SECTION 1
ANALYSIS AND DEVELOPMENT PROSPECTS FOR CONTAINER TRANSPORT

1.1 Analysis of the prospects for container transport in Ukraine

The transport industry is an integral part of the effective development of European economies, in which rail transport accounts for the largest share of the total freight transportation. According to the Centre for Transport Strategies, Ukrzaliznytsia (UZ, Ukrainian Railways) transported 174.93 million tonnes of freight in 2024 (Fig. 1.1), which is 26.5 million tonnes (18 %) more compared to 2023. In accordance with the same source, in 2024 the volume of ore transported increased to 25 % compared to 2023 and the volume of grain transported increased to 22.7 %.

Regarding export transportation, the volume of grain and ore transported by rail were 40 % and 39 %, respectively.

In 2024, the container turnover also increased to 258.000 TEU (by 28 %) compared to 2023. The most common type of freight transported in containers in 2024 was grain (46 % of the total volume of freight transported). About 20 % of the total freight turnover was ferrous metals; while oilcake ranks third (9 %) in terms of the freight transported.

The volume of export was 63 % (162.725 TEU), while the volume of import was 21.3 % (55.689 TEU).

It is expected that the container traffic volume will increase due to mobility of containers and possibility of transporting them by various transport means.

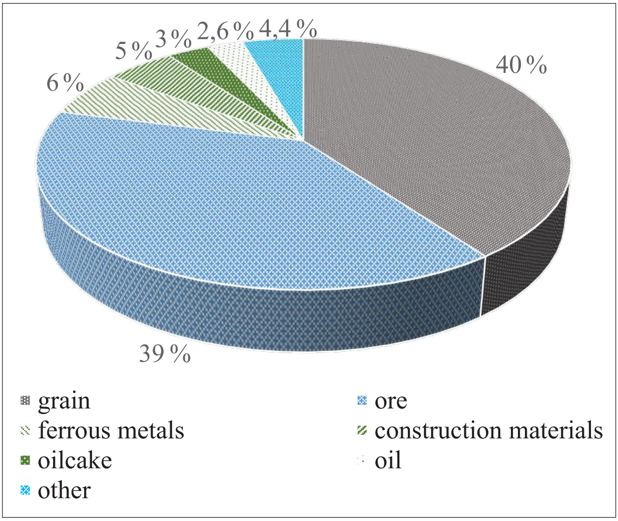

Figure 1.1 – Cargoes transported by UZ in 2024

Due to the fact that in recent years the wagon fleet replenishment has been quite low, detachable modules are being developed and put into operation; this can also be explained by the positive experience of using containers in different countries. Such detachable modules can be transported by various transport means and the demand for them has increased. They can also be adapted to transport various types of cargoes, which is rather urgent today. Thus, the designing and putting into operation of modular transport means (containers, detachable modules, etc.) is a very critical issue.

1.2 Analysis of the design features of detachable modules

The container is a transport unit designed for storing and transporting freight. Currently, there is a wide variety of container designs and their manufacturing technologies. Containers are classified by many criteria, among which one of the most important is their purpose and the load capacity.

Thus, depending on the freight type transported, containers can be divided into universal and specialized.

In terms of the load capacity, they are divided into:

– light-tonnage with the gross weight up to 3 tonnes;

– medium-tonnage with the gross weight from 3 to 10 tonnes; and

– large-tonnage with the gross weight from 10 tonnes and above.

The international classification uses the following marking for containers by tonnage and design features:

– Dry container, a standard container with a capacity of 20 or 40 feet (Fig. 1.2);

Figure 1.2 – Dry container

– HC (HQ), a standard high container with increased load capacity (Fig. 1.3);

Figure 1.3 – HC (HQ)

– Reefer or RF, a refrigerated container for perishable goods or goods, which require special storage conditions (Fig. 1.4);

Figure 1.4 – Reefer

– Flat Rack, a platform or container with an open top and without sidewalls (Fig. 1.5);

Figure 1.5 – Flat Rack

– Open top, a container with the detachable roof, which can be made of strong durable awning (Fig. 1.6);

Figure 1.6 – Open top

– Tank container, a container designed for storing and transporting bulk or liquid cargoes as well as liquefied gases (Fig. 1.7).

Figure 1.7 – Tank container

The most common in operation are universal containers designed for transporting a wide range of cargoes.

Such a container consists of a frame (Fig. 1.8) with profiled beams, namely, upper cross bearer 1, longitudinal bearing beam of the roof 6, side beam 13, lower longitudinal beam 14, and lower cross bearer 21.

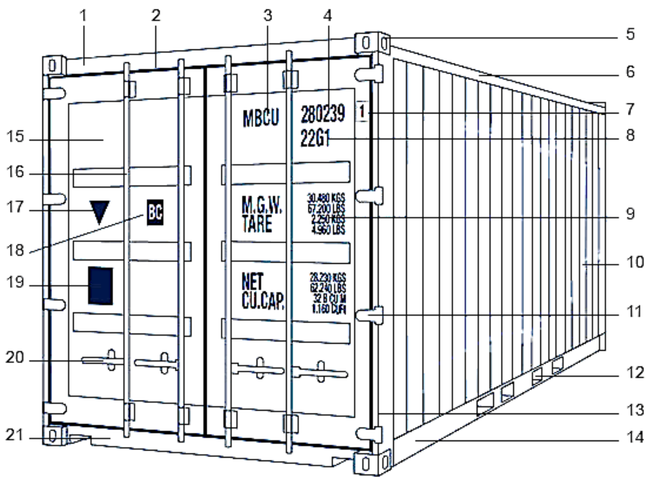

Figure 1.8 – Universal container

The container has steel corrugated panelling. The frame beams are welded and the panelling is welded to the frame. By using fittings 5 in its corners, the container can be secured on the vehicle (Fig. 1.9, a), and moved by means of cargo-handling equipment (Fig. 1.9, b).

a) b)

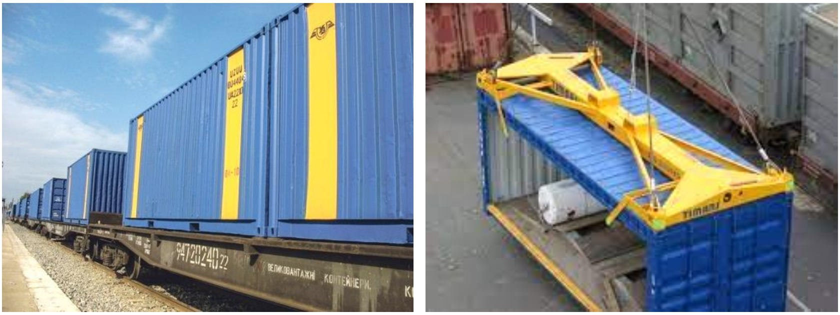

Figure 1.9 – Containers:
a) transported by rail; b) lifted with cargo-handling equipment

The container is also equipped with pockets for forklift equipment 12 for loading/unloading (Fig. 1.10).

The container is unloaded through end door 15. Rubber seal 2 is used to ensure the tightness of the container. The container also includes side corrugated grid 10, door hinges 11, locking mechanism rod 16, and handle 20.

The end wall of the container has the following marking: prefix 3, container number 4, control number 7, size and type codes of the container 8, container characteristics 9, information on the material 17, verification mark 18, information on operational approval 19.

The container is made of steel; the panelling thickness is 1.5 mm; a double coat of paint protects the panelling; the floor is formed by boards or a multilayer plywood sheet treated with a composite.

Figure 1.10 – The container moved by forklift equipment

1.3 Literature review of the container designs and their loads

When designing new containers, it is important to take into account the wide range of potential operating loads, which can be caused not only by operating modes, but also by the type of cargoes transported (packaged, bulk, bagged, etc.).

The design features of containers for long cargoes are described by M. M. Panasenko, who implemented the finite element method for determining the strength of the load-bearing elements of the container under the load from pipes. However, the issues of determining the pressure of the bulk cargo on the container walls are not studied.

The rationale for the introduction of containers to transport fruits and vegetables is given in [77]. The basic requirements for such containers and the results of their strength calculations for the main operating load modes are also presented. However, the authors do not determine the pressure forces from the cargo to the container walls.

The impact of the centre of gravity of the container on the metacentric height of the vehicle is investigated by R.S. Tsarik. The algorithm for assessing the effect of the position of the gravity centre of the container on the stability of the transport means is proposed. However, the stability of the container transported by train ferry is not determined.

The pressure forces from bulk cargo on the walls of an open wagon transported by train ferry is determined by I. M. Zemlezyn. The dynamic load that causes an additional impact on the sidewall of the wagon body is determined by differentiating the law of motion of the sea wave. However, the pressure force on the walls of the container transported by sea is not determined.

The effect of bulk cargo on the walls of the wagon body is assessed by V. I. Senko and A. V. Putiato. The load of the body is determined by mathematical and computer modelling methods. However, the authors do not determine the pressure of bulk cargo on the walls of the container transported by train ferry.

The loading and fastening techniques for rolled steel transported by rail and sea in containers are considered in [71]. The proposed solutions are grounded regarding the container stability during transportation. However, the authors do not study the stress state of the containers transported by sea.

The dynamic load of transport means, including containers, when they are transported as part of combined trains by sea is studied in [79, 80]. The conditions, under which the safety of transport means transported by sea is ensured, are determined. However, when determining the stress state, the pressure of bulk cargo is not taken into account.

The design features of a container for fruit and vegetable products are highlighted by N. N. Ibragimov. The requirements for the proposed load-bearing structure of the container and the results of strength calculation for the container under the main operating loads are also presented. However, the loads that can act on the container transported by road are not studied.

The inertial loads acting on the container under operating modes are described in [94]. The calculated loads are taken into account when determining the main strength indicators of the container load-bearing structure, and under the considered load diagrams, the strength of the container is ensured.

The main strength indicators of the components of the load-bearing structure are also studied in [91]. The calculation is carried out for a 1AA heavy-duty standard container. The research conducted have made it possible to formulate recommendations for the safe operation of the container. However, these strength calculations do not take into account the loads that act on the container transported, therefore, its operational strength cannot be assessed.

Publication [70] provides an analysis and describes the design features of load-bearing structures of ISO containers. The potential load diagrams for their load-bearing structures in operation are considered. The resistance of the structure to external loads is estimated. A solution on possible ways to improve containers is also proposed. However, the authors do not consider the issues of introducing the hopper-type container structures.

The longitudinal dynamic loads acting on the container placed on the flat wagon are determined in [88]. A methodology is proposed that can be used to assess the impact of container displacements on the dynamic load.

The dynamic load of the container placed on the flat wagon is also carried out in [72, 78]. The shunting collision of a flat wagon loaded with 20-foot containers is taken into account. The authors proposed technical solutions to reduce the dynamic load of the containers and the flat wagon by introducing flexible connections into their load-bearing structures. However, the considered publications do not cover the load of container transported by road.

The prospects for detachable bodies operating on the principle of containers are described in [65]. The study is based on China's transport infrastructure. The authors give the requirements for swap bodies which guarantee the higher efficiency of the transport system. However, the authors do not cover the prospects for designing hopper containers, which can provide transport profitability.

The study of the stress-strain state of the body-container of variable volume is given by D. V. Mishuta, who determined the highest structural load areas. The results of the experimental determination of the structural strength of the container are also presented. The author investigates the transverse skew of the container at insignificant load values. However, the issue of improving the container design taking into account the defined load areas is not studied.

In their research D. V. Mishuta and V. H. Mykhailov highlight the peculiarities of using simplified methods for measuring the stress-strain state of a variable-volume container body. They propose the load diagram and the method for testing container bodies for transverse and longitudinal tilt.

The main strength indicators of the container body lifted by crane and moved with a drag are determined by V. Yeryomin and L. Semennikov. The theoretical determination of strength indicators is carried out in APM WinMachine. The strength is experimentally studied by means of the method of electrical strain gauging. However, the issue of improving the container structures in order to expand the range of cargoes transported is not given.

The dynamic loads acting on containers placed on the flat wagon during shunting collision are determined in [86] with mathematical and computer modelling. The built models are verified according to the F-criterion. The study includes two cases: with the gaps between the fitting stops of the flat wagon and containers and without the gaps.

The dynamic loads acting on tank containers placed on the flat wagon during shunting collision are determined in [2]. The elastic-dissipative connections are used to simulate the interaction of tank containers with the flat wagon. The parameters of the shock-absorbing device are determined for the case when the bulk cargo does not move and the gap between the fittings and the fitting stops are maximum.

However, the studies do not cover the issues of the improved strength of the load-bearing structure of the container under the operating load modes.

The issue of the improved load-bearing structures of containers to reduce the dynamic loads under operating conditions is covered in [37, 38]. The use of flexible connections between container fittings and fitting stops of the flat wagon has been proposed and scientifically substantiated. The results of the strength calculation for the improved container are given. The maximum equivalent stresses that act on the improved container are almost eight times lower than the stresses in a typical container design.

Study [45] describes the dynamic load of containers (dry cargo and tank containers) under excessive load modes, namely shunting collisions and transportation as part of combined trains by train ferries. The mathematical models for the determination of the dynamic loads acting on the containers in these operating modes are constructed. The measures to improve the container strength by introducing flexible connection in their design are proposed. These solutions are confirmed by computer modelling and physical experiments. However, the author does not consider the issues of container improvements in order to expand the range of goods transported.

The strength of a heavy-duty container is determined by S. A. Kostrytsia [35], who considers the container as a spatial plate-and-rod system; the strength calculation is implemented according to MCE. The theoretical studies make it possible to formulate recommendations for the choice of parameters of container's elements, as well as the way to secure them on flat wagons. The author propose also measures to reduce dynamic loads on containers under operating conditions. However, the issue of how to improve the container design so that to increase its operational efficiency by expanding the range of cargoes transported is not studied.

The issues of determining the temperature effect on containers and their storage capacity are also quite relevant and studied by scientists in Ukraine and other countries.

Thus, the effect of corrosion and temperature on the strength of the lateral shell of the fuel tank is studied in [92]. It is taken into account that the tank is under pressure. Some recommendations for higher durability of the fuel tank under operating loads are given on the basis of these studies. However, it does not deal with the issue of how this fuel tank can be transported. That is, this container can be used to store cargo, which reduces its demand in operation.

The results of tests on metal and composite containers under the impact of low temperatures are covered in [76]. The container types advisable for transporting these cargoes, taking into account the low ambient temperature, are presented. However, the effect of high temperatures from transported goods on the strength of containers is not considered.

Study [75] deals with the strength of an open top container loaded with high-temperature cargo, namely pellets with a temperature of 700 °C. The peculiarity of the container is the heat-resistant composite panelling. This container has a solid-sided body, which requires special lifting and transport equipment for unloading, which increases its operational cost.

The improved hopper wagon for hot pellets and agglomerate is considered in [74]. It is proposed to use a heat-resistant composite panelling to reduce damage to the load-bearing structure components of the hopper wagon. The results of the calculations confirm the feasibility of the proposed improvement. However, the issue of higher efficiency of containers by their adaptation to the transportation of high-temperature cargoes is not considered.

The heat transferred through the tank of a tank container is studied in [99]. The study describes the simulation of the heat flow running through a multilayer plastic support. However, the authors do not cover the issue of determining the temperature load of the dry cargo container.

The theoretical and experimental study of the stiffness of the improved container structure is given in [100]. The calculation is carried out in ABAQUS. Based on the results of the calculations, the optimal dimensions of the container elements are determined.

The improvements for the container to increase its operational efficiency are considered in [90]. The requirements for the design and manufacture of containers are also presented. An improved container design is developed. The results of the strength calculation prove the feasibility of the technical solutions.

However, the proposed container designs do not allow transporting high-temperature cargoes.

1.4 Patent analysis of the existing dry cargo containers

In order to analyse the existing container designs, a patent search was conducted using the database of the Ukrainian Institute of Intellectual Property (Ukrpatent). Based on the search results, container designs used for transporting goods by rail have been selected.

Patent [8] deals with the design of a large-tonnage container with an open, roofless body consisting of sidewalls, bottom, sliding beams, external frame beams, end walls, one of which is a door, and the other has hooks for lifting and transporting the container; the sliding beams are rectangular and close by the channels with vertical walls. The U-shaped bottom, which is rigidly closed with two sliding beams, is made of thickened rectangular plates which close the sidewalls of the body from side to side and are welded; their joints are located along the axes of the frame beams rigidly connected to the sliding beams. The vertical sheets of the sidewalls are made of rectangular plates connecting with each other along the axes of the frame, each of them is made with a trapezoidal stamping of a rectangular type, with the height of less than or equal to the height of the frame. The rectangular sliding beams are made of channel bars closed on the open side by a vertical wall of a specified thickness, which is usually equal to the thickness of the channel bar wall. The rectangular U-shaped sliding beams are made of two corners and the bottom sheet closed from above.

Patent [19] describes the open container design with U-shaped cross bearers with elastic elements inside, covered from above with a horizontal plate, and with brackets on the U-shaped profiles to limit the displacement of the horizontal plate in the vertical plane; elastic elements are placed in the corner fittings of the container, the panelling of the sidewalls and end walls has a convex profile and is attached to the vertical poles.

The disadvantages of these container designs are that they can be self-unloaded at loading/unloading terminals.

Patent [51] describes a modular cargo unit with at least one rigid container for cargo and an elastic hopper, which is additionally equipped with a detachable container connected to it from below.

The design of the modular cargo unit presented in patent [47] consists of a platform-type ISO container equipped with a detachable cargo module. The cargo module consists of a body equipped with at least one hydraulic cylinder with an open sidewall or opening sections, which is mounted on the container module and can tilt to the openable sidewall. The modular cargo unit can be installed on a transport module – a fitting or universal flat wagon, an open wagon, or a semi-trailer for transporting containers; it can be detached in the loaded state for further intermodal combined transportation. The platform-type ISO container is 20 feet long; its body is equipped with a removable awning, detachable roof, or a roof with loading hatches.

Patent [52] describes a modular cargo unit with a platform-type ISO container module, equipped with a cargo module in the form of lodgement for placing and securing cargo, in particular ISO containers or swap bodies with end doors. The lodgement is mounted on a platform-type container; it can rotate in the horizontal plane and be fixed in the corner positions, which is needed to orientate it during transportation, side loading/unloading from ISO containers or swap bodies with end doors. The platform-type ISO container is 20 feet long.

The disadvantage of these modular cargo units is that they cannot transport high-temperature cargoes.

Patent [18] describes the design of the specialized large-capacity metal container that can be used in construction industry, agriculture and public utilities for storing and transporting bulk and small cargoes (sand, construction debris, agricultural products, etc.) on vehicles (trucks, trailers, semi-trailers) with a load capacity of 6–30 tonnes, which are equipped with a hydraulic hooklift hoist for loading/unloading and transporting the detachable containers. The container is made of sheet and profile metal.

On the front wall it has a hook clamp assembly placed symmetrically relative to the vertical axis of symmetry to connect the car hook. The hook clamp assembly includes lower poles, to the upper ends of which are attached with their lower ends, ribs inclined to the centre, as well as jaws, to the upper ends of which are attached a ring (a loop for attaching the hook). The jaws are attached to the upper ends of the inclined ribs. The upper poles are also attached to the upper ends of the lower poles so that each of them is on the same vertical line as the corresponding lower pole (the upper poles are an extension of the lower poles). In addition, a horizontal rib is attached to the upper ends of the lower poles. The rear wall is a double-leaf door attached to the side hinged walls. The door is equipped with a locking device that has a handle, an upper hook and a lower hook that clings to a pin on the outside of the bottom. The sidewalls are attached to the bottom with their lower sides, and a square-section pipe is attached to the upper edge of the walls.

Slings are attached on the outside of the sidewalls for lifting and moving the empty container. Hooks are used on the side and front walls, as well on as the doors, to attach the protective tarpaulin cover. Metal profile stiffeners are attached on the outer sides of the sidewalls, door leaves and bottom. Two rollers are used to move the container when loading it onto the vehicle. All joints in the container are welded. The disadvantage of this container is that it cannot be used to transport high-temperature cargoes.

The design of the container for transporting bulk cargo is proposed in patent [23]. The container comprises a body with sidewalls, supports installed on the outside of the opposite side to keep the container stable during unloading, and closed guide channels located vertically on the inner surface of the opposite sidewalls and designed for the directed and free movement of flexible rods of the door locking mechanism.

The door locking mechanism consists of flexible rods, the branches of which are passed through closed guide channels and fixed to the bottom leaves on one side, and on the other side to the link under the hook of the lifting mechanism, which ensures simplicity and reliability of the design. Brackets are used to connect the bottom leaves to the flexible rods. Thus, the leaf locking mechanism is reliably protected from mechanical damage and abrasive wear. The transportation and the loading/unloading of the container is carried out as follows. The flexible rods are used to transport a loaded container, which also serve as a sling for the load-lifting device. However, the design of this container is highly specialized, as it only allows the transportation of bulk cargo.

The design of the heavy-duty container is described in patent [28]. The invention relates to a heavy-duty container in the form of a stackable ISO container and can be used for transporting bulk materials, such as fluid construction materials, construction rubble, debris, industrial waste, etc. The author set the task of making it possible to use the container as a means of transport for short and medium distances. This task is solved by a heavy-duty container in the form of a stackable ISO container with a movable hook receiver on the front wall, with movable support rollers located under the bottom of the container in the area opposite to the front wall, and with two U-shaped upper straps located at a distance from each other, forming fork pockets and running along the entire width of the container and welded to the bottom of the container; guide strips are located under the bottom of the container and connected to mounting supports. In the corner areas of the container, the support rollers are arranged in such a way that they can rotate so that in the retracted position they are located within the ISO containers, and in the extended position they are located below the ISO corners, each fork pocket consists of the upper belt passing through the guide rails, longitudinal beams, and a lower belt. Moreover, between the guide rails and on the container frame profile, there are means to reinforce the stiffness in the areas of the fork pockets. However, this container is highly specialized.

Patent [9] describes a universal container for transporting and storing piece goods, mainly lightweight, packaged goods (on flat pallets) in semi-rigid containers. The container comprises a frame, walls made, for example, of corrugated sheets, a bottom, door locking and sealing devices, gripping devices for loading/unloading, and shelves located inside the container. The frame is additionally reinforced, and each shelf can fold and contains supports, a support platform, upper and lower cams and poles; the body of each of the poles has upper and lower guides connected to each other by a tension spring in the loaded state; the upper cams are fixed in the upper part of the container frame and hinged to the upper guides of the poles; the lower guides of the poles are hinged to the lower cams, to which a support platform is cantilevered; in the lower horizontal position the support platform is designed to rest on supports that are fixed to the reinforcement of the frame of the sidewalls of the container; the length of the shelf elements is selected so that in the folded position the shelf is located parallel to the upper part of the container body and is secured during the loading/unloading of the container.

Patent [63] describes a transportable block container that consists of a floor, walls, and ceiling. It is a welded structure consisting of a metal frame made of rolling closed-section profiles, covered on the outside with profiled sheet metal on the walls and metal sheet on the ceiling and floor. The inner panelling is a moisture-resistant plasterboard sheet on the metal frame made of CD, UD, UW profiles; the floor covering is made of linoleum laid on plywood flooring, and 100-mm thick insulation is provided between the exterior and interior panelling of the walls, ceiling and floor.

Patent [22] describes a container for transporting bulk cargoes. It consists of a flexible insert with fasteners to attach it to rigid parts of the transport means, with at least one loading arm located in the upper part of the container. The flexible insert has the shape of trapezoidal prism, the width of which increases at least towards one loading arm.

Patent [62] describes the container for transporting bulk cargoes, which is equipped with a flexible insert with fastening elements to attach it to the rigid parts of the transport means, and with at least one loading arm located in the upper part of the container. The flexible insert has an impermeable film attached, at least partially, to the flexible insert on its inner side.

The disadvantages of these containers are that they cannot be self-unloaded at loading/unloading terminals.

The design of the hopper container with a parallelepiped-shaped body and a bottom made of bent channels, is of interest [33]. The bottom of the body has unloading windows connected to a lock, and the bottom of the body has splitters with knives attached to their side surfaces, which are adjacent to the carriage installed under the splitters that can move along the longitudinal axis of the body. In addition, the hopper container is equipped with a hinged shackle located on the carriage, bumpers installed near the front and rear walls of the body, and a reinforced opening made in the roof of the body.

Patent [31] describes the container for transporting and storing products, which has a bottom and at least two opposite hinged sidewalls, each of the sidewalls has a hinge pin in a pocket; the pocket has a recess elongated in the direction perpendicular to the bottom of the container and the hinged sidewall can move from the lower end position, in which the sidewall is adjacent to the container, to the upper end position perpendicular to the container bottom. It is provided that when the sidewall is lifted from its lower end position, i.e., when the hinge pin rotates in the pocket, it undergoes a directed translational movement so that the sidewall moves upwards into the position perpendicular to the container bottom.

The container designed for transporting bulk cargo by road, sea and rail is described in patent [26]. The container comprises a parallelepiped-shaped body formed by a roof, floor and sidewalls, loading hatches in the roof of the body, and unloading devices in the floor of the body. The unloading devices are designed as funnels, the upper large inlets of which cover practically the entire floor of the body, and the lower smaller unloading openings have latches controlled by a mechanical drive.

The modular container complex with a container module in the form of an ISO platform container, which is equipped with a detachable loading module connected to it, is described in patent [53]. The loading module is designed as a box with a bottom and an open top, placed upside down on it.

The disadvantage of these modular loading units is that they cannot transport high-temperature cargo.

Patent [64] describes the universal container which has a rectangular structure that fully matches the dimensions of ISO containers. It is made of metal and composite materials and consists of front, rear and sidewalls, corner fittings, roof and wall panels, doors, and a fastening system. The walls of the container are solid, smooth, equipped with load-bearing poles and beams; there are two hatches on the roof panel, and additional cargo fastening points are provided inside the structure.

The hopper container is described in patent [34]. It has a parallelepiped-shaped body, the bottom is made of bent channels and have unloading windows connected to the lock. Cutters are installed on the bottom of the body, the inner sides of which have knives adjacent to a carriage installed under the cutters, which can move in the direction of the longitudinal axis of the body. The hopper container is also equipped with a drag link on the carriage, bumpers installed near the front and rear walls of the body, and a reinforced opening made in the roof of the body. The technical result is fast and simple loading/unloading of bulk cargo, as well as lower operational cost and elimination of spoilage and spillage of cargo.

The modular container complex with a container module in the form of an ISO platform container, equipped with a detachable cargo module, is described in patent [54]. The cargo module is designed as at least one container with doors facing the longer side of the platform-type ISO container.

The metal container with soft unloading for bulk cargo with a parallelepiped-shaped body formed by a roof, floor and sidewalls, loading hatches made in the roof, is described in patent [46]. It has a removable hopper-receiver for bulk cargo, which can be discharged through a lower opening located above the unloading opening of the container, made in the upper floor cover and has a soft unloading mechanism with protective petals and an unloading arm, which can be open by pulling the pin out of the petals along the lower perimeter of the unloading arm at the ends of the petals using the tape.

The disadvantage of these modular cargo units is that they cannot transport high-temperature cargoes.

The container for transporting products, mainly in the form of coils, which includes a floor, two sidewalls, a front wall, two doors and a removable rigid roof with a fastening mechanism is described in patent [29]. The floor is equipped with swivel supports with a fastening mechanism, which are grouped into at least one pair, located along its longitudinal axis of symmetry, opposite each other. In its closed position, the supports form a horizontal plane with the floor, and in its open position, they form a chute. The swivel support, which forms part of one pair, consists of a folding part connected to the support of the folding part, or a wide folding part connected to the support or the wide folding part. The folding part and the wide folding part are movably connected to the floor by means of hinges located on one of the edges; the folding part and the wide folding part are movably connected by the second edge, by means of hinges, to the support of the folding part or the support of the wide folding part. The floor is provided with two grooves parallel to each other, which run along its entire length on both sides of the longitudinal axis of symmetry and below the supports of the folding part or the supports of the wide folding part in a horizontal position.

The high-capacity container in the form of a metal body, which contains a bottom, a removable cover with cargo hatches, two sidewalls, an end wall and a standard door, the second door for unloading bulk cargo by gravity is described in patent [10]. However, these containers cannot be used for transporting high-temperature cargoes.

The container for storing and transporting food products, in particular bananas, is proposed in [20]. It has a parallelepiped shape and is made of rigid cellulose material. The container has an additional polymer packaging in the form of a bag inside. However, the design of this container is highly specialised.

Patent [30] describes the container for bulk cargo with a body consisting of side and end walls, a bottom, unloading openings, and a lock. The bottom of the container is formed by saw-like sections and pockets for a forklift, above which there are fairings. The saw-like sections are formed by fixed beams and alternating rotating covers, the axis of rotation of which is parallel to the longitudinal axis of the container. The upper parts of the rotating covers are connected to the upper parts of the fixed beams, and the lower parts of the rotating covers are hinged to rods, which are connected by lever-hinge mechanisms to a horizontal longitudinal shaft on which the fastener is located. The unloading openings are formed by fixed beams, end walls and fairings.

The container for bulk cargo with a body consisting of side and end walls, a bottom, unloading openings, and a fastener, is proposed in patent [24]. The bottom of the container is formed by saw-like sections and pockets for a forklift, above which there are fairings. The saw-like sections are formed by fixed beams and alternating rotating covers, the axis of rotation of which is parallel to the longitudinal axis of the container. The upper parts of the rotating covers are connected to the upper parts of fixed beams, and the lower parts of the rotating covers are hinged to rods, which are connected by lever-hinge mechanisms to a horizontal longitudinal shaft on which a lock is located. The unloading openings are formed by fixed beams, end walls and fairings.

The container for storing and transporting grains, legumes, and oilseeds in bulk, which is a rectangular structure with a body made of metal and composite materials and equipped with load-bearing poles and beams with the rear and sidewalls, doors, roof panels and a platform for placing cargo, and a fastening system is described in patent [21]. Inside the structure, between the sidewalls made of metal and/or composite sheets (or panelled with them) with a corrugated profile, there is a wall (partition) installed closely to the inner surface of at least one of the sidewalls. Its width is 50–100 % of the internal width of the container and its height is 20–95 % of the height of the container.

Patent [25] describes the container for bulk cargo with a body formed by a floor, two end walls and two opposite sidewalls, unloading devices made in the floor of the body. The floor is divided lengthwise into three equal parts, each part has unloading devices in the form of louver blocks designed to interact with fixed inclined walls made of bent metal sheets and placed at an angle to the horizon, which can form vertical openings along the container. The louvers are controlled by a rotary mechanism and can be fixed with a lock.

Patent [11] describes the heavy-duty container designed as a metal body with a bottom frame, a roof with loading hatches, two sidewalls, two end walls, one of which has a discharge hatch. The sidewalls extend beyond the bottom and are designed as a three-dimensional spatial frame structure made of pipes, which, in its vertical section, has the shape of an isosceles trapezoid, with the upper and lower parts of the wall positioned at an angle to the middle vertical part of the sidewall. The width between the extreme vertical parts of the sidewalls is 3.000 mm. The loading hatches on the roof are made in the form of rectangles along the container body, each hatch has a length equal to $L_л = 1\ /4L_k$, where L_K is the length of the container.

Importantly, the design of these containers does not allow them to be self-unloaded at loading and unloading terminals.

The container for transporting grain, consisted of a parallelepiped-shaped body with an opening in its upper part, a bottom, unloading windows located in the lower part of the body and connected to a fastener on the outer side of the body, and a hinged shackle, are described in patent [27]. According to the utility model, the container additionally equipped with a dust prevention device fixed in the opening, as well as a device for uniform distribution of the product located below it. The bottom of the container is a framed structure with unloading windows made in the form of pyramidal funnels sealed along their perimeters; they are adjacent to a slide valve which is installed under the pyramidal funnels and can move toward the longitudinal axis of the body, and a hinged shackle is fixed on the slide valve.

The heavy-duty container made in the form of a metal body with a bottom frame, a roof with loading hatches, two sidewalls, two end walls, one of which has an unloading hatch located in its lower part, the frames of the end walls in their upper and lower parts are equipped with corner fittings, is proposed in patent [12]. The sidewalls are extended beyond the bottom frame and made with a curved bend on the outer side, which, in vertical cross-section, has the shape of a circular arc. The sidewalls on the inner side are equipped with reinforcing elements in the form of frame beams.

Patent [13] describes the heavy-duty container in the form of a metal body with a bottom, a roof with loading hatches, two sidewalls, two end walls, one of which is equipped with a standard door, and the other with an unloading hatch located in its lower part, the poles and beams of the end walls in their upper and lower parts are equipped with corner fittings. All corner fittings are 1.3 times wider than standard fittings, the outer sides of both sidewalls together with the poles protruding outward by the increased width of the fittings, and the internal width of the container being 2.430 mm, the external width at the fittings are 2.550 mm.

Patent [32] describes the container complex which consists of a container with a rigid body, corner fittings, openings in the floor, and internal container equipment installed therein in the form of hoppers with inlet and outlet openings located above the openings in the container floor, and their latches. The unloading openings in the container floor are located so that when it is installed with fittings on the fitting stops of the fitting platform, which has openings in the frame, they are located above them.

Patent [14] describes the heavy-duty container in the form of a metal body with a bottom frame, a roof with loading hatches, two sidewalls, two end walls, one of which has an unloading hatch; the sidewalls extend beyond the base of the bottom frame and are designed as a three-dimensional spatial frame structure made of rectangular cross-section tubes, which in vertical cross-section has the shape of an isosceles trapezoid, the upper and lower parts of the wall are located at an angle to the middle vertical part of the sidewall. The longitudinal lower beam of the bottom frame is made of shaft, and the cross bearers are made of I-beams.

However, these container designs are not adapted for transporting high-temperature cargoes.

The patent analysis conducted has made it possible to conclude that most existing container designs are highly specialised or intended for transporting cargoes with similar physical and chemical properties. In addition, the container designs analysed do not allow for the transport of high-temperature cargoes.

Conclusions to Section 1

1. The statistical data on cargo transportation by rail has been analysed. According to the data of 2024, the largest percentage of cargoes transported was grain and ore, respectively, 40 % and 39 %. In 2024, the container turnover increased by 28 % compared to 2023 (up to 258.000 TEU).

The most common types of goods transported in containers in 2024 were grain (46 % of the total volume of goods transported), ferrous metals (about 20 %), and oilcake (9 %).

The analysis indicates that modular transport vehicles are expected to be used for cargo transportation, due to their mobility and the lack of replenishment of the rolling stock in recent years.

2. The design features of containers by type of cargo transported and handling technology were analysed. The design of a modular transport vehicle was considered on the example of the universal container. The features of container transportation and loading/unloading operations are presented.

3. A literature review of issues related to the design and determination of container load capacity was conducted. It was found that these issues are quite relevant and have been addressed in a considerable number of publications in Ukraine and other countries. It has been found that one of the main directions for improving containers is to strengthen their structure or introduce new materials.

4. A patent analysis of existing dry cargo container designs was conducted. It was found that the main way for improving their designs is to increase the stiffness of the frame, use more efficient materials, change the processing technology, etc. However, the issues of the introduction of energy-absorbing materials into their design, as well as the creation of modern designs of detachable modules for transportation of a wide range of cargoes are yet to be studied.