CONTAINER CONSTRUCTION - IDENTIFICATION COST AND TIME SAVINGS

Michal Tejgi [*,1]

*michal.tejgi@vutbr.cz
[1]Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, 602 00 Brno

Abstract
Construction from containers can be more efficient than construction from conventional building materials in a number of suitable applications. From an investor's point of view, the cost and speed of construction are important parameters, while from the societal point of view, it is environmentally friendly since it recycles original shipping containers. The core of this article is a case study of container construction of a primary school in Slovakia. The case study presents life cycle costs which are compared and contrasted with conventional construction. The aim is to compare investment construction costs. Finally, the results are compared with international studies on the topic of the life cycle of modular container buildings, project investment and renewability of this type of construction.

Keywords
Container buildings, investment costs, modular construction, SWOT analysis, construction time savings

1 INTRODUCTION

Modular construction offers an economic and environmental potential, especially when designed as a nearly zero-energy building (NZEB) container structure. In the case of modular container buildings, it is important to emphasize the advantages of the construction speed, sustainability, and modularity. Due to the increasing demands and innovations, construction processes are evolving. In recent decades, the construction industry has undergone significant industrialization and adopted various methods of construction. As a result of this evolution, off-site construction has become an established practice as an alternative to traditional on-site construction. This concept of off-site construction involves the production and pre-assembly of building components or modules before their subsequent installation at the final construction site.

This method has become popular around the Slovak capital where the surrounding communities are experiencing a rapid increase in population which is due to both the internal and the international migration and has a significant political, economic and labour market impact. The adjacent communities, as part of urban planning, anticipated an increase in the population and in connection with the current situation, there is a growing need for the construction of public facilities and services.

This paper aims to provide a comprehensive understanding of the costs associated with constructing a primary school from containers throughout various project phases, comparing them to conventional construction methods. Additionally, this paper critically analyses the advantages and disadvantages of modular construction. It focuses on the evaluation of the efficiency of container structures with emphasis on aspects such as cost savings and construction time. Through detailed analysis and case studies, it offers valuable insights into the economic and environmental potential of modular container construction.

The main part of this paper consists of a case study dealing with the comparison of the investment costs of a primary school building which is constructed from containers using the standard construction methods during the pre-investment and investment phase of the construction. The results of the case study were subsequently compared with scientific articles addressing the same issue and, based on this analysis, we reached a conclusion and evaluated the effectiveness of the investment costs of container construction in real-world conditions.

Present state references

This paper is based on the outputs of previously published articles and information from manufacturers of container buildings.

Within the construction industry, the modularity concept of container buildings emphasizes the assembly of smaller units to create flexible structures. This article explores the benefits of modular construction, emphasizing its eco-friendliness, adaptability, and cost-effectiveness, while dispelling some common misconceptions [1].

DOI 10.13164/juniorstav.2024.24011

Another study delves into the environmental aspects of incorporating shipping containers into sustainable construction by comparing container houses with conventional residences [2]. The advantages of container construction lie in its predominantly off-site implementation and modularity, providing an effective alternative to traditional on-site methods. It underscores the environmental attributes of modular buildings, highlighting their sustainability [3]. The study addresses potential disadvantages of modular container construction, discussing design challenges, solutions, and climate-adapted measures for creating comfortable and energy-efficient living spaces [4]. Emphasizing the need for proper insulation and ventilation, the findings suggest that well-insulated shipping container buildings can offer thermal comfort and cost efficiency, necessitating public awareness and acceptance of low-cost container structures [5]. In conclusion, the study advocates a comprehensive life cycle assessment (LCA) to compare environmental impacts, waste generation and production costs, endorsing prefabrication to reduce impacts, material consumption and waste generation, thereby promoting circularity in the construction sector [6].

2 METHODOLOGY

The research method involved exploring and evaluating existing knowledge about container construction. Based on general knowledge and acquired information, a SWOT analysis associated with container module projects was conducted.

In the next part, based on the solution of the case study, two advantages of container construction were verified by comparing three variants of the technical-material solution for the construction of a primary school based on the amount of investment costs and the duration of construction.

The assessment of investment costs employed a comprehensive methodology, integrating construction, engineering, and design expenses along with the costs associated with connecting the building to public networks. This holistic approach offers a complete perspective on the financial considerations of the project. Following this, the comparison of investment costs for the executed container school involved the identification of two alternatives based on price indicators derived from the technical-material approach to implementation, maintaining an equivalent size for the constructed space of the building object.

The container case study project used in this study is a primary school designed as a two-story building composed of eighty container modules. The main part of the structure has a rectangular layout with the overall dimensions of 15.65 × 33.70 meters, housing 12 classrooms, an assembly hall, changing rooms, and offices. The roof of the building has a height of +7.755 meters from the level of ±0.000. The project was initiated by the municipality with the aim of enhancing the quality and accessibility of education for children and youth, catering to both the existing and new residents of the municipality or adjacent smaller communities [7].

3 RESULTS

Modular construction from containers can be defined as a combination of standardized spatial units. This approach utilizes recyclable cargo containers as basic modules with simple geometric shapes. Containers used in construction are an ideal element, especially for solid structural connections. They are readily available and cost- effective [1].

Construction projects using containers respond to the current needs of users and can be easily expanded, relocated and modified for other purposes. This construction method is environmentally friendly, as it does not pollute the surroundings with long-term noise and dust, which is a common issue in traditional construction methods. For a systematic overview of the advantages and disadvantages of container construction, the SWOT analysis mentioned above was chosen.

SWOT Analysis of the Use of Shipping Containers as a Building Material

An overview of the strengths, weaknesses, opportunities and threats of using containers as a building material is shown in Tab. 1.

DOI 10.13164/juniorstav.2024.24011

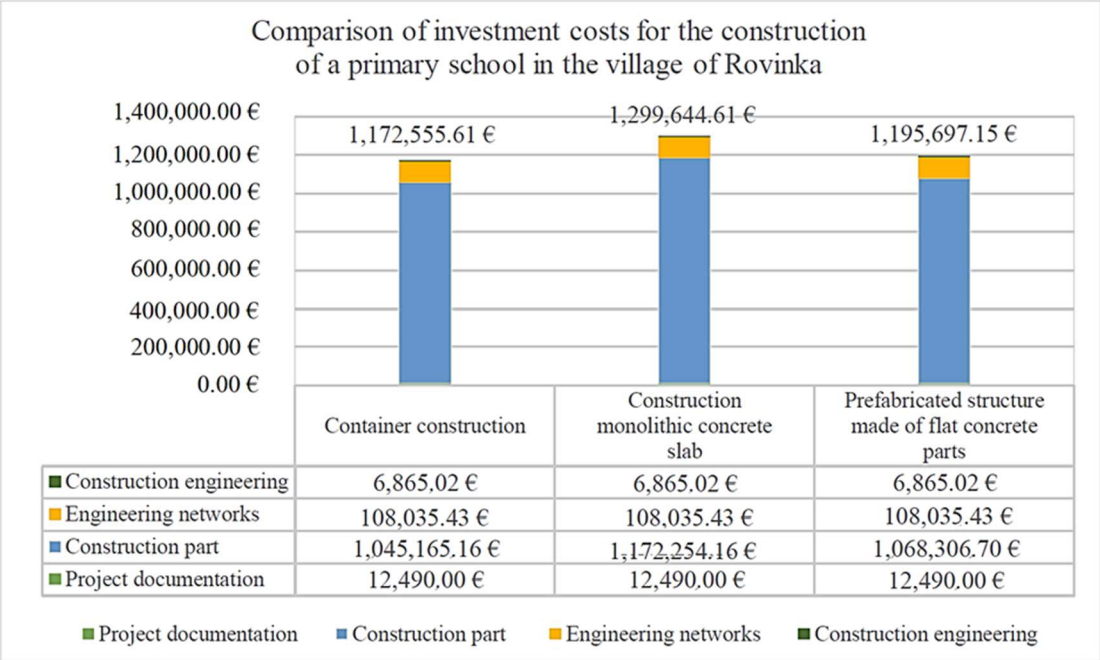
Tab. 1 SWOT analysis of the use of shipping containers in construction.

Strengths	◦ Container construction offers standardized dimensions based on ISO 1496-1, making it easy to create custom configurations and adjust the size of the building as needed (modularity) [8]. ◦ Environmental sustainability – recycling shipping containers for construction, reducing greenhouse gas emissions [2]. ◦ Quick installation and construction accuracy. ◦ Conversion of shipping containers is often more cost-effective than traditional construction methods, primarily due to their inherent characteristics and construction process [3].
Weaknesses	◦ Containers are made of steel which can cause unacceptable internal temperatures. Thermal insulation and ventilation are essential if containers are to be used for construction purposes [4] ◦ Container buildings may not be suitable for certain applications or space requirements. ◦ Wear and tear during the shipping career can affect the life and durability of containers [3].
Opportunities	◦ Recycling shipping containers can reduce waste and the need for new building materials, making container buildings an environmentally friendly option [2]. ◦ Container buildings can be constructed relatively quickly, making them an excellent choice for time-constrained projects [3]. ◦ Containers offer utilization in temporary housing projects, services, businesses, emergency shelters and permanent construction projects. These opportunities make them an attractive choice for various construction projects [3].
Threats	◦ Containers can be prone to damage from corrosion [2]. ◦ Older containers may contain lead-based colors and other substances that are hazardous to human health as well as the environment [5].

Case study - Comparison of Investment Costs according to the Technical and Material Characteristics of the Building

Information from the construction of the modular primary school in the municipality of Rovinka, Slovakia, was used for the case study. First, the investment costs of 3 variants of the building-material solution were compared. These costs included expenses on the development of architectural studies and project documentation in the pre- investment phase as well as costs in the investment phase which encompassed the construction work and the connection of the facility to engineering networks, including engineering services during implementation. The structure and costs of the individual options are shown in Fig. 1 [7].

DOI 10.13164/juniorstav.2024.24011



	Container construction	Construction monolithic concrete slab	Prefabricated structure made of flat concrete parts
Construction engineering	6,865.02 €	6,865.02 €	6,865.02 €
Engineering networks	108,035.43 €	108,035.43 €	108,035.43 €
Construction part	1,045,165.16 €	1,172,254.16 €	1,068,306.70 €
Project documentation	12,490.00 €	12,490.00 €	12,490.00 €

Fig. 1 Comparison of investment costs for the construction of a primary school in the village of Rovinka [7], [9].

In Fig. 1, the first column interprets the investment costs for the construction of a primary school using 80 container modules with a total area of 4 496.4 m^3 [7].

The second and third columns describe the costs associated with the construction using conventional building materials. The first alternative considers the construction of the primary school building with a monolithic structure, while the second option involves the use of prefabricated concrete panels. The costs of alternative solutions were calculated based on the technical and material price indicators [9].

The data shows that building an elementary school from containerized modules is cost-competitive with alternatives made from traditional building materials. Compared to the first alternative of monolithic construction, it appears that this approach can deliver cost savings of up to 10%, as confirmed by international articles comparing the cost of containerized construction with traditional materials [3], [10]. In the case of comparison with the second alternative, the differences in investment costs are smaller and estimated at 2%. This smaller cost difference is the result of the use of precast concrete which allows for savings and efficiency in the construction processes, similarly to the use of containers.

Case study – Comparison Timetables for the 3 Variant of Construction

The use of modular container construction is particularly beneficial in projects with limited construction deadlines. Examples include capacity expansion in the education sector or projects in the healthcare sector. Some studies have indicated that modular construction can save approximately 40% of construction time compared to traditional construction. As the on-site construction is labour intensive and can be affected by external factors such as weather, these time savings can significantly reduce the final cost of the project [3].

DOI 10.13164/juniorstav.2024.24011

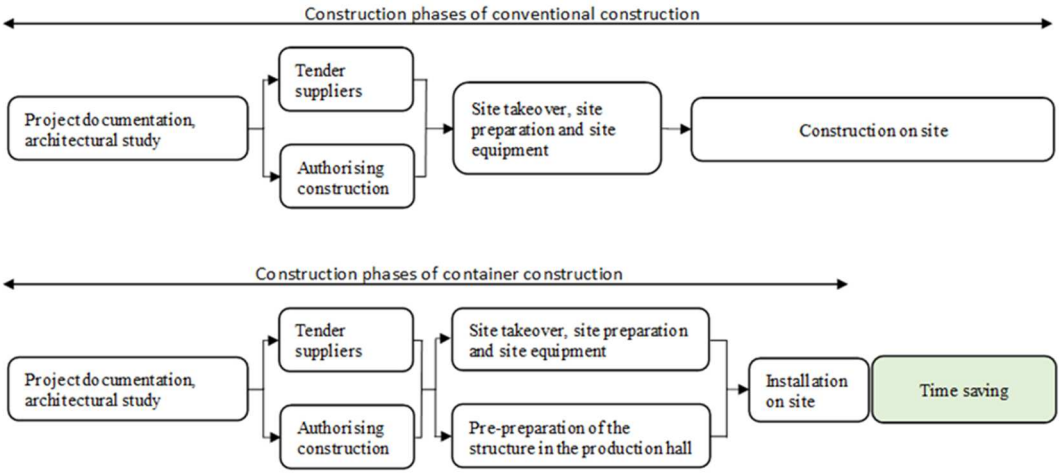


Fig. 2 Time savings in modular container construction [7].

The implementation of the modular primary school project was achieved and certified within 8 months from the start of the construction by FAGUS SK s.r.o., in compliance with the signed contract. Compared to the estimated time schedule of a conventional construction using monolithic concrete structures, this represents a potential extension of the construction time by approximately 8 months. Time savings in construction are schematically depicted in Fig. 2. This analysis confirms data from worldwide studies, indicating that modular construction can indeed save time during the implementation phase [3], [7].

4 DISCUSSION

In this paper, information corresponding to common and scientific awareness in the field of container construction was verified. Based on the obtained information, a SWOT analysis was conducted to comprehensively assess the strategic utilization of this information and the integration of insights into further developments in the field of container construction. The main benefits of modular construction include faster construction process, increased productivity, cost savings, increased safety, improved product control and quality as well as reduced environmental impact. In addition, this type of construction also has a greater potential to reuse a significant proportion of building components at the end of their operational life cycle, which can lead to reduction in waste to landfill. However, container construction faces certain challenges during implementation, including transportation restrictions, more complex engineering and planning procedures, and the need for better coordination and communication during the execution of construction projects.

The next important result of this work is the comparison of investment costs. From a case study of building a primary school from container modules, it appears that there are cost savings compared to conventional model projects. Based on technical and economic indicators, the cost of alternative solutions for the construction of an elementary school made of monolithic concrete structures and precast concrete was determined. The determined price does not include any additional budgetary costs that need to be included separately, so they were calculated based on expert estimation as 10% of the determined price and added to determine the final price of the alternative solution without VAT.

The comparison of investment costs shows that container construction is more advantageous if compared to similar traditional construction (from an economic perspective). In this case, it is important for the costs to be clearly defined. This comparison is based on price indicators, and thus, financial measurement is not the sole criterion for comparing different construction methods. As mentioned above, there are also other advantages to modular construction that can lead to indirect cost savings, such as speed of work, productivity, safety, etc. Therefore, the benefits and cost savings of container construction represent a significant factor when choosing the method of construction. On the other hand, for irregular shapes and non-repeating modules, it may be more cost-effective to use conventional construction methods, rather than modular design.

DOI 10.13164/juniorstav.2024.24011

5 CONCLUSION

This study is mainly focused on the investment phase, comparing building systems (prefabricated and conventional) and building materials (steel and concrete), considering their respective impacts, costs and production times.

The goal of this article was to critically evaluate studies related to modular container buildings and explore the key advantages and challenges in construction compared to their conventional counterparts. Through a comprehensive review of relevant literature, a SWOT analysis was conducted to provide a clear picture of modular container construction.

The results confirm the general assumption that, in comparison to conventional construction methods, container-based construction tends to be more cost and time-efficient, with cost differences typically falling within the range of up to 10% of the total cost [3], [10]. The variation in cost is influenced by local conditions. Prefabrication and modularity as part of the construction process can be a significant cost-reducing economic advantage, yet transportation costs should be considered and reviewed depending on the scope of the project and the proximity to the manufacturing facility and contractor.

Furthermore, the potential of using containers in construction projects lies in situations where conventional methods cannot meet strict time requirements. One significant advantage of such construction is its sustainability and waste minimization through recycling and eco-friendliness, particularly during the investment and disposal phases. Proper container disposal and recycling can significantly reduce waste compared to traditional construction methods. All in all, this research provides valuable insights into the construction industry, highlighting the benefits, challenges, and economic advantages of modular container construction [6].

References

[1] Company's Internet profile KOMA MODULAR. In: koma-modular.cz [online] Vizovice, 2023. [cit. 2023-11-11]. Available at: https://www.koma-modular.cz/modularita

[2] Hamidul Islam H.; Guomin Zhang G., Setunge S., Bhuiyan M.A.; Life cycle assessment of shipping container home: A sustainable construction, 2016, ISSN 0378-7788. Available at: https://www.sciencedirect.com/science/article/pii/S0378778816305989

[3] Kamali M.; Hewage K.; Life cycle performance of modular buildings: A critical review, 2016. ISSN 364-0321. Available at: https://www.sciencedirect.com/science/article/pii/S1364032116301411

[4] Shen, J.; Copertaro, B.; Zhang, X.; Koke, J.; Kaufmann, P.; Krause, S. Exploring the Potential of Climate-Adaptive Container Building Design under Future Climates Scenarios in Three Different Climate Zones, 2020. Available at: https://www.mdpi.com/2071-1050/12/1/108

[5] Oviya, K.;Shobana,; Amraotkar, Sheetal. Assessing the thermal performance of upcycled shipping container as a sustainable building material in a Warm humid climate, 2023. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/1210/1/012008

[6] Tavares V.; Soares N.; Raposo N.; Marques P.; Freire F.; Prefabricated versus conventional construction: Comparing life-cycle impacts of alternative structural materials, 2021, ISSN 2352-7102. Available at: https://www.sciencedirect.com/science/article/pii/S2352710221005635

[7] Project documentation and documents for the public contract of the elementary school, 2023. Available at: https://www.uvo.gov.sk/vyhladavanie/vyhladavanie-zakaziek/dokumenty/408643?page=2

[8] International Organization for Standardization [ISO], In: iso.org [online] 2023. [cit. 2023-11-11]. Available at: https://www.iso.org/standard/59672.html

[9] Price indicators in the construction industry for 2017. Available at: https://www.cenovasoustava.cz/dok/ceny/thu_2017.html

[10] Three Squared, Inc., Breaking Down the Cost Savings of Cargo Architecture, Detroit, 2023. Available at: https://www.threesquaredinc.com/post/breaking-down-the-cost-savings-of-cargo-architecture

DOI 10.13164/juniorstav.2024.24011