment return, connected with the development of the innovative service proposed, will depend on the time for replacement of the joinery work in more than 50 multistory apartment buildings. Taking into account that above 700 thousand buildings are to be renovated, the turnover expected is of the order of millions BGL. Using the proposed optimal design approach, the rate of profit is comparable to the expected effect of materials saving when renovating groups of apartment buildings, namely up to 20%. This rate does not include the time saving in design and the decrease of the heating funds in the renovated apartment buildings (up to 40%).

VI. CONCLUSION

EC policy connected with energy consumption in buildings, as well as the Bulgarian law for energy efficiency and the regulations referred to it, require the application of some actions, when repairing building buildings that lead to increase in their energy efficiency. These actions lead to decrease in the expenses of fuel and electrical energy, raising the comfort in such buildings, lengthening their exploitation period and increasing their price. The buildings with low energy consumption have easy support and maintenance, which guarantees low expenses and at the same time smaller ecological influence. The closest alternative of the modular system offered for optimal design of joinery work for panel apartment buildings is the replacement of the existing woodwork by qualitative aluminum or plastic joinery elements. This development will aid the renovation of the widely spread in Bulgaria panel buildings in accordance with the European standards. In some East European countries (for example East Germany), such renovation has been completed, but there is no data about the use of mathematic optimization models and methods for joinery design. Having in mind that the renovation process will cover a large volume and the requests will include large groups of apartment buildings, neighborhoods and cities, the advantages of the current proposal may be resumed as follows:

- decrease in the expenses for joinery work manufacturing (up to 25 %), thanks to the optimized dimensions of the modules;
- decrease of the time for joinery design, as a result of the use of optimal unified modules;

- decrease of the heating expenses (up to 40 %), as a result of the use of contemporary joinery, that will contribute to the decrease of the noxious gas, emitted in atmosphere by the sources of heat energy, i.e. smaller ecological influence;
- Improvement of the quality of life of the inhabitants in the renovated flats.

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