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SPATIAL CHARACTERISTICS OF CONTEMPORARY PREFABRICATED MODULAR DORMITORY CELLS

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Abstract:

Prefabricated modular architecture brings diversified opportunities for sustainable university student accommodation. Modern and modular construction systems offer affordable and comfortable housing to students. The housing units form the core construction units of the dormitories. They are made from recycled shipping containers or prefabricated modular blocks that share common characteristics. The accommodation sections of modular dormitories are characterised by efficient sorting of prefabricated cells along horizontal communications. The paper analyses characteristic case studies and defines the predominant floor plan types of modular student accommodation cells. The difference in the layout and operational solutions also results from the specifics of the supporting structures. The aim is to categorise the prevailing floor types of modular accommodation cells and to define the spatial standard of student rooms while maintaining the right measure in the relationship: efficiency – invention – user comfort. Attractive interiors can increase the value of college houses. The basis of such projects is to have well-organised floor plans, which are clear and functional, even with regard to their visual effects.

***Key words*: modular architecture; university dormitories; accommodation unit; student room**

1. INTRODUCTION

University dormitories are evolving parallelly with the general trends affecting educational facilities. As for broader developments, globalisation has also had an impact on these trends by promoting competitiveness between schools and at the same time changing students' views about campuses and their facilities. University students currently live in a dynamic, ever-changing environment that is influenced by rapid technological developments. "Globalization and the rapid spread of the Internet have had a great impact upon the structure of Generation Z, a generation growing with indispensable computers and technological breakthroughs" (Szydło *et al*., 2021, p. 5). The current young and energetic generation, influenced by a lifestyle subordinate to the digital age, has established relationships through social networks.

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Technological innovations minimise the need for community spaces that provide social interaction.

The term "modular unit" means that a building consists of separate parts or units that can be connected to each other (Wehmeier, 2005). Modularity is thus associated with catenation and buildability. Throughout the history of architecture, the term modular has referred mainly to prefabricated mobile and temporary buildings. The term module is distinguished from modular in architecture, and it was already present in the time of Vitruvius, derived from the Greek term "embater" and Latin term "modulus" which both mean a scale. The module is a relative unit of scale derived directly from construction, according to which the proportions of a building are determined. Concurrently, historically the module was an absolute and fixed unit of length, used to determine the dimensions of buildings. However, the term "modular unit" does not mean a building designed in standard dimensional modules; instead, it represents the prefabrication of a volumetric building unit. According to Knaack *et al*. (2012), modules are three-dimensional independent units or partially complete parts, which when stacked or joined together form the body of a modular building. The modular unit is a complete volumetric form of prefabrication. Lawson (2014) characterises modular buildings analogously: as "cell-type" structures which consist of identical spatial units that are suitable for transport. Furthermore, he fundamentally distinguishes modular constructions from planar and hybrid elements. Thus, a modular cell is a "three-dimensional or volumetric unit that is assembled in a factory and delivered to a construction site as the main structural element of a building" (Lawson, 2014, p. 1).

2. PIONEERS OF PREFABRICATED MODULAR ARCHITECTURE FOR ACCOMMODATION FACILITIES

The typology of capsule accommodation has been characteristic of modern architectural trends prevalent since the 1960s, influenced by remarkable projects by Archigram (an English group of architects) and Japanese Metabolists. The referential examples of Archigram show off its enthusiasm for the possibilities offered by new technologies. "Waren Chalk from Archigram began using the term capsule in 1964 – for prefabricated mass-produced housing units called Capsule Homes" (Šenk, 2018, p. 3). The architectural designs of Archigram were inspired by industrial production, science-fiction literature, and cybernetics. The avant-garde design of the student home by Peter Cook "Car Body/Pressed Metal Cabin" provided the possible replacement of worn-out modules/cells with new, technically improved units. It consisted of clusters of residential student "capsules" attached to central vertical service cores. "Thus, this architecture has become 'consumerist' like cars or other consumer goods, and the city is constantly renewing itself – through cyber control" (Haas, 1978, p. 456). According to Sadler (2005), Cook's design was literally a copy of the automotive design.

Cedric Price was also extremely beneficial to the English experimental architecture and design of the 1960s. Compared to the Smithsons, who designed the well-known modular cells "The house of the Future", he was more cautious in his designs and appeared almost technocratic in his concepts. In addition to his well-known project "Fun Palace", his design "Potteries Thinkbelt" from 1964 is inspiring for modular typologies. It uses technological systems to create a cybernetic structure of residential capsules, which can also be used to revitalise abandoned industrial areas (Ayres, 2012). Potteries Thinkbelt also includes a cyber control system for territory, transport options, education systems and an alternative education system for 20,000 students. Functioning as a mobile university that moves along a railway line (Malinowska and Lebek, 2017), it consists of mobile or fixed educational units and four basic types of mobile student suites that are to be considered as architectural pioneers of student modular living cells (Figure 1).

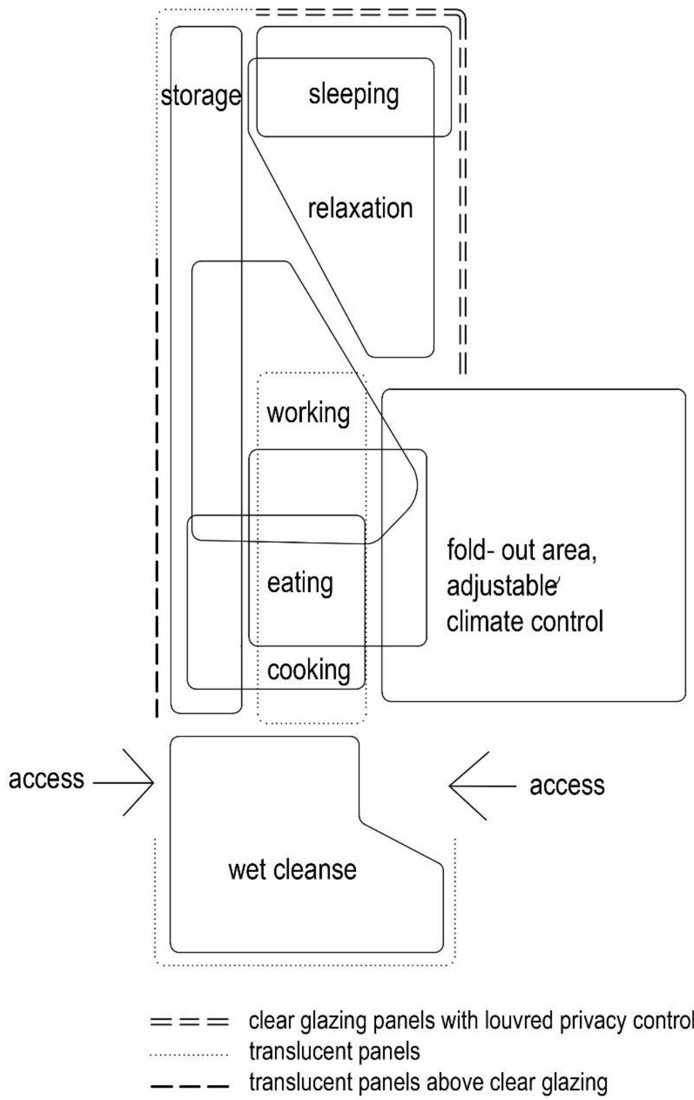

Figure 1. Potteries Thinkbelt: an ideological scheme of overlapping functions in the small space of a habitable unit. Floor plan of student accommodation cells (Source: Lobsinger, 2000)

The prefabricated modular architecture of the past has inspired architects and designers around the world with its many features. Its structures are portable, prefabricated, demountable, dynamic and adaptable. The primary skeleton of the living cell of a modular dormitory is a container or a modular block. At the same time, these modular blocks make it possible to maintain the mobility of the structure and support flexibility in the architecture.

According to Friedman (2016, p. 5), "Flexibility can involve macro changes that affect the entire building, including adding or removing space or changing the function of the building." It can therefore also contribute to changes in spaces and their layout. The prototypes of modular dormitories are alternative designs of accommodation facilities, the basic characteristic of which is the search for a minimum area suitable for individual accommodation. In the field of architecture, we refer to this as microarchitecture. Volume reduction in the optimal architectural design does not automatically mean the deterioration of quality. The active part of the space is distinct from the passive part if the student lives in one room only (Kotradyova, 2015). If the space considered is undersized compared to a spatial standard, then it is not possible to insert new functional zones between the barrier zones and construction filters (doors, walls, etc.). Consequently, miniaturisation increases the demands on the shell/packaging of the accommodation unit as well as on the organisation of the interior.

Professor Richard Horden, inspired by the Japanese Metabolists' ideas, proposed a series of projects, which may also be referred to as examples of microarchitecture. In collaboration with John Höpfner Architekten, he began mass production of a project called the Micro-compact home, which has been inhabited by students in Munich since 2005 (Krämer, 2006). The Micro-compact home is still popular among students since it is significantly cheaper than the other dormitories in the area. The cost effectiveness of the utilities and use of a smaller area have reduced the monthly rent for the student dormitories, which according to Herzan (2010) is approximately EUR 125. The aim was to design an affordable, mobile residential building with a high-quality design and construction. This low-energy concept of mobile housing for one to two people is inspired by the scale of Japanese traditional spaces for tea drinking ceremonies – the so-called Chashitsu (Bradbury and Powers, 2009). It allows real testing of a comfortable accommodation prototype in a minimal area. The Micro-compact home occupies an area of $7m^2$, the internal volume of which is 266 x 266 x 266 cm (Leydecker, 2013). The interior clear height is 1.89 m and the interior volume 18.6 m^3 (Kronenburg, 2008). The utility and dimensions of the space are also related to the multifunctionality and dynamics of the furniture and one cannot help but notice that a certain new architectural edge is derived from the notion that such area is simply not suitable for the purposes of long-term accommodation (e.g., the entire academic year). Rather, it is suitable as an alternative form of accommodation for short stays (possibly as a hotel-type facility). The above claim is also supported by research by the Technical University in Munich and NASA Space Center in Houston (Horden, 1999).

The excessive multifunctionality of the furniture and spaces can be burdensome (Haines and Mitchell, 2014) for the accommodated student. He or she is forced to rearrange furniture elements and adapt the space required for an activity for a certain period of time. Above all, when discussing this issue, it ought to be remembered that the legislative requirements for the minimum size of student rooms result mainly from medical requirements (Ministerstvo zdravotníctva SR, 277/2008), which also address the impact of confined spaces on the human psyche (Slobodian, 2012). It is a difficult task to answer the question of whether sustained residency in a minimal area can be the cause of extreme psychological stress for a student. Collaborative research carried out by the Technical University of Munich and the NASA Space Center in Houston confirms the importance of distinguishing between study space and rest areas in a confined space (Horden, 1999). Ideally, these amphoteric activities do not take place in the same area in the room. Living space in a minimal area must be optimized as well as possible with regard to usefulness but also to the mental well-being of the user. The characteristics of the interior design, such as suitable colours and touch-friendly materials, increase the comfort for users. Those characteristics are as important as the principle of easy handling and integration of technical equipment into a room. According to Kotradyova *et al*. (2019) the relation between the material used and human physiology is very dependent and, for example, the brain is under less stress in an environment with wooden materials. The contribution made by accommodation prototypes in the form of microarchitecture for the development of dormitories should not primarily be the reduction of space, but rather the variability of equipment and the resulting multifunctionality of areas.

3. TYPICAL SPATIAL STANDARD OF PREFABRICATED MODULAR DORMITORY CELLS

According to interpretive dictionaries, the term "standard" represents an achieved, common level, as well as a stable form (Šalingová-Ivanová and Maníková, 1990). In the first place, however, the standard should be a well-designed environment that suits the individuality of the user, which contributes to achieving maximum performance and satisfaction, with a minimal health burden. In the legislation of European countries, the minimum area parameters for student rooms differ significantly. In Germany, a single student room requires a minimum area of 12 m^2 (Mutius and Nussberger, 1994). In the United Kingdom, the minimum area of a single room is only 6.5 m^2. In the case of a double room, the minimum area requirement of 10.2 m^2 is significantly underestimated. A common single room size in Great Britain and the United States of America occupies 10 m^2, a double does not exceed 18 m^2 (Adler, 2007).

The real average of the spatial characteristics of a student accommodation cell on a European scale can be defined on the basis of analysing case studies of conventional (non-modular) dormitories. Research (Vráblová and Majcher, 2013) has shown that in conventional dormitories, the ratio of the space forming a typical accommodation cell is currently predominantly 63:37, where the higher value represents the student's living space and the lower value the area for accessories (hygiene, kitchenette, etc.). The width of a single student room is most often in the range of 2.75 - 4.25 m; the average value is 3.4 m. The depth of the whole cell is on average 6.85 m. The total area of the student cell (room and accessories in total) is on average 23 m^2 (Vráblová, 2009). However, the dimensions of modular accommodation units are subordinated to the carrying capacity of the means of transport, as well as the dimensional standard of the transport type.

With the aim to create a platform for a theoretical model of a modular student housing unit that would be effective in economical, energy and disposition-operational terms, 35 modular dormitories (corridor or courtyard balcony type) in European countries were researched by our team from 2019 to 2021. This included: a review of project documentation and photographic materials; a survey of published expert studies; and site visits to the dormitories to assess the level of user satisfaction. The individual disposition schemes of the housing units were analysed, as well as whole floors in the selected dormitories, and the material and construction solutions. The individual case studies were reviewed and assessed in sequences, and categorised according to an Ishikawa graph. This paper focuses on assessing one category from the Ishikawa diagram: the disposition-layout schemes of the student housing units.

Table 1. A comparison of the modular dormitories analysed (35 case studies). Abbreviations: PK – prefabricated kitchenette, PB – prefabricated bathroom, SK – standard kitchenette mounted on the construction site, SB – standard bathroom mounted on the construction site; LC – in the centre of the student cell layout; ES – entrance side of the student cell layout

HALL OF RESIDENCE_CITY architect *(Units) Average room area*	Majority room types	Layout features	Construction and material	Psychological and social aspects
SPACEBOX_UTRECHT Mart de Jong *(300) 17 m²*	single rooms (+ apartments)	PK (1400 x 500 mm) + PB; position: ES	galvanized steel columns; composite panels	lack of space for social interaction
DUWO_DELFT Mecanoo Architecten *(186) 21 m²*	single rooms (+possibility of 2nd person lodging)	PK + PB, standardised furniture; position: ES	steel frame; concrete floors; wooden wall frames; renewable materials	separation of common areas only to the ground floor level
ZUIDERZEEWEG_AMSTERDAM Fact Architect *(335) 30 m²*	single rooms	PK + PB; position: LC	steel frame; wood-based panels; renewable materials	natural material in the interior - a positive effect on the psyche
HABIT CAMPUS DE SANT CUGAT_BARCELONA H Arquitectes *(57) 56 m²*	single rooms	PK + PB; position: ES; rooms without furniture	prefabricated concrete modules covered with galvanized steel	high degree of personalization of the room - including wall and ceiling surfaces
GRØNNEVIKSØREN_BERGEN 3RW Arkitekter AS *(704) 16.5 m²*	single rooms (+apartments)	PK + PB; position: ES; rooms without furniture	steel frames and concrete slabs	personalization of the room environment; access balconies: social interaction
WOODIE_HAMBURG Sauerbruch Hutton Architekten *(371) 19 m²*	single rooms	PK + PB; position: ES, built-in cabinets and beds	wooden prefabricated modules	interior: natural (wooden)material - a positive effect on the psyche
KEETWONEN_AMSTERDAM TempoHousing *(1000) 26.75 m²*	single rooms	PK + PB; position: LC	new steel containers (non-recycled)	rooms divided into functional zones
QUBIC_AMSTERDAM HVDN architekten *(715) 24 m²*	single rooms (+ 72 apartments)	PK + PB; position: ES	former shipping containers; plastic prefabricated panels facade	social activation: groups of rooms with shared terraces
CITÉ A DOCKS_LE HAVRE Cattani Architects *(100) 24 m²*	single rooms	PK + PB; position: LC; wooden furniture	former shipping containers with independent supporting steel frame structure	social activation: shared balconies
FRANKIE & JOHNNY_BERLIN Holzer Kobler Architekturen *(417) 26 m²*	single rooms (+ apartments)	PK + PB; position: LC; standardised furniture	former shipping containers 40´; mineral wool + vacuum insulation	wide access balconies and terraces supporting social interaction
SMALLVILLE_SION DMDModular *(42) 18 m², 28 m², 35 m²*	single rooms	60 %: PB position: LC; PK position: ES; 40 %: PB position: ES; custom-made furniture	steel frame; wood-based panels; renewable materials (interior: wooden surfaces)	rooms divided to functional zones; natural material in the interior - a positive effect on the psyche
MANRESA CAMPUS_BARCELONA Xavier Tragant *(75) 46 m²*	single rooms	PK + PB; position: ES; without furniture	prefabricated concrete modules covered with galvanized steel	high degree of personalization of the room - including wall and ceiling surfaces
DYSON STUDENT VILLAGE_ MALMESBURY WilkinsonEyre *(78) 30.24 m²*	double rooms	PB position: ES; integrated built-in storage furniture and tables	cross-laminate timber (CLT) construction; the external aluminium cladding,	timber in the interior - natural living environment;

			sedum-covered roofs; 92% natural materials	central social and learning hub, shared kitchen;
CAMPUS MELATEN_AACHEN SzturArchitekten *(285) 26 m², 29 m² (10%)*	single rooms (+ apartments)	PK position: ES; PB position: LC;	recycling of 288 existing mobile residential modules; metallic facade	courtyard and exterior connecting bridges: a space for social interaction
MOLLWITZSTRASSE_BERLIN n|vier architekten *(86) 19 m²*	single rooms (+ apartments)	PK + PB position: ES; standardised furniture	modular wooden frame construction + wood-based filling panels	shared kitchens, interior social spaces, neutral colour of the interior - a positive effect on the psyche
FREIBURG IM BREISGAU Weissenrieder architekten *(147) 14 m²*	double rooms	shared kitchen + bathroom for the whole floor	wooden prefabricated modules, visible wooden wall surfaces in the rooms	natural material in the interior - a positive effect on the psyche
MIKROWOHNUNGEN_ HEILBRONN Joos Keller *(23) 17.5/35 m²*	single rooms (+ apartments)	PK + PB position: ES;	wooden prefabricated modules, visible wooden wall surfaces in the rooms	rooms divided into functional zones; social activation: shared exterior gallery
LUTTERTERRASSE_GÖTTINGEN LIMA Architekten *(265) 18 m²*	single rooms	PK + PB position: ES;	wooden prefabricated modules, visible wooden wall surfaces in the rooms	natural material in the interior - a positive effect on the psyche
MODULBAU_BRAUNSCHWEIG IWB inngenieure *(75) 19 m²*	single rooms (+ apartments)	PK + PB position: ES;	new steel prefabricated modules; facade of HPL prefabricated panels	lack of space for social interaction
STUDENT HOUSING MODULE_ REIMS XCube-Engineer.&Prefabrication *(131) 27 m²*	double rooms	PK + PB position: ES;	former shipping containers, walls finishing: mineral wool + composite panels	lack of space for social interaction; excessive colour of interior surfaces - negative effect on the psyche
STUDENT HOUSING_ HEIDELBERG XCUBE,Engineer.&Prefabrication *(265) 27 m²*	single rooms (1-, 2-, 3-room cells)	PK + PB position: ES; standardised furniture	wooden frame construction + plasterboards	lack of space for social interaction
MODULAR CHECKERBOARD_PAU 2A Design, Davis Authenac *(214) 17.5 m²*	single rooms (+ 2 apartments)	PK position: LC; PB position: ES; integrated built-in furniture; kitchenette: in the night zone	prefabricated concrete modular units	lack of space for social interaction; personalization: floors and ceiling without surface treatment
STUDENT ACCOMMODATION_ GHOTENBURG Nova Deko Modular *(162) 26.5 m²*	single rooms	PK position: ES; PB position: LC; standardised furniture	former shipping containers, sheet metal panels facade	social activation: shared enclosed balconies and exterior atrium
CAMPUS_KOBLENZ Ternes Architekten BDA *(37) 28 m²/19.2 m²*	single rooms	PK position: ES; PB position: LC; integrated built-in + standardised furniture	steel frame construction, composite panels + thermal insulation	high degree of personalization of the room; shared roof terrace
CAMPUS_WAGENINGEN Te Kiefte Architecten *(312) 21 m²*	single rooms	PK+PB position: ES; integrated built-in furniture	steel frame construction, aluminum and wooden facade cladding	courtyard and exterior access balconies: a space for social interaction
STUDENT VILLAGE_AMSTERDAM Studio Selva *(358) 18 m²*	single rooms	PK+PB position: ES; integrated built-in furniture + standardised furniture	wooden frame construction + wood-based filling panels	several courtyards: a communicative space for interaction
U2 CAMPUS APARTMENTS_ NORDVEJ Concept Living A/S *(312) 26 m²*	apartments	PK position: LC; PB position: LC; standardised furniture	steel frames and metal panels cladding	high degree of personalization of the room; courtyard and access balconies: a space for interaction

STORKOWER STRASSE_BERLIN ARUP *(129) 16 m²*	single rooms (apartments)	PK+PB position: ES; integrated built-in furniture	timber load-bearing walls and columns; reinforced concrete floor slabs	natural material in the interior - a positive effect on the psyche
PARADIES_ KONSTANZ Lutz + Roos Architekten *(134) 20 m²*	single rooms (1-, 2- room cells)	PK+PB position: ES; separate hallway; integrated built-in furniture	timber load-bearing walls and columns; reinforced concrete floor slabs	participatory planning (cooperation with students), + prototype of a modular cell
THE FIZZ SPARTAAN_AMSTERDAM Studioninedots *(361) 27,5 m²*	single rooms	PB position: ES; SK position: ES; standardised furniture	reinforced concrete floor slabs and wall parts; + wood-based filling panels	social activation: shared terrace; café and relaxation spaces
Campus Montilivi_GIRONA Xavier Tragant *(70) 47 m²*	single rooms (55 %); apartments	PK+PB position: ES; standardised furniture	prefabricated concrete modules covered with galvanized steel	social activation: gym, TV room, lounge bar, shared kitchens
KOAS SEMINAARIMÄKI_JYVÄSKYLÄ Verstas Architects *(103) 27 m²*	single rooms (91 %); apartments	PB position: ES; PK position: LC; standardised furniture	cross-laminate timber (CLT) construction; facades: fire-retardant wooden cladding	social activation: clubroom, shared kitchens
KERAMUS_ UTRECHT Jillis Kinkel *(232) 21 m²*	single rooms (+ apartments)	PK + PB position: ES; standardised furniture	steel frame construction, reinforced concrete floor slabs; facades: ceramics cladding	social activation: shared roof terraces; separation of common areas only to the ground floor level
KATZENSPRUNG_VAALS MH1 Architecten, Studio Job *(461) 21 m²*	single rooms (+ apartments)	PK + PB position: ES; standardised furniture	steel frame construction, reinforced concrete floor slabs; facades: perforated fiber cement boards,	high degree of personalization of the room; interactive exterior space between buildings
POP-UP DORMS_WIEN F2 Architekten *(86) 12 m²*	single rooms	shared kitchen + bathroom for group of units	wooden frame construction + wood - based filling panels	natural material in the interior - a positive effect on the psyche; common atrium without direct light - negative effect on the psyche

Two predominant floor plan types of modular student accommodation cells emerged from the case-study analysis. The difference between them stems from the specifics of the supporting structure used, e.g., for modular cells made from an existing shipping container, a second type of floor plan arrangement is typical.

The most common type of floor plan is specific to the utilitarian composition of two spaces: the student room and the bathroom. The rooms are mostly single. Area-minimized sanitary facilities are part of the accommodation cells, and in the room itself, near the entrance, there is an integrated kitchenette. In many cases, in some areas of the accommodation section, there are several accommodation cells consisting of a group of two, three or four student rooms with a common living room and kitchen – similar to apartment hotel accommodation for more people.

The average area of the usable space of the whole accommodation cell ranges from 17 m² to 56 m², and the predominant area is 20-25 m², which is a standard compatible with the accommodation cells of conventional university homes. The standard room width is approximately 3 m (a width greater than 3.30 is exceptional due to the complexity of transportation). The disadvantage in many of the case studies is that the rooms are accessed directly from the exterior, in addition to the reduced possibility of social interaction in the room due to the non-division of the space into private and “semi-private” zones (entry is directly into the bedroom) (Figure 2).

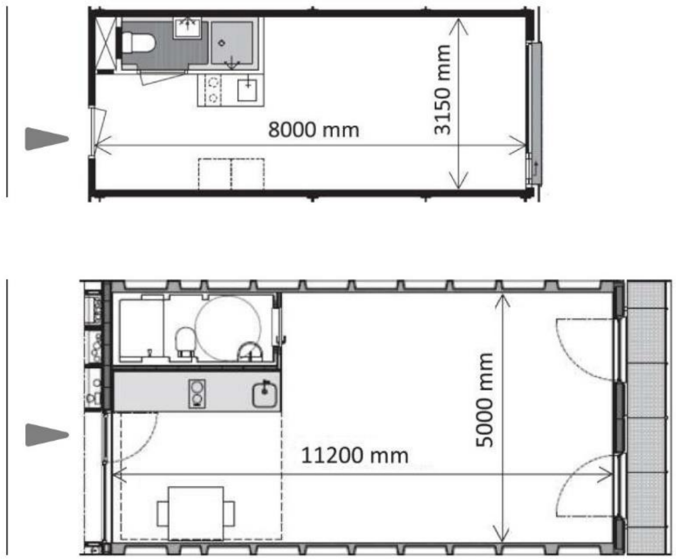

Figure 2. The first-floor plan type of modular student accommodation cells: characteristic layout-operational scheme of the spaces. Modular dormitory accommodation units: DUWO in Delft (architectural association Mecanoo) and the modular dormitory of the Catalan Technical University of Barcelona, H Arquitectes (Source: Friedman, 2016; Goula, 2013)

From the construction point of view, prefabricated modular units produced by joining large-format wooden panels are most numerous in this floor plan, using wood or steel as the frame supporting structure of the modules. According to Kotradyova *et al*. (2019), “Wood with its natural and emotional impact through visual, tactile, and olfactory interaction also has positive objective properties of the healthy microclimate, such as great contact comfort, improvement of room acoustics, the regulation of air humidity in a space, reduction of VOC (volatile organic compound) and emissions” (Kotradyova *et al*., 2019, p. 2). For modular units in taller buildings (usually 5-8 storeys), a load-bearing system consisting of a combination of steel frame structures and reinforced concrete slabs is the usual choice. Another possibility is to use plastic and composite materials (mostly polyester resins and glass fibres), which are very lightweight, and easy to shape and maintain.

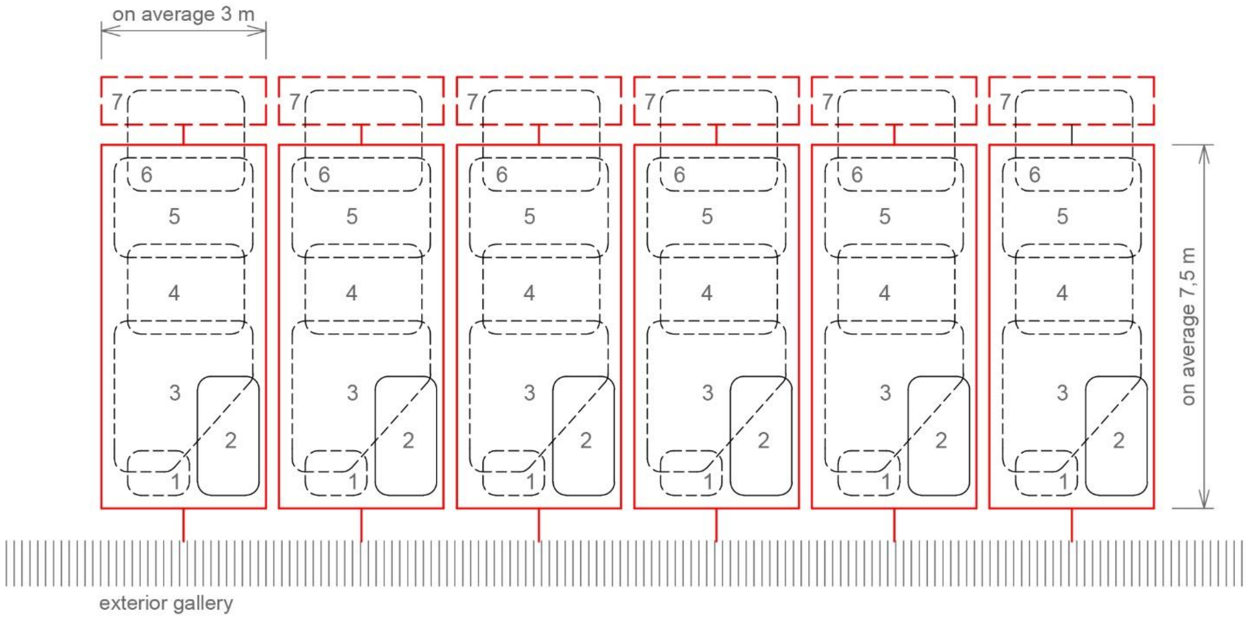

Figure 3. Theoretical model A1: modular student dormitory cell composition in the scheme of the accommodation section of the first type of floor plans. Legend: 1 – entrance zone, 2 - sanitation, 3 – cooking, eating, 4 – sleeping, relax, 5 – learning, working, 6 – relaxation, 7 – balcony (Source: Authors)

A typical arrangement for the second most common type of floor plan is one in which the accommodation cell is divided into two smaller living spaces oriented towards the opposite facades of the building. In the middle of the floor plan is an integrated bathroom between them. The kitchenette and dining area, which forms a small living room, is separated from the bedroom on the other side. The layout is thus divided into a private zone and a "semi-private" day zone – which is also used for meetings of smaller group of students. The entrance to the cell is via the kitchenette and dining area. A long and narrow floor plan is typical for the given modular blocks. The entrance area with a kitchenette also serves as an acoustic and hygienic filter for the living space, symbolically replacing the vestibule. An indisputable advantage of this concept is the direct contact between the interior and the shared exterior, i.e., the contact between the living area of the living cell and the interactive space of the common horizontal communication. The scheme supports contact between students directly in the room – in its "living area", while the bedroom remains the private territory of the occupant (Figure 4).

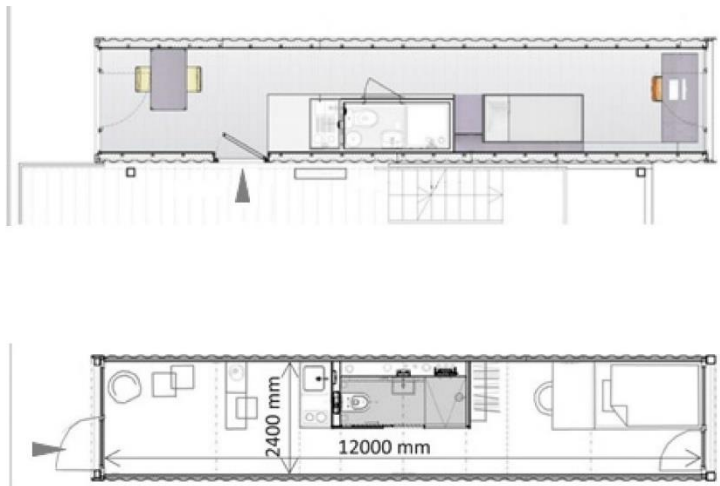

Figure 4. Characteristic narrow longitudinal floor plans of the second group of accommodation cells. Modular accommodation cells as building units of student residences Cité a docks in Le Havre (Cattani Architects) and Frankie & Johny in Berlin (Holzer Kobler Architekturen) (Source: Holzer Kobler Architekturen, 2016; Authors, 2021)

The typical narrow accommodation cells occupy an area of 25 - 30 m^2 on average, which represents a minimal increase in the dimensions compared to the first type of floor plan. Though the perceived space seems more generous in the first type of floor plan, it neither allows the structuring of the room into zones nor preserves privacy in the night zone of the room. A typical dimension of this floor plan is the atypical proportion of the area: a very narrow clear width of the room, which is on average 2300 mm in the case-study buildings (Figure 4). This proportion results mainly from the size types of the shipping containers used for conversion into modular student accommodation cells that are characteristic of the floor plan of the second type. The standardisation of the dimensions of ISO containers also affects their use in the modular building structure. In particular, 5 standard container lengths are used worldwide: 6.1 m, 12.2 m, 13.7 m, 14.6 m and 16.2 m. The so-called “40-ft” container – with a length of 12.2 m, is the most widely used size type in shipping (ECS European Containers, 2020).

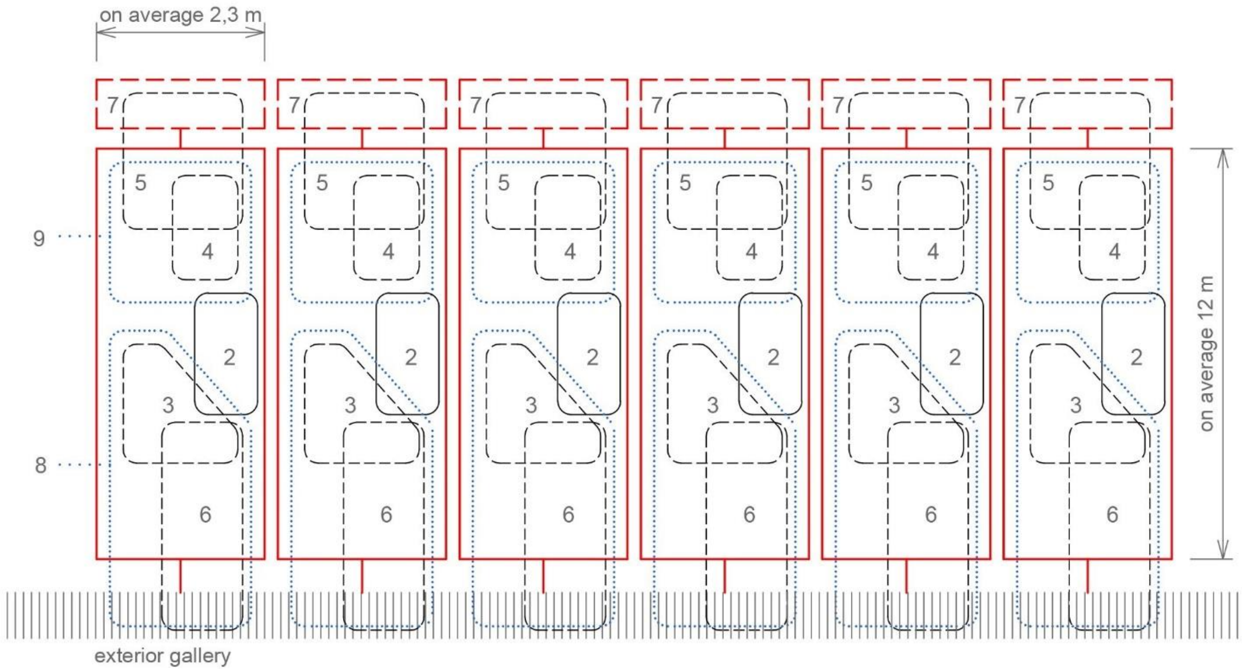

Figure 5. Theoretical model A2: modular student living cell compositions of the accommodation section of the second type of floor plan. Entrance zone lacks a solution for its functions – user enters directly into the living room equipped with a dining corner. Legend: (1- entrance zone - not available here), 2 - sanitation, 3 – cooking, eating, 4 – sleeping, relaxing, 5 – learning, working, 6 – relaxing, 7 – balcony, 8 – day zone, 9 – night zone (Source: Authors)

15% of the floor plans from the case studies with a narrow longitudinal floor plan of the second type are modular dormitories composed of prefabricated cells, often designed from easily recyclable materials. An inspiring example is the Zuiderzeeweg student residence in Amsterdam (Bellini *et al*., 2015), where the basic supporting structure of a modular cell is a steel frame structure, and the walls are filled with wood-based panels (Figure 5).

The spatial and surface maximum of the student modular cells in the case studies are subject to road transport requirements, to ensure the collision-free transport of prefabricated cells. For example, in the Slovak Republic according to Government Regulation no. 349/2009 Coll. the width of the vehicle with the load must not exceed 2.55 m and the maximum permissible length of the vehicles is 12 m (for truck sets with a semi-trailer 16.50 m). The height must not exceed 4.05 m (Vláda Slovenskej republiky, 349/2009). The given dimensional limits must also be taken into account in the design and subsequent implementation of a modular student dormitory. Moreover, this is true even in exceptional circumstances, for example if the production is carried out in the vicinity of the building plot, as the sustainability of the modular architecture has to be considered, and thus it is appropriate to support its possible mobility in the future. It follows that the maximum usable area of a modular cell (after thermal insulation of the inner space of the construction) does not exceed 30 m^2. (The maximum allowed length of the truck, including the driver's trailer and cabin, is 16.5m – therefore the container should not exceed a maximum length of 12 m to be able to load it onto the trailer).

Based on the above-mentioned minimum requirements for student accommodation and at the same time the limit parameters for transportation in European countries, it is possible to determine which size types of transport containers are suitable for conversion to a modular student accommodation cell. The most suitable space for conversion is a 40′ container, with internal dimensions of 2.352 x 12.032 x 2.385 m, and a total external volume of 67.5 m^3 (ECS European Containers, 2020). The 40′ container meets the minimum requirements for student accommodation facilities – the height of the interior space is more than 2.38 m, including a reserve for insulation and interior finishes. The external dimension does not exceed a width of 2.55 m or the maximum specified length subject to road transport.

4. DISCUSSION

In the design and implementation of these student residences, the architects' desire to maintain intimacy in the living cells while supporting the community life of the students can be seen. The observer cannot help but notice that the focus is placed on the creation of common areas for study, dining and relaxation. In fact, an additional analysis would have to struggle with the question of what would be the ideal ratio of the private zone intended only for individual use to the common areas. According to a study by Hendershott *et al*. (1992), which dealt with the evaluation of the quality of student housing, students were less satisfied with university housing than with their academic or social life. They highlighted insufficient spatial dimensions and lack of privacy as serious problems. Preservation of privacy is also mentioned as one of the priorities of Twale and Damron (1991), who described a student residence as satisfactory only if it offers a quiet environment structured for smaller groups of residents, providing privacy and appropriate room sizes.

The quality of the interior design of the student room has a great influence on the general satisfaction of the residents with regard to their university home and whether they give positive feedback. The student accommodation cell is the main determinant of satisfaction with the accommodation facility. Tailor-made progressively integrated interiors in buildings such as the Horden "micro-compact home" or the prefabricated Woodie dormitory cells cannot be fully adapted to a student's requirements. Despite the general positive response of the professional public to their design, there is a risk of a negative impact on the students' psyche. According to Thomsen and Eikemo (2010) young people need to develop and express their own identity, and living environments without opportunities for personalisation can have a negative impact on housing satisfaction. There are many possible reasons for this, for example, they do not feel comfortable in the interior, the placement of furniture does not suit them or the design restricts them. A suitable solution is the flexibility of the interior: its adaptability to the user's current activity, which has the disadvantage of increasing the cost of construction.

Student dissatisfaction with their accommodation can stem from the insufficient manner in which the issue of privacy and intimacy is dealt with, in contrast to the encouragement of social interaction provided by the designs. This is because the designs promote the development of relationships between the residents living together, without considering whether this is something they truly desire. Indeed, many of the problems that students report arise in response to forced social activity and the absence of opportunities to spend time alone. Students responded negatively with regard to the lack of space where they could spend time doing activities such as learning or just resting. “The dormitory rooms are supposed to provide students with required physical conditions and also spaces for spare time activities.” (Kilicaslan, 2013, p. 451) This implies inadequacy of the design of double and multi-bed student rooms, which do not provide intimacy and privacy to the individual. However, the solution is not only the design of accommodation sections with single rooms, but also the use of apartment-type accommodation, where roommates can perform activities with the added benefit of privacy.

In the case studies, as well as other implementations of modular student dormitories, accommodation in single rooms is clearly preferred (Table 1). The problem of creating various smaller groups of students is solved here by connecting the modular units, so that 2-4 single rooms have a common living room with a kitchenette, and form a student accommodation cell. In the case of student dormitories that possess exclusively single rooms of adequate size, it is possible to reduce social spaces to a minimum. Students meet friends directly in their rooms, which are actively connected with balconies or courtyards where they can socialise (Figure 6). The operational solution for accommodation cells with the second type of floor plans supports the preservation of intimacy and privacy of the individual, and at the same time it offers another area for meeting friends. As for the concept of accommodation cells with only one compact space in a room, there is no boundary between the perception of privacy and common social areas. According to a study by Kobue *et al*. (2017), students prefer single rooms that provide a feeling of privacy, a fast internet connection and flexible furnishing. The interest in single rooms stems from the fact that most students have never shared a bedroom, and many do not even have experience with a common bathroom (Rickes, 2009).

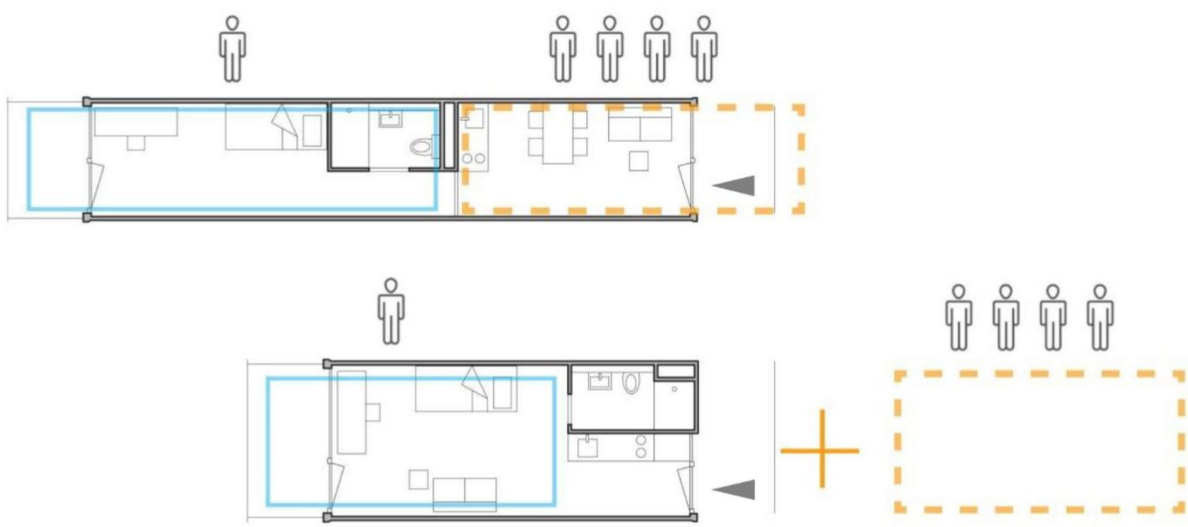

Figure 6. An operational solution for accommodation cells of the second (container) and first type (with only one compact space) – the perception of privacy. (Source: Authors)

The interior of modular student cells is mostly furnished with flexible, easy-to-maintain furniture. A complex bathroom block, as well as a kitchenette, are integrated into the overall structure directly in the factory. In regards to conventional dormitories, the ratio of the students' living space to the area covered by accessories (hygiene, kitchenette, etc.) is 63:37 (Vráblová and Majcher, 2013). This is in contrast to the ratio found in the case studies for modular dormitories, in which the living space area is 83% of the entire unit. The furniture and finishes are implemented in various ways, one being a comprehensively furnished interior designed accordingly to previously taken measurements, as an integrated part of a prefabricated cell. Another option is to furnish the cell with standard furniture after mounting it at the construction site. In some case studies, the accommodation cell is not furnished, neither are the wall surfaces treated (in such cases students furnish the room themselves according to their own ideas). The advantage of a fully integrated interior is a higher quality of processing and a lower price, which is a consequence of the nature of mass production. The disadvantage is the impossibility of rearranging furniture according to the students' wishes. The extent of the degree of interior prefabrication depends on the capacity of the university home and the volume of the planned investment (as well as possible regional specifics).

Integrated built-in furniture tends to take up less space, which allows for better usability of smaller rooms. The resulting minimised living cell area reduces the costs of construction and especially the building operation, despite the integration of more demanding interior features. These buildings are then competitive with traditional buildings. However, built-in furniture requires more demanding and precise planning. The disadvantage of integrated built-in furniture is the inability to move it – to individualize the student room. One solution would be flexible furniture (rotating, sliding, folding pieces), which would make it possible to adapt the room for operation during the day and night.

The characteristic modular prefabricated student room has a large window opposite the main entrance over the entire area of the front facade. The large glazing of the windows provides space with plenty of daylight for typical long narrow spaces. The entrance to the rooms is either from an enclosed corridor or directly from the exterior gallery. Although the absent vestibule filter brings heat losses in the winter, it helps to ventilate the rooms in the summer. The accommodation sections of modular student residences are characterised by efficient sorting of prefabricated cells along a horizontal communication – most often in the form of an exterior gallery. The cells are oriented (in the more effective cases) by their shorter walls to a common communication and the windows are mounted on the front-facing facades or on both front walls. The composition of accommodation cells with a floor plan divided into two smaller living areas (long narrow floor plans of cells) does not allow a layout scheme of the three tracts: accommodation cell – communication – accommodation cell, because there would not be sufficient daylight in one part of the cell. The solution is to offset the opposite row of cells, creating a common courtyard that also supports the social interaction of students (Table 2). The suitability of the choice of floor plan for the accommodation section results from the characteristics of the parcel and the number of students accommodated. However, it cannot be stated that the typological form consisting of shorter modules (the first type of floor plan) is more effective, as the requirements for the creation of common spaces are increased and the room does not consist of an intimate and a social zone. Architectural design brings a number of variants of grouping modular residential student units into a functional unit, but it is important to find the right measure in the relationship between efficiency – invention – user comfort.

Table 2. The relationship between the functional division of the modular dormitory accommodation section and the manner in which they are used (35 case studies)

	space /use	individual use (1, 2 persons)	group use (up to 4 people)	common use
	room	100 %		
private zone	entrance hall	33 %	67 %	
	bathroom	92 %	8 %	
	separate toilet	7 %	33 %	
daily use zone	kitchenette	65 %	25 %	
	kitchen with dining	28 %	38 %	4 %
	dayroom			
leisure activities zone	study room			
	clubroom			4 %
	sport spaces			32 %
	laundry room			58 %
auxiliary equipment zone	sanitary facilities			5 %
	technical facilities			2 %

5. CONCLUSION

The concept of modular architecture in the general typology of university dormitories is a new understanding of spatial solutions for student rooms, resulting from the prefabrication of three-dimensional compositional spaces/cells. The architectural design of modular accommodation units is subject not only to conventional legislative requirements, but also to the standard of various transport modes. The disadvantage of the initial volume limitation of the prefabricated cell becomes a benefit in the sustainability of university campuses. The dormitory buildings are easily dismantled, transportable, and can be adapted. The main characteristic of modular student housing is its high degree of prefabrication. For the characteristic forms of modular units that are comprehensively prefabricated or modified from transport containers, a specific organisation of the interior space is necessary. In contrast to conservative (non-modular) university dormitories, a modular scheme creates a new floorplan of a residential student cell: a longitudinal floor plan with sanitary zone in the middle of the layout. The dual space of the longitudinal single room meets the current demands for progressive and socially valuable accommodation for university students. A secondary effect of a divided floor plan is its convertibility in the event of a change in the building's function in the future: a divided space with a two-sided orientation of living spaces brings more efficient use (for example in the form of lower standard apartments). The aim of the correct design is to have user-friendly, ecologically and economically efficient modular accommodation cells designed according to universal design requirements as the basic compositional unit of the dormitory.

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