ANALYSIS OF SHIPPING CONTAINERS, THEIR EVOLUTION AND THE PATH TO CONTAINER ARCHITECTURE

Andrea Vokřálová[1], Richard Sovják[1]

[1] Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic

Link to this article: https://doi.org/10.11118/978-80-7701-044-3-0063

Abstract

The paper analyses the historical development of shipping containers, the change of their use from standardized shipping containers to a building element from which both a building with architectural value and a useful building for humanitarian and social housing can be constructed very quickly and cheaply. Materials, technologies and technical solutions for construction are constantly advancing and it is therefore essential to address current and future issues concerning our planet. After the supply-chain crisis, production of shipping containers is on the rise again due to the worldwide increasing demand for international transport of goods. Retired containers need to be disposed of in a meaningful way and given an alternative use as a building block. This paper summarizes the information necessary to create an ergonomic manual for the rapid construction of cities with all the social amenities. It is also important to take into account the impact on people through the quality of interior comfort, the speed and sustainability of production and the social convergence between the population and nature. To evaluate the efficiency of use, to explore its further progression for the benefit of the population of our planet and beyond.

Keywords: container, transport, ships, architecture, living, sustainable, humanitarian, office

INTRODUCTION

The paper deals with the development of the shipping container, its function as a box for transporting products and later recycling for use in the construction industry. The standardization of dimensions has enabled the stacking of containers and caused a global flow of trade. However, this stroke of genius has also seen its further application in architecture as a building element to create very attractive, economical and sustainable buildings, popular not only among the young population.

The aesthetic design of modern container housing must flawlessly integrate the individual parts into a functional whole. The great advantage of this type of housing is the unification for production and assembly worldwide.

It must be stressed that shipping containers are environmentally friendly and sustainable with regard to the extraction and production of raw materials contrasted with the bulky amount of materials used in traditional construction. Construction using shipping containers can take place off-site without the need for technological interruptions in the construction process. The advantage is especially the speed and reduction of additional waste during construction. Containers in different levels of wear (one way or discarded due to damage) can be widely used for the construction of private or public buildings (vaccination centres, schools, alternative housing during emergency situations, etc.) [1].

If we summarize all the available information we come to the conclusion that containers serve excellently for the rapid and sustainable construction of various types of architectural use. Thanks to the standardisation of dimensions, they are easy to transport to the site and quick to assemble. Such a construction system is ideal in dealing with crisis situations for various humanitarian and social projects, as well as luxury and economic housing.

Historical Development of Shipping Containers

The forerunner of the first shipping container was designed by James Brindley in 1766. This container was part of the Starvationer and was used in England to transport coal from the mines. In 1795, Englishman Benjamin Outram designed the first container made of wood for transporting coal, which was hauled by horses from the mines to ships in port. By the 1830s, containers were being transported by rail on some continents. Up to 4 containers could fit on one car. These were then transported by horse-drawn carriages, one container at a time. Later, metal containers were produced, and by the beginning of the 20th century, they were already being produced enclosed [2].

As a result of the advent of the Industrial Revolution, there was a demand for efficient transportation without unwanted time gaps.

The American merchant Malcolm McLean realized the need for unification of shipping containers and began to investigate different variants. He adopted a 35‘ (about 11 m) container model that is still known today as the shipping/storage container. Today's modern containers have established length dimensions of 20‘ and 40‘. They are a standardized, durable, stackable, easy to load and lock solution that allowed for transloading between train, ship and truck [3].

Revolution in Transport

Shipping containers were one of the key elements that enabled the globalisation of modern trade. Their adoption and standardisation have revolutionised logistics and business processes around the world, not only in the transport sector, but also in construction and other industries. Today, approximately 90% of all world goods are transported in containers [4].

Standardised Container Dimensions

Shipping containers are manufactured in standardized sizes according to ISO 668 international standards and may vary slightly depending on the manufacturer.

These containers are referred to as ISO Class 1 and consist of several types. The most common types seen are the 20‘ (1C) and 40‘ (1A) containers, which allow up to 6 containers to be stacked on top of each other. Standardization has also made good use of internal dimensions for efficient transport. The container can accommodate 3 Euro pallets per width.

The width of the container has a constant dimension, but the length and height of the containers vary according to the types. The basic models 1A and 1C are 2,438 mm high, but there are also elevated models 1AA and 1CC with a height of 2,591 mm and a tall container 1AAA with a height of 2,896 mm (Tab. I) [5].

I: *Standardized container dimensions [3] [5]*

Container size		External dimensional (mm)	Interior dimension (mm)
20'	length	6,058	5,898
	width	2,438	2,352
	height	2,591	2,393
40'	length	12,192	12,032
	width	2,438	2,352
	height	2,591	2,393
45'	length	13,716	13,556
	width	2,438	2,152
	height	2,591	2,698

Container Support Material and Surface

The supporting structure of the shipping containers is made of high-strength corten steel (composition Fe, Cr, Cu, Ni and P). This steel has high corrosion resistance, excellent mechanical properties, but above all, it has a long service life.

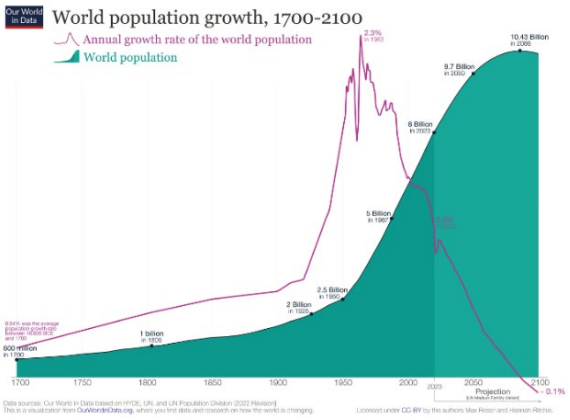
Corrosion forms a patina/rust layer which prevents further rusting. For this reason, it is not necessary to apply protective coatings to the containers, but for operational and aesthetic reasons these treatments are carried out [6].

The advantage of using Corten steel without surface treatment is the characteristic oxidation of the steel (Fig. 1), which finds application in building facades, bridge construction and other civil engineering structures [7].

1: *Corten surface [8]*

Population Growth

According to the information and graphs available in the Our World in Data articles, it is certain that the world's population is still growing. In recent years, the increase has not been as marked as in the second half of the 20th century, when the population grew by about half, from 2.5 billion to 5 billion. This year, the population has exceeded 8 billion,



2: *World population growth [9]*

3: *Cointainer hotel in Quepos, Costa Rica*

and growth forecasts estimate that we will reach 10 billion in 2058 (Fig. 2), [9].

Important questions arise in the redesign of shipping containers that focus on their benefits to society, the purpose of their construction, the possibility of disrupting the advantages of modularity (non-traditional architecture) and aesthetic treatment.

Methodology

This paper uses a qualitative approach for evaluation based on primary and secondary sources, research on the history of container housing and research on the existence of construction companies in the market that are already working with containers.

It analyses the production of shipping container manufacturing in recent years and the developments that have taken place since the beginning of the 20th century. It describes the current direction of container housing construction and its possible prediction for the future.

Developing a SWOT analysis of container housing with respect to current use and prospects for future applications, including interpretation of the results from this analysis.

Results

Shipping containers were initially used by companies for quick solutions to accommodation problems of their employees, mostly construction workers, etc. In the early 21st century, shipping containers began to be widely used by architects/designers for the construction of hotels (Fig. 3), schools, offices, holiday housing and glamping. Today, however, these buildings are even more popular due to their low purchase price, low environmental burden on nature, sustainable living, as well as low energy consumption in their operation.

Containers are now commonly used to build various types of „box houses“, schools, nurseries (Fig. 8), offices and Even doctors' surgeries. London-based Container City (Fig. 4), founded in 1998, is a major player in this type of construction. As an example, the Container City™ project, located at Trinity Buoy Wharf in the heart of London's Docklands, was completed in five months in 2001. Container City I was initially three-storeys providing 12 work studios on 446 m^2. A fourth floor was added in 2003 to accommodate three additional live/work apartments. The actual installation of the prefabricated containers on site took 2 days.

Another project that followed on from Container City I is one of the most famous buildings in the world (Fig. 4), Container City II. The colourful and distinctive building has five storeys and occupies 8,208 m^2. It took 15 days to assemble the ready-made boxes [10].

A Breakthrough in the Development of Container Architecture

The first ideas of converting shipping containers into housing were pioneered by Phillip C. Clark in 1987, who registered US patent US4854094A „Method for converting one or more steel shipping containers into a habitable building at a building site and the product thereof“ [11].

4: *Container City I, London [10]*

5: *Watter Hub, New York, 2013 [12]*

6: *House design Carroll House, California [12]*

A single-family house in Brooklyn by the architectural firm LOT-EK (Fig. 5 and Fig. 6). The house was designed by Italian architects Ada Tolla and Giuseppe Lignano in 1993 [12].

An as-yet-unrealized 2017 design for a single-family home in California's Joshua Tree National Park by English architect James Whitaker (Fig. 7), [13].

7: *Design of Family House, California [13]*

When the Costa Mesa Waldorf School in California decided to expand, they chose to use shipping containers due to their sustainability. The school used shipping containers to create a new wing of eco-conscious buildings. The project utilized 32 shipping containers to create an additional 4 buildings on their campus. In addition to extra classroom space, the new additions include a library, 2-story auditorium, and a science lab. (Fig. 8), [14].

8: *Waldorf Costa Mesa School, California [14]*

Adam Kalkin

Adam Kalkin is a prominent American architect working on container buildings. He tries to combine the function and aesthetics, but also the economic side of these buildings. Among his most notable projects is the Illy Push Button House, which is a revolution in the perception of building technology.

He designed this building in collaboration with the coffee company Illy and presented it at Art Basel in Miami. Kalkin has combined aesthetics, design, sustainability and the enjoyment of good coffee. The shipping container opens like a flower at the push of a button (Fig. 9). The motorised walls use hydraulic struts to open all the side walls and a coffee bar is created [15].

Many construction companies and architects are involved in the construction of shipping container buildings. We mainly encounter design aesthetic buildings for living. However, this building element offers a very wide range of building applications for: schools, hospitals, cultural houses, factories, studios, housing for the homeless and, above all, buildings for humanitarian and emergency situations.

9: *Push Button House, Adam Kalkin [15]*

The bonus is its recycling reuse for another purpose from a sustainable material and that is corten steel. To make such a building fully sustainable it is essential to address its internal wall and floor design, i.e. insulation and materials for furniture production.

Completely Independent Box on Utility Networks

Nowadays, it is possible to build a completely independent house from utilities quickly and easy to implement and cheaper than conventional buildings made of other materials. A bonus is the simple composition of standardised container sizes, differently stacked to create visually aesthetic buildings.

If the carbon footprint is reduced as much as possible with their handling and the use of building insulation, etc., the residential container box will be fully eco-friendly and sustainable.

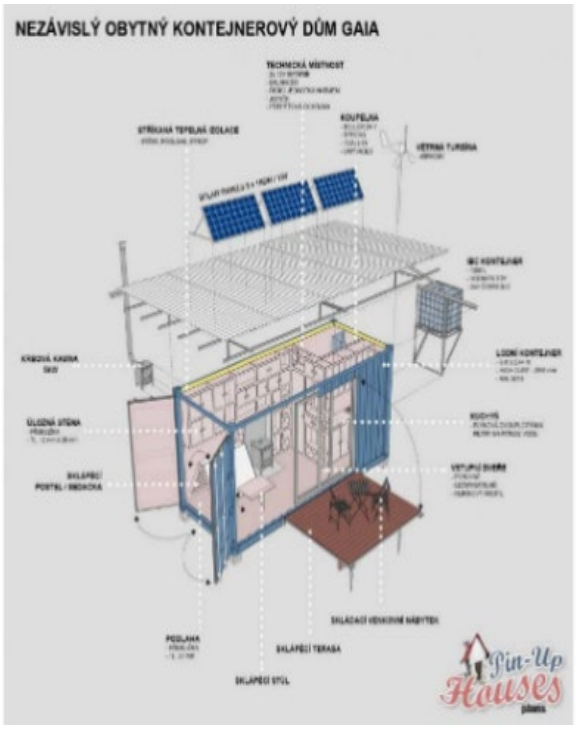
The current options for building independence from utilities is based on the principles of:

- electricity generated by photovoltaics or wind power;
- rainwater harvesting and recycling using filtration units;
- ecological composting toilet [16].

Off-Gridd House Gaia

Shipping Container House Gaia is a project of experimental self-sufficient house, it is a so-called Off-Grid House (Fig. 10, 11). The house is equipped with solar panels and a wind turbine that recharges the batteries at night and during the winter months when the solar panels are less powerful. Battery status, consumption, recharging and other factors can be monitored using a mobile app. The house retains rainwater, which is filtered and distributed to the bathroom and kitchen. It is equipped with a refrigerator, a water boiler for heating water and other appliances at 12 and 24V. At the same time, a higher voltage of 110V to 230V can be created using an inverter. Clever storage space, a folding bed/sofa, furniture and table is standard. The outdoor patio can be folded using a winch to close the container.

10: *Gaia living container (Ing. Arch. Vojtěch Valda) [16]*



11: *Gaia living container (Vojtěch Valda) [16]*

The main building materials are a marine HC 20‘/6m container, wooden KVH prisms and wrapping spruce plywood which defines the entire interior space. The inner walls of the container are insulated with sprayed thermal insulation. The steel roof structure is covered with galvanised corrugated sheet. The generous roof overhang increases the catchment area for rainwater, which is collected in a 1,000 litre IBC container.

Kebin

KEBIN is a mobile container with dimensions of (2.6–7.0) m and a height of 2,780 mm and works on the OFFGRID principle (Fig. 12). It is therefore self-contained and without the need for connection to utilities. The project authors, architect Jan Bek and builder Stanislav Líkař, designed the container to be as comfortable as possible, to have a practical use and to blend in with its surroundings [17].

12: *OFFGRID house Kebin, 14.2 m² [17]*

II: *SWOT Analysis of shipping containers [1]*

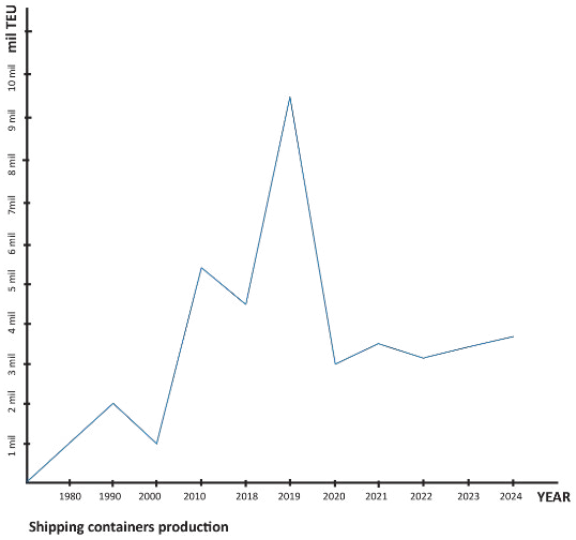
	ADVANTAGES	DISADVANTAGES
Internal	Reduction of the price for transport of products (materials bricks, ...)	High carbon footprint during transport
	Easy maintenance and pest resistance (wooden buildings)	
	Modularity and speed of construction (Reduction of construction energy)	
	Possibility of non-traditional architectural solutions	
External	Recycling requirements and reuse	Energy intensity of modifications (change in energy prices)
	Reducing the consumption of input materials (reducing the environmental burden associated with mining, production of building materials)	Health and safety aspects (necessary control of decontamination of shipping containers due to transport of unknown goods)
	Mobility (easily relocatable - reducing the environmental burden associated with demolition and construction of new buildings)	Lacle of shipping containers (crisis in the steel industry, excessive demand for shipping containers)
	Attractiveness of housing (speed and cost of construction)	
	Modularity of transport	

SWOT Analysis

SWOT developed from a redevelopment perspective of shipping containers to container housing (Tab. II).

DISCUSSION

Container architecture brings significant benefits and is applicable both in urban areas and in more remote locations where rapid and efficient construction is needed. Typical examples are student halls of residence, emergency shelters, commercial and office space.



13: *Chart of containers production (1 TEU is equivalent to one 20' container) [18] [19] [20]*

The production of standardized containers is again on the rise (Fig. 13). Containers have a lifespan of 10–15 years for transportation needs, resulting in the accumulation of large quantities of discarded containers [21]. Containers can, however, continue to serve an ecological purpose in the construction industry and change the established approach in urban development.

Shipping containers can be the basis for sustainable construction, provided that the prerequisites for minimising the negative environmental impacts associated with their handling and transport are met. It is important to ensure that their reuse respects modern building requirements with regard to the use of natural insulation/environmentally friendly materials for energy efficient housing. Important aspects in the construction of container housing are the location and also the purpose of the construction. In the case of construction in locations with favourable climatic temperatures, it will not be necessary to ensure perfect insulation against installations in cold/very warm climates. What is essential is the use of container housing, namely seasonality or permanent housing.

Increasing urbanisation, the high cost of traditional housing, sustainability and design flexibility also play a significant role. Containers are used for both low-cost housing and luxury modern projects.

- Global population growth is increasing the demand for housing, underlining the importance of sustainable and low-cost solutions such as container architecture.

- A number of construction companies around the world specialise in projects based on container architecture, from emergency shelters to luxury homes.
- Innovations in the 21st century, such as Adam Kalkin's pioneering designs, have accelerated the construction of container buildings with an emphasis on lower costs and speed of construction.
- The public's changing preferences are leaning towards smaller, more efficient living spaces with modern design, due in part to economic factors.
- Environmental factors such as climatic conditions significantly influence the feasibility and popularity of container architecture.
- Clustering, modularity of shipping containers and finishes (cladding) aesthetically enhance the architectural design of container housing

CONCLUSION

The analysis presents a path for the conversion of shipping boxes from wood to steel containers of standardized dimensions. Its enormous impact on the world globalization in transportation and the change in the perception of shipping containers as an essential building element that has changed the perception of architecture. The advantage of these containers is the use for transportation as well as eventually for use in construction. This makes it a fully sustainable building element ready for quick and cheap housing construction, not only because of the unification of dimensions (building in modules).
The production of containers is fully dependent on the economic and political situation in the world. This fact can be seen in the chart (Fig. 13) which records the production of shipping containers since the beginning of the 21st century.
The forecast for containers as a building element is increasing. They are gradually being integrated into the construction industry and stand out primarily as design buildings, but containers offer far more extensive social possibilities such as the creation of buildings for the homeless, refugees, victims of natural disasters, etc. Examples include building London firms such as Container City, Modulus Homes, SG Block and New York's Lot-ek.
Container architecture is a revolutionary approach to construction that combines sustainability, efficiency and flexibility in construction. A major advantage is the ability to quickly address global housing needs with adapted shipping containers, especially in crisis situations. Further research and innovation is needed to improve container reuse, optimise insulation and reduce the environmental impact of construction. The future of container architecture promises speed of construction, but above all both social and environmental benefits, from affordable housing to luxury design.

REFERENCES

[1] HZ KONTEJNERY. 2024. *Bydlení z kontejnerů*. HZ containers.com [Accessed: 2024-11-23] https://hz-containers.com/cs/bydleni-z-kontejneru/

[2] TUONG HOA. 2023. *The history of container shipping*. 20/9/2023. [Accessed: 2024-11-23] https://tuonghoa-imex.com/en/logistics-knowledge/the-history-of-container-shipping.html

[3] LEVINSON, Marc. 2016. The Box. In: *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*. Princeton University Press, p. 191–196. ISBN 9780691170817

[4] HZ KONTEJNERY. 2024. *Historie lodních kontejnerů*. HZ containers.com [Accessed: 2024-11-23] https://hz-containers.com/cs/historie-lodnich-kontejneru/

[5] NOVÁK, Jiří. 2020. *Rozměry a stohování lodních kontejnerů*. Obalové Materiály. 13. 2. 2020. [Accessed: 2024-11-23] https://www.obalove-materialy.cz/o-nas/clanky/rozmery-a-stohovani-lodnich-kontejneru

[6] KUMARAVEL, D.; RAJA, V. K. Bupesh; BALTHASER, Kabasker; ANANDAN, Jayaganthan; SAHAS, S. *et al.* 2022. Investigation on Wear and Corrosion Behavior of Cu, Zn, and Ni Coated Corten Steel. *Advances in Materials Science and Engineering*. 2022, 7341201. https://doi.org/10.1155/2022/7341201

[7] ABRA SERVICE. 2024. *Cor-ten*. Abra Service. [Accessed: 2024-11-23] https://www.abraservice.com/cs-cz/materialy/ocel-odolna-vuci-povetrnostnim-vlivum/corten

[8] MONAGHAN, Aidan. Grillagh Water House/Patrick Bradley Architects [photography]. In: *Archdaily*. [Accessed: 2024-11-23]https://www.archdaily.com/593806/grillagh-water-house-patrick-bradley-architects/54d01ae0e58ece5c5e0003de-6_am_-no_water-jpg?next_project=no

[9] ROSER, Max; RITCHIE, Hannah. 2023. *How has world population growth changed over time?* Our World in Data. [Accessed: 2024-11-23] https://ourworldindata.org/population-growth-over-time

[10] CONTAINER CITY. 2022. *Container City 1*. [Accessed: 2024-11-23] http://www.containercity.com/container-city-1

[11] BLANFORD, Mike; BENDER, Stephen. 2020. Upcycling Shipping Containers for Houses. Cityscape. 22(2), 95–100. [Accessed: 2024-11-23] https://www.huduser.gov/portal/periodicals/cityscpe/vol22num2/ch7.pdf
[12] BRIGHT, Danny. 2016. CARROLL HOUSE [photography]. LOT-EK. [Accessed: 2024-11-23] https://lot-ek.com/CARROLL-HOUSE-1
[13] ŠTECH, Adam. 2021. Modulární architektura aneb když se z kontejneru stane dům. *CAMP Magazine*. 10. 3. 2021. [Accessed: 2024-11-23] https://praha.camp/magazin/detail/modularni-architektura-aneb-kdyz-se-z-kontejneru-stane-dum
[14] CONTAINER TECHNOLOGY INC. 2023. *Build a School Out of Shipping Containers*. CTI. Published 12. 10. 2023. [Accessed: 2024-11-23] https://containertech.com/articles/shipping-container-schools/
[15] ANAKIN. 2009. Push Button House by Adam Kalkin. In: *Luxuo*. 26. 5. 2009. [Accessed: 2024-11-23] https://www.luxuo.com/culture/art/push-button-house-adam-kalkin.html
[16] VALDA, Vojtěch. 2021. *Off-Grid Dům "Gaia" z Námořního Kontejneru*. Publikováno 1 února 2021. Vojtěch Valda. [Accessed: 2024-11-23] https://vojtechvalda.cz/off-grid-dum-gaia-z-namorniho-kontejneru/
[17] KEBIN. 2024. *Luxusní obytný kontejner*. KEBIN. [Accessed: 2024-11-23] https://kebin.cz/
[18] COSCO SHIPPING. 2023. *CSR*. Cosco Shipping. [Accessed: 2024-11-23] https://lines.coscoshipping.com/home/About/socialResponsibility/sustainabilityReport
[19] TEU Volumes. [Accessed: 2024-11-23] https://containerstatistics.com/
[20] RODRIGUE, J.-P. 2024. *World Container Throughput, 1980–2021*. The Geography of Transport Systems. [Accessed: 2024-11-23] https://transportgeography.org/contents/chapter5/intermodal-transportation-containerization/world-container-throughput/
[21] HZ KONTEJNERY. 2024. *Námořní kontejnery ISO*. HZ containers.com. [Accessed: 2024-11-23] https://hz-containers.com/cs/namorni-kontejnery-iso/

Reviewer
Dr. Manja Kitek Kuzman, PhD – University of Ljubljana, Slovenia

Contact information
Andrea Vokřálová: andrea.vokralova@mendelu.cz