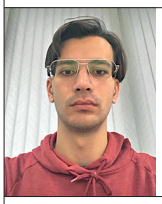
UDC 69.003

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Improvement of the methodology for creating an architectural digital information model of a residential building using a modular approach

The aim of the study is to analyze the application of a modular approach based on a library of standardized building blocks and Building Information Modelling technologies (BIM technologies) in the design of typical residential buildings.
Research hypothesis: creation of BIM models of typical residential buildings using a modular approach and a library of TIM components reduces the time required to complete design work, reduces cost and improves the quality of design work. Research methods: analysis, synthesis and modeling.
The methodology for creating digital information models of typical residential buildings, described in principle in previous works, was considered in relation to all possible special cases. Based on the projects of the Atomstroykomplekscompany, fundamentally possible variants of typical residential buildings were determined — these are three groups: point, sectional and corner buildings with different floor areas, divided into subgroups by the number of elevators.Staircase and elevator unit modules were created for each subgroup. At the next stage, the parameters of the number of storeys and floor area for the BIM models in each of the subgroups of residential buildings were changed, and the changes occurring in the library modules were determined. As a result, the actions that need to be taken to library modules for their adaptation for use in apartment buildings with different numbers of storeys and floor areas were described.
As a result, the following was determined:
- possible variants of architectural forms of plans of residential buildings;
- changes that library modules may undergo due to changes in the area of a residential building during the design;
- measures that should be taken to adapt library modules to allow for changes in the area of sections of residential buildings.

Keywords: *building Information Modeling (BIM), digital information model, methodology for creating digital information models of typical residential buildings, BIM module library, residential construction, library for design work, mass housing construction.*



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INTRODUCTION

Full implementation of BIM technologies[1,2] into the business processes of an enterprise[3] leads to the development of solutions to increase the efficiency of their use [1]. In the case of a large volume of similar construction projects, such a solution may be unification, which, in turn, helps to speed up the implementation of stages of the life cycle of typical residential buildings from the pre-investment stage to the construction stage. This article covers the design stage of the life cycle.

For example, the Atomstroykompleks corporation designs and builds a wide range of facilities, such as schools, kindergartens, medical institutions, public buildings, sports facilities, restored cultural heritage sites and standard facilities — mass residential housing. Mass residential housing is typical because in this type of objects it is possible to identify elements of the building, premises and zones that can be repeated from project to project after standardization. After analyzing completed projects, unification was conducted with the aim of moving to modular design. Modularity is the division of a residential building into elements — modules, which are the volumetric-planning parts of the building. Which building elements were chosen as modules and how they were standardized is described in previous articles [2–4]. Modularity involves the repeated use of modules from project to project, while a building can consist of modules either 100 % or partially with local individual design.

As a result of the project analysis, the following module classification was created:

- modules of the first level, representing the rooms of apartments (bathrooms, loggias and balconies);
- modules of the second level, representing apartment modules and modules of staircase and elevator unit modules, including an elevator hall, a stairwell and an inter-apartment corridor.

For the selected building elements, the company created standard albums containing a list of possible volumetric planning solutions for each element. These albums became the basis for the creation of BIM module library. Taking into account the regulatory framework a BIM module library was created,

[1] SP 328.1 325 800.2020. Building information modeling. Rules for describing information model components. URL: https://minstroyrf.gov.ru/upload/iblock/117/SP-328.1325800.2020.pdf (date of access: 29.03.2025). (rus.).

[2] SP 54.13330.2022. SNIP 31-01–2003. Residential multi-apartment buildings. URL: https://www.minstroyrf.gov.ru/upload/iblock/eef/SP-54.pdf (date of access: 29.03.2025). (rus.).

[3] Atomstroykompleks has started designing residential buildings in BIM. URL: https://atomsk.ru/company/press/news/atomstroykompleks-nachal-proektirovat-zhilye-doma-v-bim/ (date of access: 20.09.2024). (rus.).

which so far includes only staircase and elevator unit modules and modules of the first level. The library elements are digital information models created in accordance with the Employer Information Requirements (EIR) of the company.

The library is owned by the customer, who should benefit from the implementation of modular design. One of the areas of application of modular design is to accelerate and reduce the cost of the design process of the main type of company facilities — typical residential buildings.This is justified by the fact that a designer, receiving a ready-to-use BIM module library as part of a design assignment, can create a typical residential building from a typical floor to the roof entirely or almost entirely from the components of this library. The contractor will not create a completely unique building (with the exception of the ground floor and basement), therefore, the involvement of highly qualified specialists and a large number of man-hours is not required. The use of library components with the LOD 400 (Level of Development) will allow us to come to the conclusion that the BIM models at the stages of project and working documentation will differ only in the design of the project sheets. It should be noted that verification of structural calculation, hydraulic calculation, insolation calculation and others inherent in classical design remains necessary. In addition, using library components, the designer is limited in the use of materials and technical solutions that deviate from the standard of the company. If a company has its own contractors, the use of standard components and materials will improve the quality of construction and installation work and, accordingly, the operational characteristics of the facilities.

Some foreign researchers are engaged in the implementation of a modular approach in the design and construction of typical residential buildings [5, 6]. There are authors who also suggest using the module library in the design process and describe the mechanism for changing layouts [7–9]. Other authors are taking steps to create a system for automatically filling the library with modules based on previously created projects, as well as automatically checking potential modules for compliance with the requirements [10–12].

CREATING A TYPICAL FLOOR PLAN

In previous studies, an initial set of elements of the BIM module library for the design of typical residential buildings was created, which included:

- staircase and elevator unit modules;
- modules of the first level.

Methodological recommendations have been developed for creating a digital information model using a BIM module library. The conducted timing measurements of the creating of a typical floor of the architectural section showed that the use of a BIM module library accelerates the process of creating an information model by almost 40 %. The previous article [2] contains an algorithm for creating a model of an architectural section.

Fig. 1 and 2 show the floor plan of a typical residential building assembled from library elements. The green color indicates the staircase and elevator unit module, the green-blue color indicates apartment modules, the blue color indicates bathroom modules, and the brown color indicates loggia modules.You can see that the bathroom and loggia modules are part of the apartment modules.

IMPROVING THE LIBRARY OF STAIRCASE AND ELEVATOR UNIT MODULES

In the process of testing the methodology for constructing a typical floor of an architectural section, it was discovered that the staircase and elevator unit modules need to be improved. Their disadvantage is that in the existing configuration the blocks are designed for a certain floor area, and therefore a certain number of apartments. At the same time, from an architectural point of view, the shapes of sections of residential buildings in the plan can be point, corridor and corner.

In point buildings (Fig. 3), the inter-apartment corridor is located around the core with elevators and is its border on three sides. The increase in the floor area of point buildings does not have a significant impact on the architectural section, since it occurs in most cases due to the increase in the area of apartments, while the dimensions of the inter-apartment corridor do not change. Even if the number of apartments increases, the configuration of the staircase and elevator unit module does not change; it is only necessary to provide for the possibility of installing additional water supply, heating and electricity supply systems.

In corner and corridor buildings (Fig. 4, 5, respectively), the inter-apartment corridor adjoins the core with elevators and is its border on only one side. When increasing the area of the section, either due to the area of the apartments or due to an increase in the number of apartments, the length of the corridor may change.

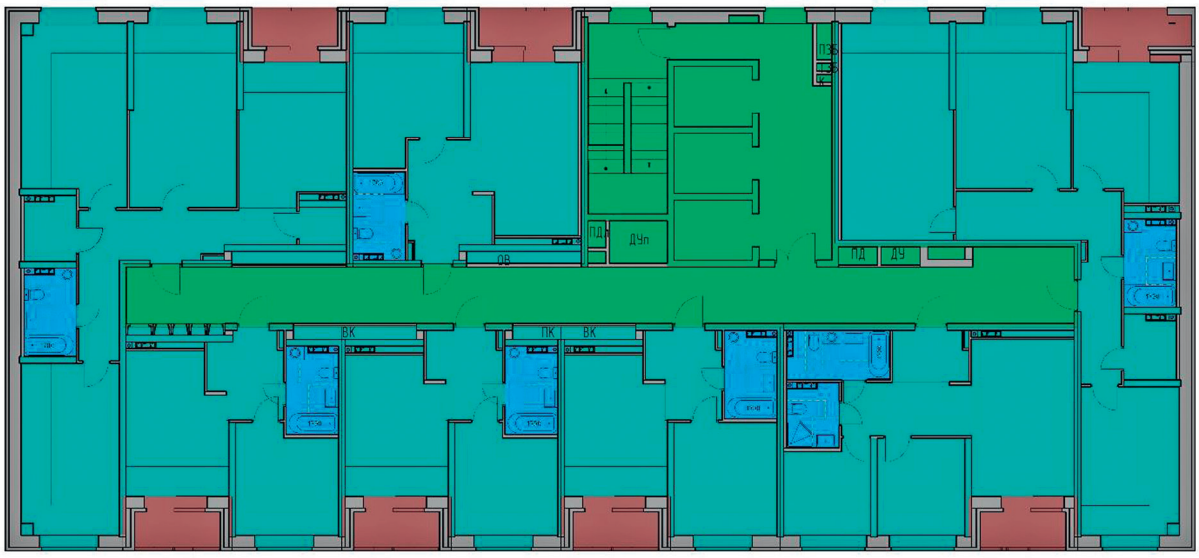


Fig. 1. A typical floor plan consisting of elements from the BIM module library

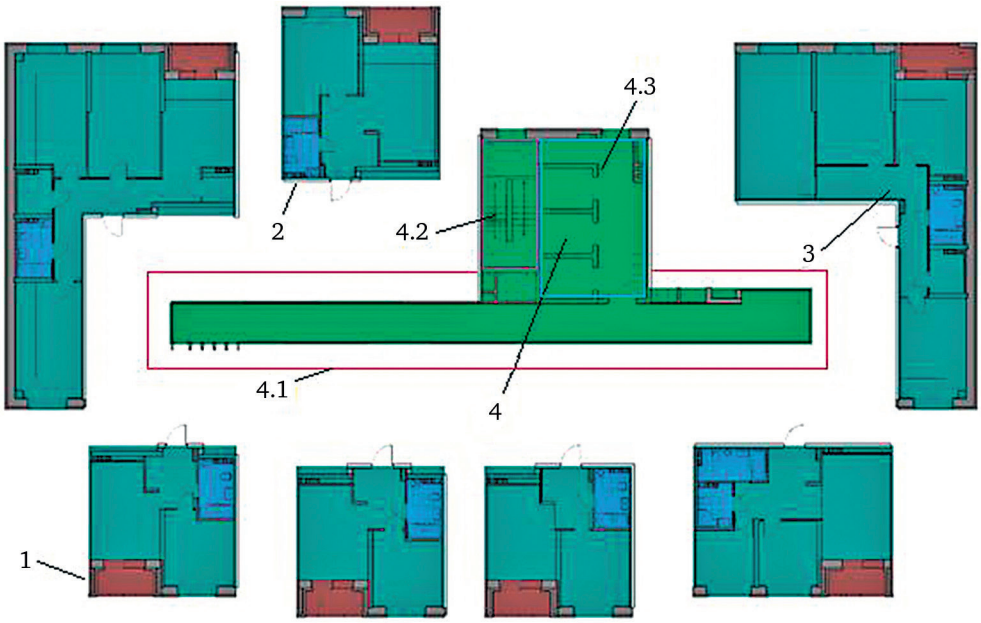


Fig. 2. Elements of the BIM module library that make up a typical floor plan: 1 — loggia module; 2 — bathroom module; 3 — apartment module; 4 — staircase and elevator unit module; 4.1 — inter-apartment corridor as part of staircase and elevator unit module; 4.2 — stairwell as part of staircase and elevator unit module; 4.3 — elevator hall with elevator shafts as part of staircase and elevator unit module

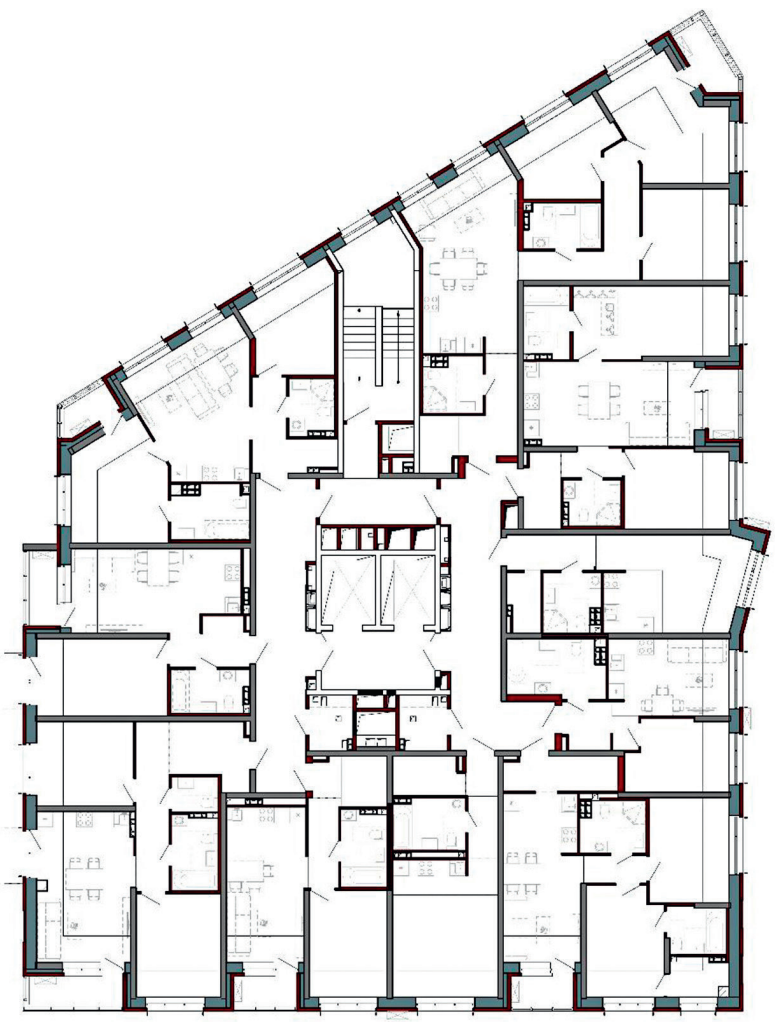


Fig. 3. Example of a point section

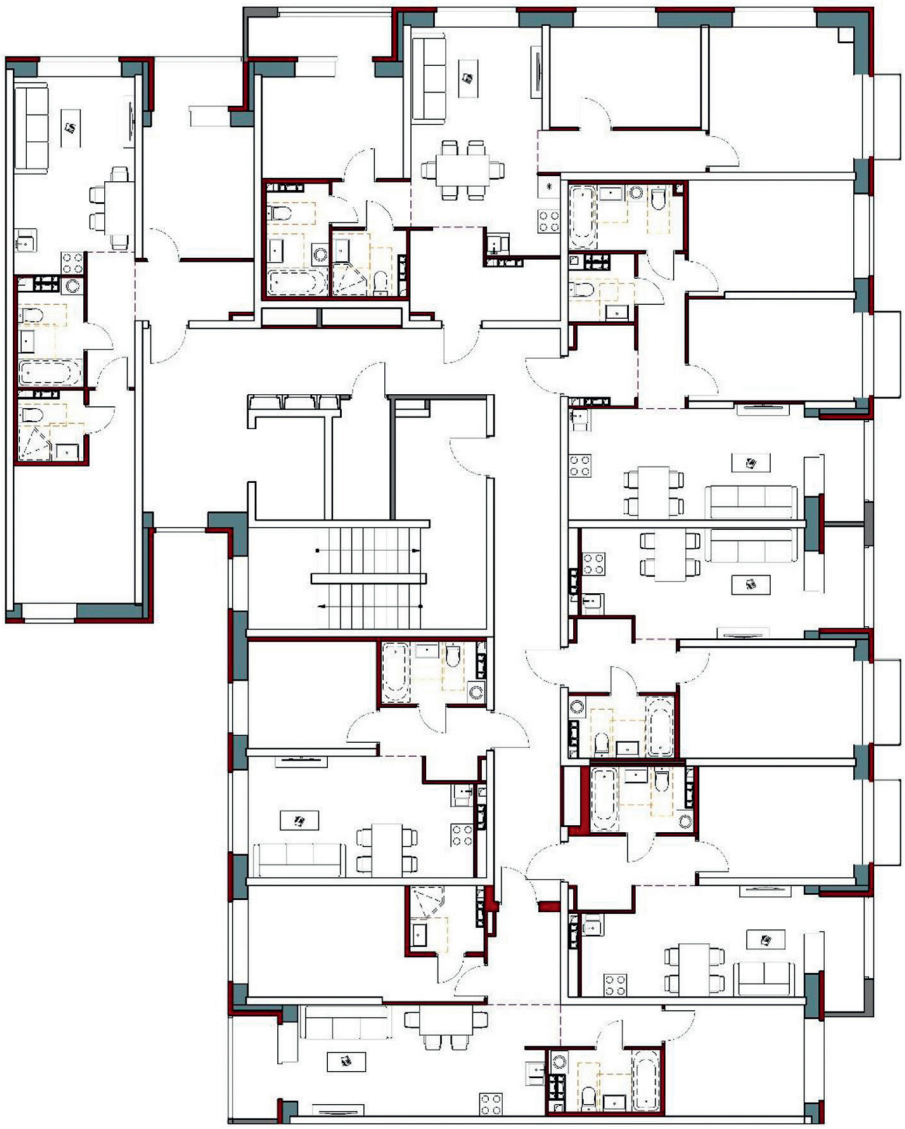


Fig. 4. Example of a corner section

The change in the length of the corridor and, consequently, the area of the section is limited by the length of the escape route from the apartment to the entrance to the stairwell.

In the corridor and corner sections, niches for utility networks are located directly in the inter-apartment corridor. An increase in the floor area, both due to a change in the area of apartments and due to a change in the number of apartments, changes the configuration of the inter-apartment corridor in terms of the location of the entrance doors to the apartments. The relocation of entrance doors to apartments in turn entails the relocation of niches for utility networks in the space of the inter-apartment corridor and/or the installation of additional water supply, heating and electricity supply systems. As in the case of point sections, as well as in the case of corridor and corner sections, it is necessary to standardize the dimensions of niches for engineering systems in order to increase or move them in the corridor space and seamlessly increase the number of systems.

The possibility of changing the configuration of the staircase and elevator unit module of the architectural section entails changes in the staircase and elevator unit modules of the engineering sections.Engineering systems should be modified so that they can be placed in standardized niches to seamlessly change their location in the plan or increase the number of systems.

ADDITION OF THE METHODOLOGY FOR CREATING A TYPICAL FLOOR

The developed methodological recommendations provide the following composition of the architectural module of the stair-elevator unit:

- staircase unit;
- vertical load-bearing structures;
- non-load-bearing walls and partitions;
- trays for electrical networks;
- ventilation ducts;
- premises and basic finishing of premises.

However, in the process of testing the methodology for creating an architectural typical floor, it became necessary to refine the staircase and elevator unit modules. It was established that staircase and elevator unit modules can be of three types: point, corridor and corner.

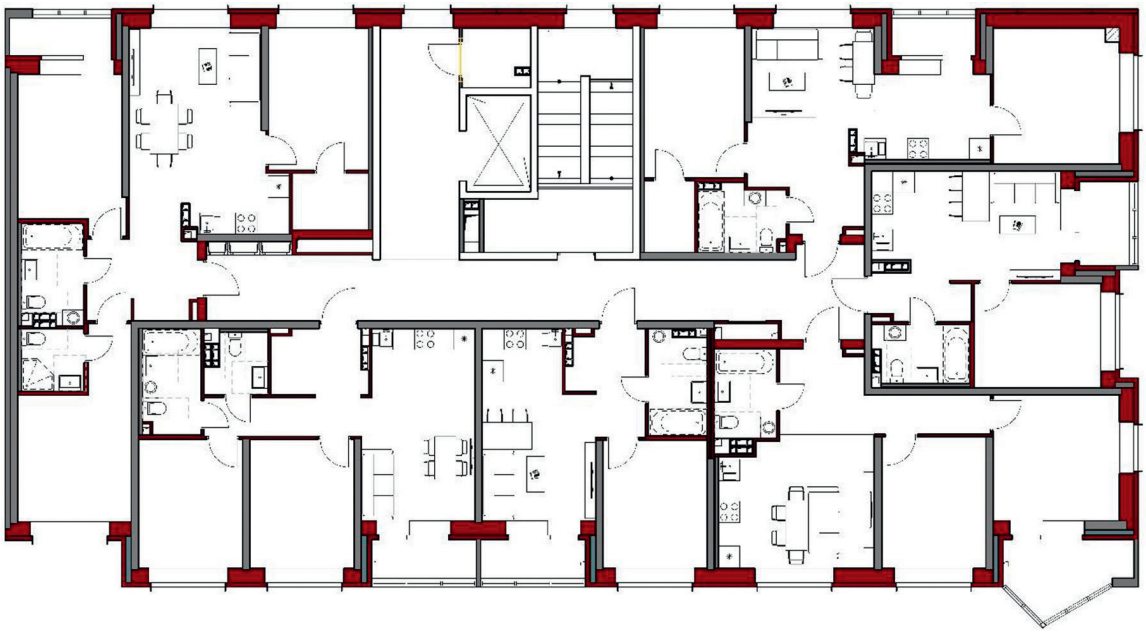


Fig. 5. Example of a corridor section

The principle of constructing the model was initially based on the construction of point building models. However, in the previous section it was established that it is necessary to decompose the staircase and elevator unit modules into 3 types. In connection with the described features of the staircase and elevator unit module types, the composition of the staircase and elevator unit modules and the procedure for working with them must be changed.

For point modules, the composition does not change, the dimensions of the inter-apartment corridor remain unchanged, it is only possible to increase the number of niches and trays for placing electrical networks in them. After placing the staircase and elevator unit module, it is necessary to add a check of the number of niches for the placement of engineering systems.

The composition of point and corner modules can be divided into two categories. The first category is permanent elements, which include the stairwell, elevators and elevator hall with the structures that limit them. The second category is variable elements, which are the inter-apartment corridor and the structures that limit it. The procedure for working with these types of staircase and elevator unit modules should include a process for checking the number of niches for placing engineering systems. The process of creating a typical floor plan must be supplemented by the process of linking the location of niches for engineering systems with apartment layouts. After creating a typical floor plan, a process must be added to check the compliance of the length of the inter-apartment corridor with the requirements of SP 1.13130.2020[4] and bring the length into compliance with the standards by editing the floor plan.

CONCLUSION

In the process of researching the methodology for applying a modular approach to constructing architectural digital information models of residential buildings, shortcomings were discovered that arose due to the expansion of the range of modules of staircase and elevator unit modules. The disadvantage is the lack of adaptation of modules to a possible increase in the floor area or an increase in the number of apartments on the floor, which consists in the inability of modules to change the number of engineering systems or change their location in common areas.

To eliminate this deficiency, the following measures were taken:

1. The nomenclature of staircase and elevator unit module was classified into modules for point sections, modules for corridor sections and modules for corner sections.

2. For each type of staircase and elevator unit modules, it was determined which elements and how would be subject to change when the area of the section floor changes.

3. The methodology for constructing a digital information model was adjusted, operations were added for each type of staircase and elevator unit module, taking into account the possibility of changing the area of the section floor.

In the future, it is necessary to test an improved method for constructing digital information models using improved modules of staircase and elevator unit modules.

[4] SP 1.13130.2020. Code of Practice. Fire protection systems. Evacuation routes and exits. (rus).

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Совершенствование методологии создания архитектурной цифровой информационной модели жилого здания с применением модульного подхода

Предметом исследования является процесс проектирования типовых многоквартирных домов. Цель исследования — анализ применения модульного подхода, основанного на библиотеке типовых модулей зданий и технологиях информационного моделирования (ТИМ), в проектировании типовых многоквартирных домов.

Гипотеза исследования: создание цифровых информационных моделей типовых многоквартирных домов с применением модульного подхода и библиотеки ТИМ-компонентов снижает стоимость, повышает качество и сокращает сроки выполнения проектных работ. Методы исследования: анализ, синтез и моделирование.

Методология создания цифровых информационных моделей типовых многоквартирных зданий, принципиально описанная в предыдущих работах, была рассмотрена применительно ко всем возможным частным случаям. На основе проектов компании Атомстройкомплекс были определены принципиально возможные варианты типовых многоквартирных домов — это три группы: точечные, секционные и угловые дома с различной площадью этажа, разбитые на подгруппы по количеству лифтов. Для каждой подгруппы были созданы модули лестнично-лифтовых узлов. На следующем этапе изменялись параметры этажности и площади этажа для ЦИМ в каждой из подгрупп многоквартирных домов, определялись происходящие изменения в модулях библиотеки. В итоге были описаны действия, которые необходимо предпринять в отношении модулей библиотеки для их адаптации к применению в многоквартирных домах с различной этажностью и площадью этажа.

В результате определены:

- возможные варианты архитектурных форм планов жилых домов;
- изменения, которым могут подвергнуться модули библиотеки из-за изменения площади жилого дома в процессе выполнения проектных работ;
- указаны мероприятия, которые следует предпринять для адаптации модулей библиотеки для возможности изменения площади секций жилых домов.

Ключевые слова: *технологии информационного моделирования (ТИМ), цифровая информационная модель, методология создания цифровых информационных моделей типовых жилых зданий, библиотека ТИМ-компонентов, жилое строительство, библиотека для проектирования, массовое жилое строительство*

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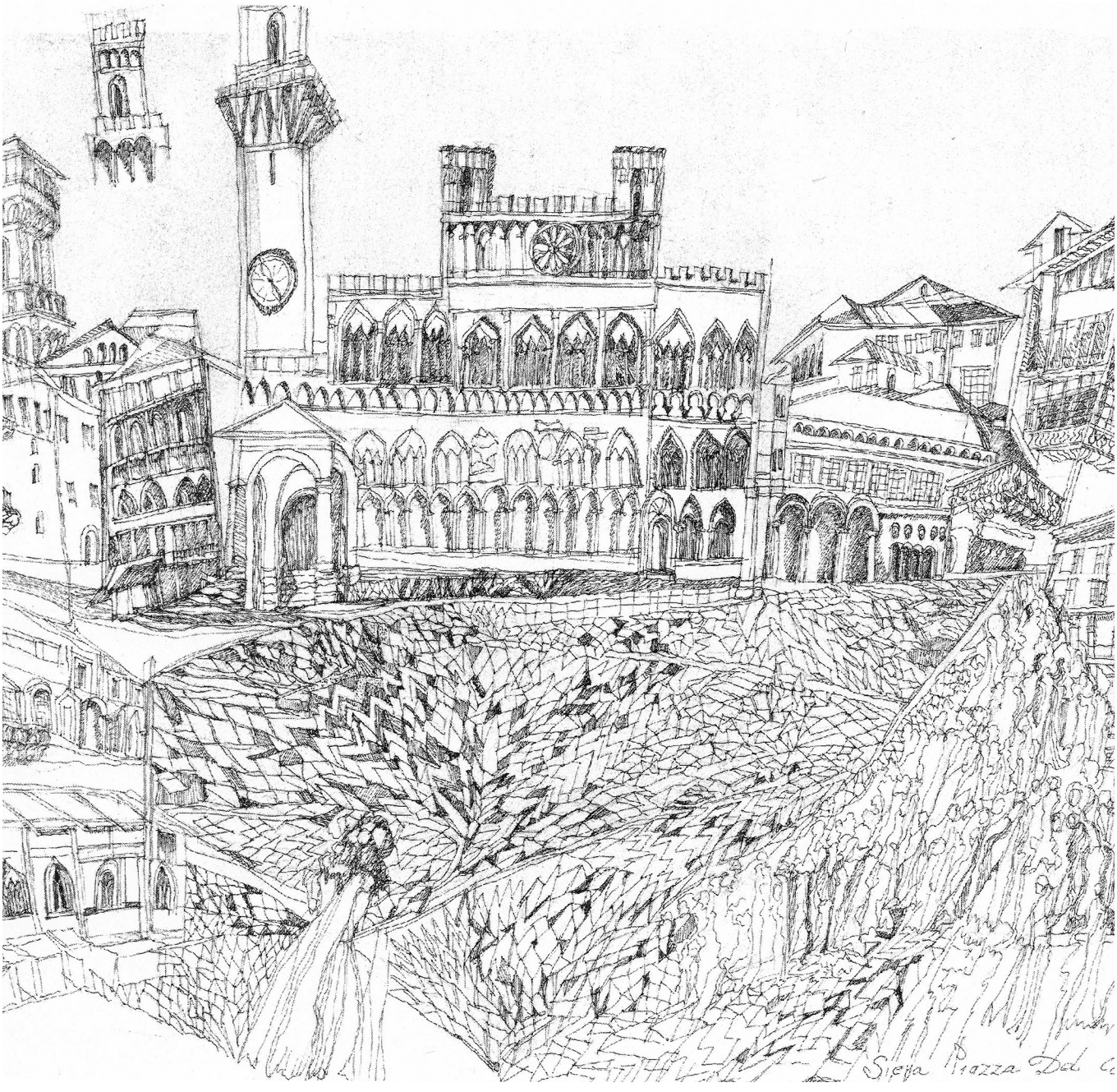
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