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Technical and technological trends in the area of rolling stock for intermodal transport in Poland in the light of sustainable development

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Abstract
The general goal of transport policy is to ensure efficient service of the economy's transport needs while minimizing the negative impact of transport on the environment. One of the objectives in this area is to support the share of rail transport in maintaining and increasing its share in servicing the indicated needs of the economy. Transport policy, in general, supports the development of combined transport, including container transport technologies, which are intended to handle unitized loads in order to use rail transport as the basic branch, complementing the delivery and collection functions performed, for example, by road transport. This article aims to present the effects of adapting the structure of railway wagons to the unitized loads handled as part of intermodal rail transport in Poland. The research methodology employed comprises a case study and simulation involving handling a 100,000-ton cargo batch.

Keywords: intermodal transport, railway transport, sustainable development, transport policy

1. Introduction

The overarching objective of transport policy is to efficiently meet the economy's transportation needs while concurrently minimizing the adverse environmental impacts associated with transportation. A pivotal tool in achieving this objective is the support of the rail transport sector, aimed at maintaining and augmenting its role in meeting the identified economic requirements. Rail transport, distinguished by a high energy efficiency index and lower land consumption compared to road transport, holds intrinsic environmental advantages. However, due to its flexibility, the dynamic expansion of road transport in the intermodal division of transport tasks contributes to the escalating negative environmental effects and augmented external costs.

To address this, transport policy endeavors to support the development of combined transport, notably container transport technologies, designed for handling unitized loads. This approach envisions utilizing rail transport as the foundational component, complementing the delivery and retrieval functions performed by road transport. Deregulation in the rail transport sector in Poland has resulted in carriers organizing rail transport based on routes, facilitating the optimization of wagon structure to maximize cargo weight within technical and technological constraints of railway infrastructure, such as axle load and train length. These trends extend not only to rolling stock handling bulk cargo but also to those handling unitized loads in intermodal rail transport.

The primary aim of this article is to present the effects of aligning the structure of railway wagons with unitized loads within the context of intermodal rail transport in Poland. An additional goal is to advocate for the inclusion of potential co-financing in the transport policy for the acquisition of rolling stock, considering parameters that reduce the proportion of tare mass in rail transport. Such an initiative is anticipated to positively impact the realization of sustainable development goals and enhance the competitiveness of rail transport.

The research methodology employed comprises a case study and simulation involving the handling of a 100,000-ton cargo batch. The study focuses on specific relations within the PKP PLK network on railway lines with a 25.5 T axle load. It utilizes one freight train in two variants of wagon sets operated on the PKP PLK network by Polish railway carriers engaged in intermodal transport. These include a container train employing Sgmmnss series platform wagons with HTSYP type containers designed for bulk cargo transport and a train set employing E-series coal wagons of the Eaos series, conventionally used for transporting bulk cargo such as grain, coke, and fertilizers.

2. The sustainable development paradigm in the EU and Polish transport policy

The primary strategic objective of transport policy is to configure a sustainable transport system that significantly contributes to the expeditious socio-economic development of the nation. This goal takes into consideration the contemporary realities of social, economic, and political contexts. The imperative is for the transport system, along with its constituent elements, to enhance the competitiveness and efficiency of the Polish economy. Notably, the socio-economic components of Poland, including transport and innovation policies, operate within the overarching framework of EU policy due to Poland's membership in EU structures. These guidelines, as articulated by the European Commission, encompass the following imperatives (Ministry of Infrastructure, 2019):

a. Ensuring that transport services exhibit a standard of excellence, recognized by high quality and reliance on emerging technologies.
b. Placing a particular emphasis on fortifying security systems within the transport infrastructure.
c. Mitigating the adverse environmental impact of transport activities, thereby contributing to sustainable practices.
d. Promoting the implementation and development of Intelligent Transport Systems (ITS) in road transport.
e. In rail transport, advocating for the adoption and refinement of Traffic Management Systems, specifically the European Rail Traffic Management System (ERTMS).
f. In air transport, endorsing the deployment of SESAR (Single European Sky ATM Research) to enhance air traffic management and efficiency.
g. Implementing the Galileo positioning system to bolster and optimize supply chain logistics.
h. Undertaking actions to optimize the utilization of the existing transport network, emphasizing efficiency and resource utilization.
i. Enhancing the systems governing the maintenance of transport infrastructure to ensure longevity and operational resilience.
j. Propelling an increase in the utilization of market mechanisms within the realm of transport, enhanced by initiatives such as the separation of infrastructure management from operational activities, thereby augmenting the role of market forces in the provision of transport services.

These articulated guidelines underscore a comprehensive approach wherein the European Commission strategically directs actions across a spectrum of domains to collectively advance the overarching goals of the transport policy framework.

The fundamental shared objective of both implemented industry (sectoral) and horizontal policies is to ensure sustainable economic growth, contributing to the enhancement of societal well-being. This objective is intricately linked to addressing the imperative of meeting transport requirements. It is emphasized that conventional investment in transport factors of production does not inherently guarantee their satisfaction. There exists a looming threat of reaching critical thresholds in traffic and transport intensity, beyond which road and street congestion may become chronic. Additionally, constraints on available space for new infrastructure facilities and the depletion of energy resources, fundamental to prevailing mechanized transport technologies, pose significant challenges (Brunewicz, 2010).

In response to these challenges, interventions in the domain of transport should be directed towards augmenting the functionality and efficiency of transport systems. Simultaneously, there is a pressing need to curtail energy demands associated with transport activities. This necessitates the development of land transport on multiple levels, encompassing ground, underground,

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and overhead modalities. The pervasive integration of intelligent traffic control systems across various modes of transport and the evolution of a new generation of logistics optimized for transportation are identified as critical measures (Brunewicz, 2010).

On one hand, these strategic initiatives aspire to harness the potential of the broadly defined transport infrastructure effectively. On the other hand, they seek to engage novel transport potentialities, thereby ensuring a comprehensive and forward-looking approach to addressing the evolving dynamics of the transport landscape.

The extant governmental framework delineating transport development in Poland is encapsulated in the document entitled "Strategy for Sustainable Development of Transport until 2030," adopted on September 24, 2019, by means of a decision of the Council of Ministers (2019). This strategic blueprint, prepared under the auspices of the Minister of Infrastructure (P.P., 2019), is underpinned by the overarching goal of enhancing Poland's transport accessibility, bolstering road user safety, and augmenting the efficiency of the transport sector while mitigating its adverse environmental impact.

Specifically within the ambition of rail transport, the strategy entails a comprehensive agenda encompassing the modernization, expansion, and revitalization of the railway network. This initiative integrates the implementation of infrastructure investments aligned with the trans-European transport network (TEN-T) and the conceptualization of the Central Communication Port (CPK). Furthermore, strategic investments are earmarked for improving transport safety within the rail domain. An integral facet of this strategy is its emphasis on interoperability and intermodality, fostering collaboration between rail transport and other modes, both for passenger and freight transport. These initiatives seek to amplify the role of rail transport in meeting the transportation needs of Poland, driven by the lower environmental impact associated with ecologically sound modes of transportation.

Current endeavors within rail transport focus on financial support for diversification, including linear and point infrastructure investments, as well as backing for rolling stock investments in the domains of passenger and intermodal transport. It is anticipated that financial support for rolling stock investments in rail transport associated with the management of cargo flows incompatible with intermodal transport (WNP, 2011; Laude.pl, n.d.a) may encounter constraints and be less likely to secure financial backing.

3. Organization of transport using intermodal technologies

Combined transport makes it possible to reduce the negative effects and external costs of transport, in accordance with the principles of sustainable development, by using the energy efficiency of rail transport, thus generating lower external costs in comparison to the very flexible road transport. Combined transport, also referred to in the literature as intermodal or multimodal transport, allows, thanks to the solutions used in the field of cargo units and specialized reloading terminals, the use of the positive features in the area of reduced environmental impact of rail transport as the main mode of transport, while the flexibility of road transport can be used in the delivery-removal relationship. Therefore, intermodal technologies allow the implementation of the transport process on a specific transport route between the place of origin and the place of destination (e.g., producer plant – consumer plant/processor) with the dominant role of rail transport and the complementary role of road transport, as presented in the figure below.

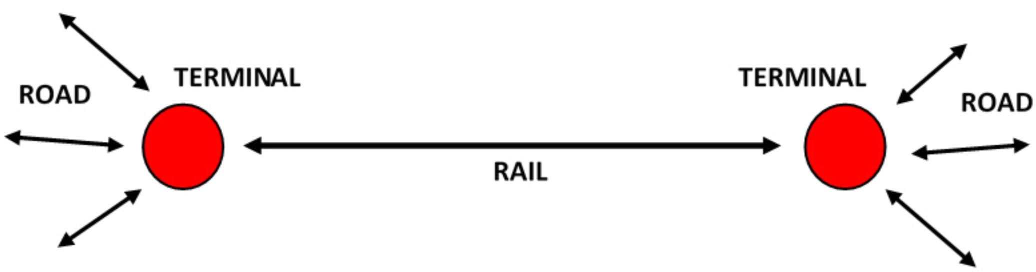

Figure 1. Organization of combined transport (rail and road). Source: The authors' own work.

The promotion of combined transport as a modern, environmentally friendly cargo transport technology has become one of the priorities of European transport policy. The European Union has long been striving to gradually reduce the role of road transport and promote ecological modes of transport, including railway transport. These activities in Poland include, among others, the following areas (Ministry of Infrastructure, 2019):

a. Modernization of railway infrastructure based on EU funds.
b. Construction, expansion and modernization of intermodal transport terminals with co-financing of up to 50% of eligible costs.
c. A discount for railway carriers operating intermodal trains in the amount of 25% for access to PKP PLK railway infrastructure.
d. Co-financing the purchase of rolling stock, i.e., platform wagons for the transport of intermodal units (European Commission, 2019), containers, swap bodies, etc., and locomotives for driving intermodal trains up to 50% of eligible costs (in the previous

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programming period, i.e., 2014–2020, it was possible to also obtain funding for diesel locomotives used to operate intermodal trains, in the current programming period 2021–2027, funding was limited to zero-emission locomotives).

e. Co-financing of research and development projects in the development of intermodal technologies. An example is a project co-financed under the RPO of the Kuyavian-Pomeranian Voivodeship entitled "Preparation of technical documentation and a prototype of an innovative multi-functional container for the transport of coiled goods and other goods" (Laude.pl. n.d.b).

The effect of the transport policy is to increase the share of rail transport in servicing the transport needs of the Polish economy, including an increase in the share of intermodal transport. Poland, by adopting the Sustainable Transport Development Strategy by 2030 (MP, 2019), will implement the assumptions of the EU transport policy.

4. The functioning of the intermodal transport market in Poland as an element of railway transport

Intermodal transport refers to transportation that utilizes specific cargo units carried out through various modes of transportation, including rail transport. The most commonly used cargo units in intermodal transport are containers or swap bodies. In Poland, containers are the predominant cargo units, constituting over 96% of transported cargo units.

Intermodal transport in Poland is carried out by various railway carriers operating in the country, and among the largest players, with a market share exceeding 10%, are PCC Intermodal, DB Cargo, and PKP Cargo.

The shaping of the railway transport market, including intermodal rail transport, is presented in the following tabular summary.

Table 1. Characteristics of the cargo mass handled by rail transport, including intermodal transport in 20212–2022.

Years	Load weight [T]					
	Railway Transport	Intermodal Transport	Sum (rail + intermodal)	Intermodal Share (%)	Intermodal Dynamics year/year	Dynamics Mass Intermodal 2012 database
2012	231 403.0	8 055.83	239 458.8	3.36		100%
2013	233 196.9	8 633.26	241 830.2	3.57	107.17%	107.17%
2014	228 866.0	9 610.29	238 476.3	4.03	111.32%	119.30%
2015	224 777.3	10 386.39	235 163.7	4.42	108.08%	128.93%
2016	222 225.3	13 428.68	235 654.0	5.70	129.29%	166.70%
2017	239 885.4	15 080.53	254 965.9	5.91	112.30%	187.20%
2018	250 251.1	17 703.30	267 954.4	6.61	117.39%	219.76%
2019	236 396.3	19 509.49	255 905.8	7.62	110.20%	242.18%
2020	223 241.9	23 776.87	247 018.8	9.63	121.87%	295.15%
2021	243 633.1	26 530.24	270 163.3	9.82	111.58%	329.33%
2022	248 542.0	26 157.86	274 699.9	9.52	98.60%	324.71%

Source: The authors' own study based on information from the UTK (Urząd Transportu Kolejowego, 2023).

Table 2. Characteristics of transport work performed when handling cargo by rail, including intermodal transport in 20212–2022.

Years	Transport Work Volume [btkm]					
	Railway Transport	Intermodal Transport	Sum (rail + intermodal)	Intermodal Share (%)	Intermodal Dynamics year/year	Intermodal Dynamics 2012 base
2012	49 039 417	3 044 869.16	52 084 286.04	5.85		
2013	50 900 254	3 066 986.39	53 967 240.45	5.68	100.73%	100.73%
2014	50 097 631	3 401 655.37	53 499 286.64	6.36	110.91%	111.72%
2015	50 605 534	3 718 045.35	54 323 578.90	6.84	109.30%	122.11%
2016	50 620 169	4 695 934.92	55 316 104.18	8.49	126.30%	154.22%

2017	54 829 029	5 571 306.81	60 400 335.80	9.22	118.64%	182.97%
2018	59 642 032	6 436 431.30	66 078 463.57	9.74	115.53%	211.39%
2019	55 905 458	7 069 382.86	62 974 840.86	11.23	109.83%	232.17%
2020	52 217 929	7 838 546.99	60 056 476.46	13.05	110.88%	257.43%
2021	55 986 763	8 181 085.68	64 167 848.68	12.75	104.37%	268.68%
2022	62 499 367	8 610 761.05	71 110 128.05	12.11	105.25%	282.80%

Source: The authors' own study based on information from the UTK (Urząd Transportu Kolejowego, 2023).

The presented data indicates a dynamic growth in the handled cargo mass through the utilization of intermodal transport, showing an increase of over 324% over a span of 10 years (2012–2022). This is contrasted with the practical stagnation of cargo mass handled by rail transport alone. The stagnation in the handled cargo mass by rail transport (excluding intermodal transport) signifies a decline in rail transport's attractiveness in cargo handling. Despite this stagnation, the transport work volume increased by approximately 10% during the same period.

Notably, despite the overall stagnation, the transport work volume in intermodal transport increased by around 280% during the analyzed period. Favorable trends in intermodal transport in Poland, characterized by growth, reflect the effectiveness of support for this segment of railway transport services. These trends are also a result of the implementation of technical and technological solutions enabling unitization (containerization) of bulk cargo, such as wood chips, grains, etc., that was traditionally handled by regular railway wagons.

5. Case study of transport using modified HTSYP bulk cargo containers

The case study, as a qualitative research method, illustrates the prevailing trend in the market of railway cargo transportation regarding the enhancement of energy efficiency through the reduction of tare mass (structural weight of wagons). Simultaneously, considering this phenomenon in relation to cargo batches rather than individual wagons allows for the delineation of efficiency areas from the perspective of the railway carrier. This approach is substantiated by the fact that the developed modified wagon designs are not produced as individual units but rather as production series, facilitating the formation of entire train compositions based on the modified wagon designs. Such a comprehensive approach enables the elucidation of the primary stakeholder's goals, assumptions, and motives, namely the railway carrier.

Trends in the development of intermodal transport, including the possibility of consolidating a number of loads, are visible in rail transport. Solutions are appearing on the market aimed at containerizing bulk cargo, which was previously transported in coal wagons. The emergence of container solutions of various designs allows for the containerization of bulk cargo such as coal (Zasiadko, 2021), coke, biomass, cereals, artificial fertilizers and others. An example of this type of solution may be Ecco-box containers adapted for rail transport (Pol Osteg, n.d.), whose own weight (tare) is 3.35T and load capacity is 21T (Lokomotywownia, 2019a). Ecco-box containers are presented in Figure 2.

Figure 2. Ecco-box containers Seria Sgs. (Lokomotywownia, 2019a).

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Another example of containers used in rail transport are containers for the transport of bulk materials of the HTSYP type (rigid top + loose goods) from Laude Smart Intermodal. Compared to a standard 20-foot container, the HTSYP-type container is characterized by an increased height, a capacity larger by 11 m3 (43 m3), and a greater load capacity of 5-10 tons (up to 33 tons). The innovation of the container lies in the possibility of pouring the goods through the rear flap of the door and loading from the top through the hatches of the latching roof (alternatively, a tarpaulin roof can be installed). The container can transport up to 14 Euro pallets on one level (Paszkiewicz, 2024) container with increased height and width.

If it is necessary to unload bulk goods through a flap door, Laude provides specialized semi-trailers allowing the goods to be unloaded at any destination and, in the case of full-train quantities, a reach stack trolley.

The solution based on Laude's HTSYP containers is presented in Figure 3.

Figure 3. Laude's HTSYP containers. (Lokomotywownia, 2019b).

In general, it should be noted that intermodal technologies, including container technologies in rail transport and bulk cargo, are characterized by a less favorable energy consumption rate, resulting from a greater share of the tare weight, i.e., the weight of the container platform and the container itself (tare), in relation to the transport of these loads, e.g., using E-type coal wagons (e.g., Eaos). This unfavorable ratio of the gross weight of the train understood as the weight of the transported cargo and the own weight of wagons and containers, resulted in the need to increase total transport performance expressed in gross ton-kilometers (bt-km) or in train-kilometers necessary to transport a specific mass of cargo on a specific transport route. Increasing the number of train kilometers to handle a specific batch of cargo is often caused by the limitations of the railway infrastructure in Poland in the form of the maximum length of trains on the PKP PLK network, which is generally limited to 600 m (750 m on modernized lines, there is also a "narrow throat" in terms of the maximum length of trains on a specific section of the railway line, e.g., up to 550 m) (the length of the train should be taken into account with the train locomotive), and the maximum axle load – basically, there are two standards on the PKP PLK network (22.5 T/axle and 20.0 T/axle). Railway carriers take steps to limit the negative consequences of containerizing bulk cargo by optimizing the parameters of rolling stock dedicated to this type of transport.

An example of such optimization will be presented below, where handling a load weighing 100,000 tons was assumed, which was previously transported by E-type coal wagons – Eaos type. Container wagons and HTSYP containers transported on Sgmmnss series container platforms were adopted as an alternative to intermodal transport. In order to illustrate the differences, the assumption was made of operating one trainset both in the transport of type E coal wagons and in the field of container trains. An identical transport relationship was adopted, which made it possible to assume the same distance between the sending station and the receiving station, i.e., 722.019 km both on the loaded and empty route (handling of the cargo batch based on a cargo route). It was assumed that the entire transport route is carried out along a railway line, allowing trains to be driven with an axle load of 22.5T. Information from RJK PLK was used to calculate freight charges (Polskie Linie Kolejowe, n.d.). Identical train transit times were assumed, as well as identical cargo service times at the loading and unloading stations. The results of the calculations are presented in the table below (Tab le3).

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Table 3. Handling of a load weighing 100,000 tons on a container platform and in a coal wagon

TECHNICAL AND OPERATIONAL PARAMETERS		
Parameter description	**container platform**	**coal wagon**
Tare weight of the wagon (tare)	17 T	24T
Length of the wagon	13.50 m	14.04 m
Number of axles in the wagon	4 (wagon bogies)	4 (wagon bogies)
Train length	600 m	600 m
Maximum number of wagons in a train	42	41
Number of 20’ HTSYP containers on the wagon	2	Not applicable
Tare weight of containers (2x3T) on one platform	6T	Not applicable
Wagon capacity	(2x43 m^3) 86 m^3	73 m^3
Train capacity	3,612 m^3	2,993 m^3
Cargo weight per wagon for a railway line with a load of 22.5 T/axle	67T	66T
The weight of goods that can be transported in one train	2,814 T	2,706 T
Tare mass of the wagon train	966T	984T
Weight of the train locomotive	120T	120T
TECHNICAL AND ECONOMIC PARAMETERS OF TRANSPORT IMPLEMENTATION		
Number of loading trains/trips necessary to transport 100,000 T of cargo	36	37
Gross train load (with the train locomotive)	3,900 T	3,810 T
Gross empty warehouse (with the train locomotive)	1,086 T	1 104 T
Length of the train transport route	722.019 km	722.019 km
Draft work – loaded trains [gross-tonne-kilometer]	101 368 800	101 780 340
Train work – empty trains [gross-tonne-kilometer]	28 227 312	29,492,256
Total gross-tonne-kilometer for service 100,000 T	**129 596 112**	**131 272 596**
Composition rotation time	130 h	130 h
Handling time for a batch of 100,000 T	195 days 6.5 months	201 days 6.7 months
Calculated cost of access to railway infrastructure on route x for one loaded train	15,001	19,754
Calculated cost of access to railway infrastructure on route x for one empty train	6,456	8,621
Total cost of access to infrastructure in connection with the transportation of 100,000 T of cargo in a shuttle relationship (loaded/empty)	PLN 772,452	PLN 1,049,875

Source: The author’s own study based on information from Polskie Linie Kolejowe (n.d.).

The presented analyzes indicate that the transport task of handling cargo with a volume of 100,000 tons on a route of 722.019 km, carried out on railway lines with an axle load of 22.5 tons, with the organization of transport based on a shuttle route, a railway carrier using coal transport type E will have to perform transport work worth 131,272,596 gross ton-kilometers. However, by using a shuttle route based on a container train (HTSYP type containers), it will achieve a transport performance of 129,596,112 gross-ton-kilometers, i.e., less by 1,676,484 gross-ton-kilometers (1.3%). This difference is not significant, as it represents a reduction in the necessary transport work by 1.3%. Assuming an identical, estimated cost of transport work for one gross ton-kilometer at the level of PLN 1 (indicative), the savings in using the intermodal technology described would be at the level of PLN 1,676,484. In addition to the financial dimension, savings on transport work also have an ecological dimension, as the environment will be less burdened by the negative impact of transport. Additional financial savings due to the organization

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of handling batches of cargo using intermodal technology would be obtained by the railway carrier due to the costs of access to the railway infrastructure, as PKP PLK has a 25% discount for the passage of an intermodal train in relation to a "traditional" freight train, e.g., E. This amount is PLN 277,423. The order execution time with the assumed parameters using one trainset is similar, as in the case of intermodal transport, it is 195 days, and in the case of transport with a beam train, it is 201 days. This difference results from the fact that a carrier carrying out transport based on a coal wagon train must perform one more train (loaded and empty train journey) compared to transport based on an intermodal train. Differences in the number of trains necessary to run a given batch of landings, as well as in the volume of transport work, will change if we planned a transport route along railway lines (in whole or even in part – the bottleneck principle – the lowest parameter determines the entire transport) by reduced axle load, i.e., 20T/axle. The carrier can achieve significant financial effects in terms of investment outlays for the purchase of rolling stock due to the fact that the purchase of rolling stock (wagons and locomotives) with the possibility of co-financing of up to 50% of the purchase cost. Assuming that the cost of purchasing an electric locomotive allowing to drive freight trains with a gross weight exceeding 3,000 T is approximately PLN 30,000,0000, and the cost of purchasing a coal wagon is approximately PLN 300,000, while the cost of purchasing a platform wagon for transporting containers with the indicated parameters is approximately PLN 250,000, the co-financing the purchase of a train for intermodal transport may amount to PLN 15,000,000. In the case of an intermodal train, the cost of purchasing HTSYP containers should be added, which can be estimated at 20,000 PLN/pcs. The above assumptions indicate the estimated value of investment outlays related to launching the train:

- based on coal wagons (PLN 30,000,000 + PLN 12,300,000 = PLN 42,300,000)
- based on container platforms PLN 15,000,000 + PLN 5,250,000 + PLN 1,680,000 = PLN 21,930,000).

Therefore, the investment outlays necessary to launch one trainset of a specific length (number of wagons or number of containers on container platforms) may be lower by PLN 20,370,000 if funding is obtained in the amount of 50% of the estimated costs of purchasing a rolling stock for intermodal transport, and running a train on an electrified line (an electric locomotive is a zero-emission locomotive and may also be subsidized. In the case of routes where there is no electric traction, an alternative is to purchase a diesel locomotive, which is excluded from funding. The theoretical option is to purchase a hydrogen locomotive, but there is no operational experience that would allow estimating the cost of purchasing such a locomotive as well as the cost of its operation. For this reason, the authors assumed that the transport task would be carried out based on a route allowing the train to be operated by electric traction.

6. Conclusions and discussion

One limitation of the conducted study is comparing two types of wagons operated on the PKP network. Subsequent research could involve comparing various types of coal wagons as well as different types of container platforms for handling the same cargo. Despite such constraints, our study has allowed us to draw several interesting conclusions. We have proven that financing the acquisition of rolling stock for intermodal transport, due to the absence of funding for rolling stock dedicated to transporting other cargo, especially bulk cargo, prompted the exploration of solutions facilitating the "containerization" of bulk cargo. The case study presented demonstrates handling a 100,000-ton load over a distance of 722 km, utilizing a single train (shuttle) with a rolling stock investment of PLN 38 million. This investment yielded funding of PLN 20 million, a notably attractive prospect for railway carriers. What is more, implementing a container train service, utilizing modified containers results in reduced operating costs. This reduction is attributed, in part, to tariff relief concerning infrastructure access costs compared to transportation conducted with a train composed of traditional E-type coal wagons. It is worth noticing that a variety of solutions emerging on the market, coupled with systemic financial support for intermodal transport, has generated considerable interest among railway carriers. Modifying railway wagons for mass and intermodal transport diminishes the proportion of the tare weight, thereby reducing the necessary transport work for handling a given load weight. Moreover, the wagon turnover ratio emerges as a pivotal parameter in handling specific cargo flows by rail, significantly impacting the financial outcomes of railway carriers and the competitiveness of their offerings. It is judicious to recommend co-financing the acquisition of modified railway wagons by carriers, extending beyond the realm of intermodal transport. Such a measure would facilitate an increase in the gross train weight of a freight train within the confined train length of 600 m. In the context of modernizing railway infrastructure, emphasis should be directed towards accommodating trains with a length of 750 m and an axle load of 22.5 T.

This study suggests the possibility of conducting further research, for example, on constructing other types of wagons. Additionally, within the scope of platform wagons, the described phenomenon of introducing railway platforms with altered structural parameters oriented towards handling specific unitized cargoes may restrict the potential utilization of such wagons in dual-use technologies, for instance, in the transportation of heavy military equipment (e.g., tanks). This consideration assumes its increasing significance in light of the current political situation in Europe.

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Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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