Mirosław Antonowicz
Dr
Członek Zarządu PKP S.A.,
Akademia Leona Kuźmińskiego w Warszawie

Henryk Zielaskiewicz
Dyrektor Biura Logistyki PKP S.A.,
Akademia WSB w Dąbrowie Górniczej

DOI: 10.35117/A_ENG_19_06_05

Intermodal terminals, aspects of the selection of design solutions

Abstract: The authors present trends of changes in intermodal transport in Poland and the importance of the development of linear and point infrastructure to maintain favorable trends in the growth of this segment of cargo transport. An important element of the point infrastructure transport system are intermodal terminals. Appropriate selection of locations for future transport infrastructure has a significant impact on the course of the investment process and the economic success of the project. An important stage is the stage of investment planning and development of the concept, adjusting the object to the anticipated cargo protocol taking into account time factors.

Keywords: Intermodal transport; Transport system; Intermodal terminal; Design process

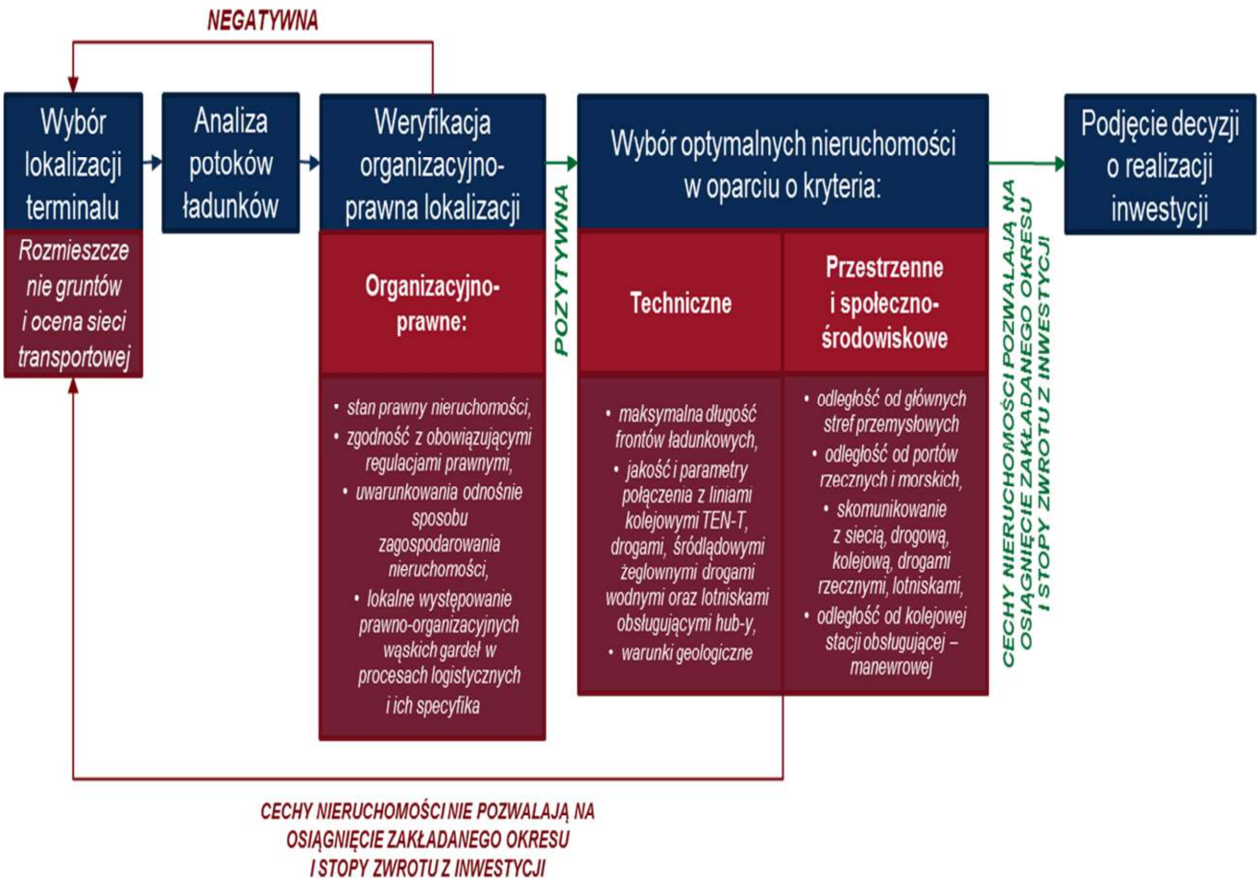
Introduction

Current trends in the transport of intermodal units indicate that this cargo segment will be in an upward trend in the coming years. The analysis of statistical data shows the scale of development: in 2010 it was 440 thousand tons, and after eight years, in 2018, the volume of transported mass was already 17.02 million tons. The number of statistical TEUs in the same period increased from 584 thousand TEU to 1894 thousand TEU. The number of transported intermodal units in the period of the eight years has increased from 354 thousand UTI to 1259 thousand UTI in a year. Transport of intermodal units connects individual transport branches in supply chains using their best features. Finally, they solve a number of problems in the functioning of transport systems, which has a bearing on the flow of streams. Optimistic transport forecasts affect the development of terminal infrastructure, which should work in a network system. Infrastructure development must precede the development of transport in relation to the needs, and thus exceed the transport needs. This is due to the long period of building infrastructure. Infrastructure standards, in turn, should ensure high-quality service for all loads, including those from the group of hazardous materials. Like every product or service, intermodal transport also goes through its "product life cycle". It can be considered that currently in Poland participants of the intermodal market meet with the phase of dynamic growth of their services, but this state will not be permanent. With optimal economic and legal conditions, it should be assumed that after reaching a certain ceiling, both on the demand and supply side, there should occur so-called maturity phase characterized by growth, but with much lower dynamics or worse conditions - even stagnation. This is a dangerous moment for entrepreneurs, because the next phase of the life cycle may be a decrease in transport. In order to avoid this unfavorable period, it is necessary to take actions that will enable further development of products related to intermodal transport. One of the important conditions is an adaptation to the growing streams of cargo, both linear and point infrastructure, i.e. various types of terminals, new organizational solutions, wagon and traction rolling stock, and IT support technologies.

The development of railway transport is not supported by the decreasing number of sidings - in 2002 there were more than 2,000 of them, currently, it is around 1160. Due to the large construction costs and subsequent operation of railway sidings and the difficult procedure of obtaining safety certificates, enterprises do not choose this form of transport service. Road transport due to the much better-developed line infrastructure and several times lower fees for access to it can offer a lower price of the freight, and at the same time is more flexible in organizing the transport process. Due to the current conditions resulting from the state transport policy, including the number of access rates to transport infrastructure for individual modes of transport, the economic viability of the unit mass of cargo transported by road transport is several times higher than in rail transport. This dependence mainly applies to small cargo streams. Bearing in mind the large deficiencies of drivers in transport companies and the conditions of their work, especially on several-day routes of cargo transport, growing congestion, and therefore delays in the delivery of cargo, new organizational solutions are needed. Large car transport companies should cooperate in the development of intermodal transport, especially on routes with significant distances. One train consisting of 30 wagons transporting semi-trailers, covering a distance of 900 km, can bring about 500 - 600 hours of drivers' work savings, which is equivalent to four employees per month. With such an organization it is imperative that the company has at its initial and final stretch of the route a sufficient number of tractor units. In this transport segment, the most universal is the transport unit which is the container. It created a number of possibilities for its use thanks to an easy method of transshipment from one means of transport to another or the possibility of damaging it during storage. The necessity of its widespread use resulted from the need to optimize overall costs, transport time and availability of larger parts loads. Optimal adaptation to the type of cargo transport provides different construction solutions for this unit. The unified loading unit allows for the construction and production of necessary means of transport, reloading and storage by various companies. Observing the global tendencies of containerized cargo flows, i.e. further dynamic development of containerisation in trade between the European Union, Asia (China, India) and the United States as well as Brazil - a rapidly growing trend in the recent past, an important area of activity is establishing business relations in order to implementation of projects aimed at servicing the flows of cargo, especially in the aspect of creating so-called sea - rail connections. Another strategic direction is also the development of transport using the so-called New Silk Road (NSR). The streams of intermodal units in this direction are growing at a rate of around 20% / year, but the scale of these transports is several times lower than in sea transport. In 2017, the volume of intermodal transport on all NSR routes amounted to approximately 380 thousand TEU, while our ports in the same year transhipped in total 2385 thousand TEU and in 2018 it was already 2834 thousand TEU. It follows that the flows of cargo through Polish ports are several times greater than those that pass through our eastern border crossings. If there are no significant economic breakdowns, further development of intermodal transport in Poland is inevitable. It is expected that for the next 3 - 4 years its growth will be at the level of several percent annually, and then the growth will stabilize and will be at the level of 5-6% per annum. In our country, this figure is at the level of 10.33% in transport performance and 6.80% in the volume of goods. Considering that in Western European countries, on the intercostal transport market, on average, around 15 - 16% of intermodal transport is a factor and that this transport segment is growing, and four pan-European transport corridors and three EU rail freight corridors pass through our country: 5, 8 and 11, this segment has a good chance of further development, however, a well-prepared line and point infrastructure is needed. Without a properly prepared infrastructure, this large flow of load will burden our roads.

The process of preparation and implementation of intermodal terminals - selected issues

There are currently 36 intermodal terminals of various sizes and technical condition in Poland. Many of them are makeshift, adapted for this purpose generally available for loading and unloading squares. They do not provide full service and adequate quality of services. Most of the intermodal terminals that meet European standards were made with the support of financial support in the financial perspective 2004-2006 and 2007-2013. In the current perspective, 6 projects received financial support: one for the construction of a new terminal and five related to the expansion of existing terminals. The basic directions of cargo streams and the current arrangement of intermodal terminals and cargo generators, which are special economic zones, technology parks and storage centers around larger cities, allow identifying locations where new intermodal terminals or railport terminals should be created. Criteria for choosing a location for an intermodal terminal can be divided into several areas, however, the most important will be organization-legal, technical, socio-environmental and the most important which is the market.



1. The process of selecting the location for the intermodal terminal. Source: Own study

The high costs and long-term construction period of the terminal infrastructure, from the selection of the location to the completion of the investment, require that the process be preceded by a series of preparations - pre-project activities and investment preparation phase. The diagram below shows the course of the investment process.

2. The course of the investment process of building an intermodal terminal.
Source: Own study

Each stage of the process is important and ultimately influences the choice of nature and work technology, size, and parameters of the planned object. The concept of logistics infrastructure network in Poland should constitute a planning document for a large operator, showing both the so-called Optimal as well as potential sites for the creation of logistics infrastructure, for which it is necessary to conduct more detailed analytical research. It should illustrate the initial technical assumptions and intended use of the planned infrastructure resulting from market needs and communication conditions. The concept of the chosen location presents an idea for the development of a given area, often multi-variant with more detailed market analyzes and technical conditions as well as legal and organizational locations. The choice of the target and optimal construction model, and then the terminal work, usually takes place at the stage of creating a business plan or feasibility study, as well as a functional and operational program (PFU). These are documents on the basis of which a decision is made to implement the investment process, therefore they show not only the shape of the target infrastructure but above all the economic and financial aspects of its creation.

When developing the concept of intermodal terminal operation, we take into account its technical and organizational aspects, which should be adapted to the forecasted cargo flows. The selection of the size of the storage yards, type of surface, length and number of tracks, type of loading equipment, and finally the method of regionalisation the squares with their area according to their intended use (dangerous, depot, customs, temperature control) and the layout of internal roads, as well as car parks, do not affect only technical conditions and the layout of the environment, but first and foremost the size and type of forecasted streams of cargo, as well as the profitability of their service, and thus the commercial conditions. Elements supporting the assessment of the relation of the size of the stream in relation to the concept of terminal management are calculated indicators of the UTI handling capacity and the components of the facility. Since the terminal organization's handling capacity is also influenced by the adopted organization and trading conditions with customers, it is necessary to consider not only the expected intensity of cargo streams but above all the expected average storage time of units and their generic structure (20 ', enumerating capacities and reloading capacities of the future infrastructure) 40, temperature-controlled, semi-trailer) affecting the occupancy of the square. It should also take into account the distribution of containers on the square due to the type of cargo, e.g. isothermal, chemical, with a particularly dangerous load, etc.

A large number of factors affect terminal handling capacity. its equipment and technical solutions, interdependent and separately calculated by an algorithm developed using Excel. These include internal conditions, such as the number and type of reloading devices, the speed of their operation, the specificity of the terminal's work, the size of storage areas (by destination), length and number of transshipment tracks, terminal operation time and external factors forecasted, i.e. the number of individual container types (dangerous, temperature-controlled, semitrailers, 20 ', 40') and the resulting occupancy of the square and method of storage, type, quantity and structure of the required services with an average time of their performance (reloading wagon - wagon, wagon - car, wagon - square - car), storage time of units, as well as the proximity and type of station serving the station and its size. The arrangement of roads leading to the terminal is also important.

Calculating the reloading capacity of the designed object is usually associated with the determination of its module, which has the smallest throughput capacity, so-called bottleneck or according to Adamiecki's theory - a "cylinder" with the smallest throughput capacity in the rolling mill, at which the terminal is no longer able to reload. This module limits the reloading capacity of other elements. The estimated number is usually the maximum terminal handling capacity, and if you want to increase it, you need to compensate for a particular obstacle, e.g. by setting up a larger number of handling equipment, increasing the length of the transshipment front, or the number of tracks for loading and unloading. The parameters of the designed terminal for a given reloading forecast (up to 10 years) should provide a minimum 10-20% buffer capacity of each of the elements affecting the reloading capacity of the terminal. When planning transhipment equipment, it is necessary to take into account what character the terminal will have, whether it is a port terminal, inside the country or on our eastern border. When choosing between the crane and reach stacker, first of all, the planned transhipment technology and dimensions as well as the shape of the yards should be taken into account. In the case of the transshipment of the wagon - wagon and wagon - square, with narrow squares, it is most economical to choose gantries, whereas the wider the square, the more profitable is the purchase of "reach stackers". The main reason for this approach is the price and operating costs of both types of equipment. The costs of using cranes are much lower than the reach stackers' exploitation costs, but this also translates into the purchase price, which is several times higher, and as the span between the supports increases and the need for additional boom equipment, the purchase price increases significantly. Constructions of reloading devices are modernized - new, better and more efficient construction solutions appear. Increasingly, at the terminals, cranes with RTG wheels are used, the span of which currently extends up to 33 meters. Such a crane moves on concrete runways of adequate load capacity. It is adapted to the possibility of changing the roadway, so it can handle a wider area. It replaces RMG classic overhead cranes that move along the crane rails. However, this solution is much more expensive. Overhead cranes of this type can have a much greater span between supports up to 50 meters and, additionally, side extensions up to 1/3 of the span between supports. However, the construction costs of the crane and rail tracks are high due to the existing loads. In the case of large terminals, the solution allowing the optimization of outlays and costs of subsequent operation may be the purchase of tractors, in addition to overhead cranes and reach stackers, that enable the distribution of intermodal units into various areas of the plots. For the handling of empty containers, the best device is a lightweight "reach stacker or so-called a stacker, the purchase price of which is lower by half, and in operation, it is much cheaper than the "reach stackers".

A very important element in the design of terminals is the selection of the type of its surface. An example of a solution can be reinforced by concrete pavements. The selection of the type, as well as thickness, and hence the specific strength of the surface (resulting from the number of possible calculation axes a day), depends primarily on the planned intensity of traffic on the square, which in turn is correlated with the projected flow of cargo passing through the facility as well as, importantly, the used reloading devices.

When planning to use only gantry cranes, it is possible to use a thinner foundation and a concrete pavement with lower strength, while using "reach stackers" or gantry cranes on PTG tires it is necessary to choose a stronger surface of squares. Currently, more often instead of the traditional reinforcement of the terminal board made of reinforcing steel bars, dispersed reinforcement of steel or polymer fibers is used.However, it should be borne in mind that the smaller the thickness of the last top layer of the terminal board, the thicker the foundation must be from the aggregate. The aggregate foundation is responsible for taking over the main load.

Another solution may be the use of precast concrete slabs. Their characteristics are low costs and the ability to quickly assemble and use, however, the strength of the squares created is small, so this solution is used at temporary terminals or in storage areas and depots.

A very interesting and cheap technology for making storage yards was used at the terminal in Wrocław at Krakowska Street. The storage yards are made of an aggregate, while the paths on which the reach stackers move are made of modified surface hardened asphalt. The terminal is currently unoperated. The terminal is an example of the correct creation of logistic infrastructure in Małaszewicze. Already at the stage of the logistics infrastructure network concept, it was one of the most important locations where the investment process should be started first. In 2009, PKP Cargo S.A. completed the first stage of modernization and expansion of the intermodal terminal in Małaszewicze co-financed from the resources of the Sectoral Operational Program Transport, under the European Regional Development Fund. As a result of the implementation of two phases of this project, a modern intermodal terminal was obtained with storage and handling yards along roads with an area of 19100 m^2 and four reloading tracks with a total length of 2472 m. The handling capacity is currently around 190,000 TEU per year, while the areas of the squares allow components of approx. 1310 TEU. In the current financial perspective, the terminal has received funding for further expansion.

Terminal slab construction

An important element in the design of terminals is the selection of an appropriate location and selection of the type of pavement of the handling and storage yard. We must bear in mind that this is the most expensive element of the project and it should be made in the right technology. Currently, the most commonly used technology of its implementation is a concrete slab. The selection of the type, as well as the thickness, and hence the specific strength of the surface (resulting from the size of the workload and the pressure of the stacked container layers), depends on the planned intensity of traffic on the square, which in turn is correlated with the projected flow of cargo passing through the facility , as well as what is important - the transhipment devices used. Other parameters should be characterized by the surface of the square, where self-propelled pile stackers work, and other plots where only gantries are employed, as well as other yards for storing empty containers. The solution that meets the requirements for the work of all the mentioned devices and the universality of the reloading plate itself is the plate carrying loads according to class E600, and in the case of access roads, internal roads, parking lots, the surface corresponding to the classes KR-5 and KR-3. Unfortunately, this technology is not the cheapest.

Sample constructional cross-sections of squares:

• cement concrete surface B-40 dowelled- reinforced in the area of the bottom mesh bars 16 mm with a mesh of 12x12 a thickness of 25 - 32 cm,

• geotextile with a weight of 400 g / m2,
• concrete foundation made of B20 concrete, 10-20 cm thick,
• a layer of lean concrete with Rm = 6-9 Mpa, 10 - 20 cm thick,
• auxiliary foundation made of crushed aggregate 0/63 mm mechanically stabilized with a thickness of 20 - 40 cm,
Total about 92 cm.

It is a solution in the most durable and, at the same time, expensive technology.

Surface KR-5:
• layer wearing course with SMA o. 0/12.8 mm, about 4 cm thick, with SMA o. 0/12.8 mm, about 4 cm thick,
• binding layer with BA o uz. 0/20 mm, about 9 cm thick,
• layer of the main foundation of BA o. 0/25 mm, about 18 cm thick,
• auxiliary foundation made of broken aggregate mechanically stabilized with 0/63 20 cm,
• frost-resistant ward, approximately 20 cm thick,
• soil stabilized with cement Rm = 2.50-5.0 MPa, approximately 15 cm thick,
• bring the substrate to the load class G-1.
Total about 91 cm.

Surface KR-3:
• wearing layer course with SMA o. 0 / 12.8 mm, about 4 cm thick,
• binding layer with BA o uz. 0/20 mm, about 7 cm thick,
• layer of the main foundation of BA o. 0/25 mm, about 7 cm thick,
• auxiliary foundation made of broken aggregate mechanically stabilized with 0/63 20 cm,
• frost-resistant ward, approximately 20 cm thick,
• soil stabilized with cement Rm = 2.50-5.0 MPa, approximately 15 cm thick,
• bring the substrate to the load class G-1.
Total about 73 cm.

The type and structure of the terrain on which it is being built are of significance for the thickness of individual layers on the terminal board, so it is advisable to conduct geological tests before proceeding with its construction.

An important element in the construction of the terminal board is the implementation of proper drainage that meets the requirements of the terminal operation itself (longitudinal and transversal falls, water collectors, etc.), as well as environmental protection by building capture devices such as settling tanks and separators with coalescing inserts. Depending on the reloading technology, rainwater can be discharged through street rain drains and/or linear drainage. Fire-fighting water network should meet the requirements for fire protection for this type of facilities and capacity of 30 l/s.

When designing and then implementing the investment, it is necessary to separate storage and handling yards for containers with hazardous materials of fire hazard class I, II and III. The method of storage should also take into account the division into areas of preventing water as an extinguishing agent and determining the extent of use of foam. Due to the fact that containers may also contain highly flammable liquids, which are both toxic and corrosive, it is necessary to determine the risk category for a serious industrial accident, therefore the classification of the plant should be reported to the Provincial Headquarters of the State Fire Service:

- full safety report
- internal emergency plan,

and implement the security system as an integral part of terminal management.

As previously indicated, when planning the use of only track cranes, it is possible to use a thinner foundation and a concrete pavement with lower strength, while using self-propelled loading equipment it is necessary to choose a stronger surface of squares.

Another solution can be the use of dedicated prefabricated concrete slabs. Their characteristic features are low costs and the possibility of quick assembly and use, however, the strength of the resulting squares is low, which is why this solution is used at temporary terminals, or in sidings and depots. This technology works well when using an overhead crane, while in the case of heavy self-propelled handling equipment (70-80 tons) by adding the weight of a loaded container we get a total weight of about 120 tons, the period of site strength is significantly reduced. An example technology of making panels is making it from B-52 pressed concrete 15 - 20 cm thick reinforced with a mesh with 8 mm or 10 mm rods. To avoid corrosion, the boards are surface ground. On each side wall, gaps are made in which connecting clamps are placed. The panels can be dismantled - it is estimated that about 10-15% of the panels may be damaged during dismantling. However, this makes it possible to recover a significant part of them and use a new terminal for construction. Such technology was used at the intermodal terminal in Sławków and in the now-closed terminal in Sosnowiec. A 10 cm thick cement cube made of B-40 concrete is also used to build the terminal. In this technology, e.g. the terminal plate in Wels in Austria is made, but due to frequent cases of impact with heavy containers on the ankle, numerous cracks can be seen.

It should be borne in mind, however, that the smaller the thickness of the last upper layer of the terminal board, the thicker the aggregate foundation must be.

Conclusions

All activities aimed at the development of terminal infrastructure working in a network system, and in the field of promotion affecting the technological development of intermodal transport are the elements needed to maintain the growth rate in the coming years. The intermodal supply chain is associated with the participation of several market participants, therefore increasing the market attractiveness of the whole should be associated with activities enabling better information flow or effective cooperation in the loading unit's transport processes. The modernization of the line infrastructure, which is currently carried out on a very large scale, without point infrastructure, which is also intermodal terminals that act as traffic generators, will not bring the expected effects in the form of a modal shift of loads from roads to rail. An important direction of activities is the continuous increase of public awareness of the advantages of this branch of transport-related to ecological aspects, the safety of transported goods or the economic profitability of logistics chains with the dominant share of rail transport. The state's transport policy is of major importance in the development of intermodal transport. There are many areas of support for this form of transport, but one of the directions is the need to equalize opportunities for curbing rail and road transport by balancing the costs of access to infrastructure and creating regulations that reduce the cost of transporting intermodal units to and from the terminal on the principles of the last mile. Creating optimal logistics chains and at the same time profitable for logistics industry companies in which ecological rail will play a dominant role is an important direction in reducing the adverse environmental impact of transport processes in a dynamically developing economy.