Innovations in shaping the residential and retail buildings. Functional and pro-environmental potential of shipping containers in architecture

A M Berbesz¹, I M Szefer¹

¹ Wroclaw University of Science and Technology, Faculty of Architecture, Department of Housing and Industrial Architecture, Interior Design, Rural and Landscape Planning and Visual Arts, W1/K6

E-mail: anna.berbesz@pwr.edu.pl, ilona.szefer@pwr.edu.pl

Abstract. Shipping containers are currently one of the innovative trends of shaping architectural objects. They are used to build portable and permanently set in the ground residential and public buildings. Realization with the use of shipping containers appear all over the world, i.a. single- and multifamily houses in the Netherlands, Spain, Denmark and France, the bus station in the Netherlands, the art gallery in Tokyo. Particularly, many realization with the use of shipping containers relate to housing environment due to ease of transport, speed of installation and assembly, shorten the construction time and pro-environmental potential. In contrary, conventional housing is responsible for ¼ forest logging area, absorbs 1/6 of fresh water resources and consumes 2/5 of liquid fuels and materials. The respect for the environment in the aspect of the global direction of shaping residential and retail buildings is particularly important. This paper focuses on pro-environmental, usably and economical aspects of architectural objects with the use of shipping containers on the example of Polish and world-wide realization.

1. The concept of container architecture – ideology

‘The essential element in architecture is the manipulation of space. It is essence which separates it from all other arts’

Paul Rudolph

Container architecture constitutes a contemporary type of architecture making use of steel maritime shipping containers as the primary construction element. The appearance of containers in international trade around the year 1956 facilitated transport, reduced costs [1] and enabled the global economic growth [2]. Given the modular construction allowing easy structure shaping in a horizontal and vertical direction, this solution was adopted in architecture. An ever increasing interest in containers in architecture led to a new term - cargotecture. Objects built of shipping containers offer an innovative approach to shaping the human environment, including ecological and economic aspects. The first ideas and realizations based on shipping modules date back to 1989 when Phillip C. Clark issued a patent application described as: ‘Method for converting one or more steel shipping containers into a habitable building at a building site and the product thereof’[3].
The popularity of universal container modules as building blocks comes largely from their durability and accessibility. Frames and transverse elements of containers are made of 4 mm-thick steel profiles and outer walls from trapezoidal metal sheet. Flooring is most often made of wood plates or plywood having a thickness of 28 mm. A container gate is equipped with bolt locks and the whole construction is perfectly sealed. Thanks to high-quality materials, containers can withstand any atmospheric conditions, heavy load and transportation. Their average life expectancy in extreme conditions is about 30 years, but a vast majority of typical sea containers is used for maximum 10 years. A special advantage of shipping containers is also an unlimited choice of available sizes (and easy modification): from universal/standard, to HC (High Cube), to PW (Pallet Wide), to Open Top containers, and thus they are ideal for designing building development dedicated to housing, service and commercial, office, recreational, cultural and even medical functions.

2. Legal and economic aspects of container solutions

From the legal perspective, according to the Polish regulations, a container is classified as a temporary building object ‘dedicated to temporary use over a period shorter than the container’s technical durability, designed to be moved to another location or deconstructed, not connected to the ground permanently’[3]. Such objects (meant to be used temporarily during construction works) do not require building permit, yet their deconstruction or relocation has to take place no later than 180 days after the beginning of the construction defined in the building notification. The new location of the relocated object has to be reported to a competent authority again. The current regulations do not ban a relocation within the same plot.

In the case of a permanent connection between shipping containers and the ground (provided that the anchorage method is reliable enough to guarantee the building’s durability and ability to withstand external conditions, which could change its position or even lead to its destruction), in accordance with the Polish building code, a notification or - in the case of an impact of the object on neighbouring plots - building permit is required. Based on the information obtained from competent municipal authorities, the building procedures are the same as in the case of traditional development. Similarly, as far as planning offices are concerned, there are no obstacles related to the object construction proposed.

From the economic point of view, an undeniable advantage of container-based constructions is lower building costs, easy transportation as well as a short assembly time. According to SG Blocks, a company dealing with deep-sea container adaptation on a wide scale, an application of this technology helps to shorten the construction time by up to 40% and reduce the costs even by 70% [4].

Harbours around the world store over 30 million containers since, for financial reasons, their transport without cargo to the home-port is not cost-effective. Finding a right container is not so difficult. An average cost of a single standard 20’ module (6.1 m long x 2.4 m wide x 2.6 m high) and
a 40’ module (12.2 m long x 2.4 m wide x 2.6 m high) is only about 2,000 $, with the price depending on the technical condition and delivery costs. In Poland, prices are around ~1,640 $ (6,000 zl) per piece. Maritime container adaptation in the world is popular now and yet in Poland this is a narrow building niche. One of the companies that specialize in this kind of development is Flexicube. The smallest single-storey apartment in a container costs around ~15,030 $ (55,000 zl), a large multi-storey building ~48,920 $ (179,000 zl) (net prices not including transportation and anchorage costs - established individually depending on the location). On the Polish territory, transport and anchorage of containers is in the cost range of ~273 – 957 $ (1,000-3,500 zl). In contrast, the cost of building a house in the traditional system with an area of 135 m² with an attic is, according to the web page Kalkulatory Budowlane, about ~114,786 – 125,718 $ (420,000-460,000 zl).

Figure 2. Scheme of costs of traditional building house system and house from shipping container

3. An outline of technological and material solutions in container-based objects

The contemporary container architecture, thanks to a use of modern technologies, materials, installation solutions and financial resources, allows designing objects respecting the natural environment based on the idea of sustainable growth. According to SG Blocks, each year hectares of forests are cut down for building industry purposes, 1/6th of fresh water and 2/5ths of liquid fuel resources and materials produced are used. Shipping containers substantially balance CO₂ emissions and decrease the demand for natural resources. Disposing of one container costs about 8,000 kWh of energy, whereas recycling and upcycling consume only 500 kWh. A substantial energy surplus may support the object’s operation regardless of its function.

Adaptation of shipping containers as living and service modules requires adjustments to pre-existing climate and geological conditions in a given place. Detailed information about the adaptation, insulation and installation solutions applied in the adaptation of container units is available within Residential Shipping Containers Primer (RSCP™), which constitutes a set of references to building objects based on ISO containers. It is managed by architects and designers with experience in designing and producing residential and service buildings and pop-up pavilions on the basis of containers as basic units [5].

One of the first stages of adaptation of containers as architecture objects is, apart from cutting out openings for windows and doors and adjusting the functional arrangement of the structure, proper insulation. A choice of good insulation will improve the operation of the object and ensure a proper user’s comfort. One of the options is internal batt insulation using e.g. glass wool. In this technology, it is important to choose materials with the highest density. According to NAIMA (North American Insulation Manufacturers Association), glass fibers make up over 50% of the insulation material market in the USA. Producers use 25-40% of recycled glass in the production process. Another
solution is sprayed insulation using low-toxicity materials, e.g. polyurethane foams (PUR). The blown-in technique is also used in applications of cellulose. This method minimizes the occurrence of thermal bridges in an object. Moreover, recycled cellulose allows retrieving 75% of the material and cellulose fibers exhibit resistance to biodegradation. An alternative to traditional insulation materials these days is SIP (Structural Insulated Panel) whose construction comprises facings made of OSB plates with a polymer foam insulation core [6].

Anchoring a shipping container construction to the ground may be based on various kinds of foundation. The most frequently used solution is traditional cast-in-place foundation walls and point-like foundations in the form of foundation footings. In locations where the frost line runs not deep in the ground, it is recommended to use shallow foundations in the form of a slab on the ground (slab-on-grade foundation). A use of traditional foundation no longer allows considering a container object as a temporary building object.

When adapting deep-sea containers so that they can serve as residential buildings, one may also consider alignment to the cardinal points analogous to shaping passive buildings. Then, longer walls should be situated along the east-west axis. The southern wall should face the Sun between 9 A.M. and 3 P.M. Spaces requiring illumination should be situated in the southern part of the object. Container structures can be located in places equipped with installation terminals, but they can also function as off-grid units or fully autonomous ones which requires a use of installation solutions independent from the pre-existing terminals.

4. Examples of technological objects and their functional division

4.1. Single-family housing development

An interesting example of an application of shipping containers is a house designed and built in 2012 for an art collector and his family in the Andes near Santiago in Chile. The house created by the architect Sebastián Irarrázaval consists of five 40’, six 20’ and one 40’ open-top container dedicated to serve as a swimming pool. The total area of the object is 350 m². While designing, the author’s priority was to integrate the new object with its nearest vicinity strongly influenced by the presence of the Andes, both visually and tectonically. Another key issue was to secure free air flow through the building (avoiding mechanical cooling installation) [7]. The use of cheap, durable materials which do not require maintenance has given the owner a possibility to live in a unique object and ensured low operation costs as well as a capacity of the building to age and increase the value of its materials and itself [8].
4.2. Multi-family housing development
Drivelines Studios is an object opened in September 2017 aimed at multi-family housing function, whose main construction elements are adapted deep-sea containers. The realization took place in Johannesburg (The Republic of South Africa) in the Maboneng district. It constitutes one of the largest enterprises in that region of the world utilizing container architecture. At the same time, this development direction is justified by the fact that the city plays host to one of the largest inland ports with an industrial shipping park. The realization was handled by an office specializing in widely-understood cargotecture - LOT-EK (founded by Giuseppe Lignano and Ada Tolla). The building is V-shaped with a free-access gallery and a view of the inner yard. All housing units make up 100 studio-type apartments, each having an area of 40-60 m$^2$. Additionally, the object has been equipped with three service units. Each housing unit has been designed to allow for alternative energy sources, e.g. solar panels, rainwater-based systems. The idea of the city officials is to convert the heart of the Maboneng district into a culture and commercial hub of the city. The container-based housing development is meant to act like a magnet attracting new residents through its innovative character [9]. The current apartment rent cost is 4,900 R (about 1,400 zł per month) [10].

Figure 4. Scheme of multi-family house in Johannesburg, proj. LOT-EK, author: Szefer I, based on http://www.skyscrapercity.com/showthread.php?t=542573&page=88, access: 15.03 2018.

4.3. Collective housing buildings
• Dormitory
The dormitory building Urban Rigger designed by the architecture office BIG (Bjarke Ingels Group) in Kopenhagen in 2016 is an equally inspirational example. The project aims at securing affordable halls of residence for students located in the central part of the city and docked in the harbour. The object consists of 9 maritime shipping containers situated on a floating foundation, the so-called buoy. In order to protect the structure against rising sea levels, the containers were angled so that they create an inner patio as a common space for residents [11]. Flat roofs serve three functions: one of them is a terrace, the second roof is a green area and the third has been equipped with solar panels [12]. In total, the object’s rooms, each having an area of 23-27 m$^2$, may accommodate 12 people. There is a plan according to which by 2025 next units will have been built [13]. Urban Rigger is a long-term urban project aspiring to create revolutionary and innovative system of floating student accommodation units. From the perspective of its founder and originator Kim Loudup, Kopenhagen seemed to be an ideal city given its harbour spaces and at the same time being one of the most expensive cities to live in for young people at the beginning of their higher education period [14].
Noteworthy is also an atypical and eco-friendly hotel Quadrum Ski, using modularity of containers in Gudauri in Georgia, opened in 2017. Built at an altitude of 2,200 m above sea level, it has been named a new ski resort. Thanks to its unique construction, the hotel offers amazing views of the Caucasus mountains both in single and double rooms as well as in deluxe apartments. The architects who undertook the designing work of this demanding project were Sandro Ramishvili and Irakli Eristavi [15]. The proposed interiors constitute a combination of minimalistic and luxurious solutions [16].

4.4. Public buildings

• Library
An example of a public building in which deep-sea containers have been used is a library in Batu (Indonesia) being a project of Dpavilion Architects. Eight deep-sea containers 820 USD each were utilized in the object. Batu is a small city with a growing wealth disparity. The idea of the project was to fill the education gap by providing a public library space equipped with 6,000 books and creating a clinic with a basic public healthcare service. Colours, corresponding to various functions, play an important role in the object. The blue volume is dedicated to entertainment and popular books, the red containers offer a terrace and scientific books, the yellow unit is reserved for women and the green one serves as a lobby space [17].
Mobile healthcare objects
One of the contemporary applications of container structures is their use as temporary objects relocatable to places stricken by natural disasters and serving as mobile medical units. Here, apart from aesthetic considerations and eccentric likes of the Investor, humanitarian aspects are of great importance. The first clinic based on container solutions was invented by Michal Wawrzewski, the author of the concept Clinics in a Can in 2005. M. Wawrzewski was also nominated to AAPA 2005 Physician Assistant of the year for his work on boosting the quality, optimization and accessibility of healthcare [18]. Clinic in a Can is now a firm providing medical objects adapting shipping containers to, among others, Ecuador, Haiti, Liberia, Nigeria, Sierra Leone, Kenya, the USA, the United Arab Emirates and the Philippines. The units can be delivered in the form of three functional groups. The first is connected to intensive medical care where the units have been equipped with an X-ray system, an ultrasound device, a suction machine, a portable ventilator, a multi-parameter screen and laboratory diagnostic devices, among other things. The second group is related to primary healthcare units enabling medical treatment for all people from the newborn to the elder. The third functional group is a solution for a time of an epidemic or infectious disease and provides proper quarantine spaces [19].

5. Summary
Shipping containers, as a type of modular architecture, are now a commonly used element prefabricated in the building industry. Many realizations with various functionalities have been created these days. In Poland, there is a number of firms adapting shipping containers, i.e. Carodesign, Flexicube, Weldon, etc. Currently, shipping containers are frequently used to shape the residential environment, especially single-family units. Apart from economic aspects, more extravagant objects are also produced. A pioneer of such solutions is Adam Kalkin, the author of numerous projects and books concerning adaptation of shipping containers, among other works: Quick Build: Adam Kalkin’s
ABC of Containers Architecture and Architecture and Hygiene [21]. Given the economic and technological advantages, such structures may be also used in places touched by natural disasters and military conflicts providing temporary habitable spaces as well as primary medical care. Such an implementation of container structures gives them a humanitarian aspect, opens new perspectives for applications of this type of objects in architecture and can be a solution to housing problems in the future [22,23].

References

[1] Levinson M 2006 The Box. How the Shipping Container Made the World Smaller and the World Economy Bigger (Princeton University)
[2] Palma Oliveras A A 2010 Sustainability in prefabricated architecture, A comparative life cycle analysis of container architecture for residential structures Victoria University of Wellington Faculty of Architecture and Design School of Architecture
[3] Clark P C 1989-08-08 Method for converting one or more steel shipping containers into a habitable building at a building site and the product thereof, (patent no.: US4854094A) https://patentimages.storage.googleapis.com/48/c5/f8/9183a02b6bbad5/US4854094.pdf
[4] The Act of July 7, 1994 Building Law (Ustawa z dn. 7 lipca 1994 Prawo budowlane (art.3 pkt 5))
[5] https://www.sgblocks.com/, access: 06.03 2018
[6] http://residentialshippingcontainerprimer.com/what%20is%20RSCP, access: 03.03 2018
[7] http://residentialshippingcontainerprimer.com/insulation, access: 04.03 2018
[8] https://www.archdaily.com/394846/caterpillar-house-sebastian-irarrazaval-delpiano, access: 01.03 2018
[9] http://sirgear.com/hilltop-shipping-container-house-in-chilean-the-inside-is-so-cool/, access: 27.02 2018
[10] http://www.lot-ek.com/DRIVELINES-STUDIOS, access: 04.03 2018
[11] https://www.hippo.co.za/news/johannesburgs-new-container-homes-open-in-maboneng/, access: 06.03 2018
[12] https://www.big.dk/#projects-con, access: 05.03 2018
[13] https://www.dezeen.com/2016/09/22/big-bjarke-ingels-shipping-containers-floating-student-housing-urban-rigger-copenhagen/, access: 04.03 2018
[14] http://www.urbanrigger.com/urban-rigger/, access: 26.02 2018
[15] http://www.urbanrigger.com/about-us/our-history/, access: 02.03 2018
[16] https://www.georgianjournal.ge/discover-georgia/33407-extraordinary-container-hotel-built-in-gudauri-georgia.html, access: 04.03 2018
[17] http://quadrum-gudauri.com/, access: 04.03 2018
[18] https://www.designboom.com/architecture/dpavilion-architects-amin-shipping-container-library/, access: 05.03 2018
[19] http://www.hospitalsofhope.org/images/stories/Documents/news/aapa7-30-05.pdf, access: 01.03 2018
[20] http://www.clinicinacan.org/#about, access: 04.03 2018
[21] Kalkin, A., ABC of Containers Architecture and Architecture and Hygiene
[22] Cherenet Z Sewnet H 2012 Building Ethiopia: Sustainability and innovation in architecture and design Ethiopian Institute of Architecture Building Construction and City Development
[23] Martinez-Garcia M 2014 Alternative Housing: The Shipping Container Home Center for Realtor Technology, NATIONAL ASSOCIATION OF REALTORS