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THE RAILWAY SYSTEM TRANSFORMATION – IMPLEMENTATION OF THE INTEROPERABILITY REQUIREMENTS ON THE RAIL NETWORK

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Abstract

Accession of the Republic of Poland to the European Union (EU) has committed Poland to adopt, among others, policy of opening up the market of products and services in the area of rail transport. Follow decision about the opening of the EU market and transport services for rail transport, the European Parliament and of the Council have introduced a number of safety and interoperability directives for implement interoperability on the rail system in EU. Their goal was to get the integration of rail transport systems, despite the differences in control-command and signalling systems, power supply and operation system, to be rich on the safe and not disrupted train running over the different countries (different infrastructure managers). This process so-called „migration" of the rail transport system.

Among others in the paper are presented existing railway system – transformation inputs to outputs, new railway system – transformation inputs to outputs, transformation of the railway system, structure of railway system, interoperability of railway line, interoperability of trains, interoperability of the rail network, interoperability between superstructure and infrastructure.

Keywords*: system transformation, railway system, interoperability, demand for the interoperable transport*

1. Introduction

Commissioned by the European Commission's analysis and the development of Study [12], [14] on the market and transport traffic in Europe indicated the social benefits and the economic effect of full participation in transport "without internal frontiers". The abolition of borders between Member States of European Union (EU) caused to opening the market for transport and transport services, within the EU, and contributed to the increase in demand for international transport and for reduces cost of transport services [13, 17].

These favourable changes were observed basically in the road and aviation transport, while there is lack of this phenomenon in the railway transport, as shown in [3].

Important factors limiting the possibility of creating an open market of services and the rail transport are technical differences in European railway systems, such as other control systems, traction power supply, management and operational traffic rules, etc., as well as in the area of legal – administrative issue, inter alia concerning the approval of vehicles and rail infrastructure to service [2]. The conclusion of these analysis and evaluation of opportunities of opening the market for rail services in the EU is to identify actions in order to implementation of the requirements of interoperability, integration of systems for the movement of passenger and freight trains without unnecessary aforementioned restrictions. The European Commission, the European Parliament and the Councils adopted a number of legislative initiatives designed to revive rail transport by the gradual establishment of an integrated railway area at European level.

The transposition sentence from [2] into Polish the Railway Transport Act reads: "Interoperability is the ability of a rail system to allow the safe and uninterrupted movement of trains which meets the technical conditions, mobility, operational and legal persons whose

behaviour ensures compliance with the essential requirements for the interoperability of the rail system and enables efficient movement of the trans-European rail network". Detailed discussed in Art. [20].

The first steps in this direction have been made with the adoption of Directives 91/440, 95/18 and 95/19 concerning the separation of accounts, tariffs for infrastructure and capacity allocation. In the 2004-2012 years, it was adopted directives: 2004/49/UE (as. amended.) on the safety of railway traffic, 2012/34/EU (originally 2001/14/EC) concerning the allocation of routes, 2008/57/UE (as. amended.) on the interoperability of the rail system, implementing decisions – Technical Specifications for Interoperability.

Introduced into national legislation aforementioned legal acts have caused changes in the railway system in the issue: technical, operational and management rules, which entitles to the thesis that this change is systemic and provides a new approach to the operation of the rail system.

2. Demand for the interoperable transport

Publications of the trends and anticipated changes in the rail transport market and expectations of its stakeholders [2], [14] (described in [20]) indicate that the implementation of interoperability on EU countries, and these railway network, may raise the demand for cross-border rail transport and cause transposing the stream of passengers or freight from roads and air transport to rail.

The demand for freight transport between industrial and distribution of good areas, the demand for passenger transport between agglomerations and cities, confirm the existence of untapped potential for rail transport in the EU [17].

The large international corporations' point of view, the key is to secure sources of supply through diversification and dispersal of supply bases and subcontractors. As is shown in [23] the process of co-operation between firms is carried out in factories, a few thousand kilometres away from each other. This one set up the concept of management and strategy this firms, which involve using components from different suppliers, and the manufacturing process preceded without any disturbance, eliminating the risks of problem with one of the suppliers, strikes, failure of components etc. Article [26] described the basis of empirical research Nitsch (2000) and a pair of researchers Head and Mayer (2000), about non-tariff, the limit barriers and transaction costs are importance for EU trade. In the 80's and 90's of the last century trade relations between the regions within one country were much more intense than between regions belonging to different countries. At the moment, there are many other negative factors affecting the trade and dealing with language, culture, missing transport links and laws, in Countries such Poland, Germany, Czech Republic. According to paper [26] the transport will greatly increase, follow the global output increasing, income and foreign trade. International goods trade largely influence on to development of the transport infrastructure in the region. At the national level, both in Germany (67%), Poland (80.5%) and Czech Republic (77.8%) are dominated by the transport on the roads. While the railway infrastructure in these countries is maintained between 19.4% and 22.1%. Because the GDP and foreign trade in the region of the Elbe / Oder River will develop, load all modes of transport will increase, which may be lead to deficits the transport capacity.

As reported [26], the availability of numerous seaports and waterway ports is important for the communication infrastructure in the region of the Union of Chambers (15 German, 6 Polish and 9 Czech chambers of industrial – commerce). The exchange of goods takes place mainly in the way of direct trade these ports with other regional ports of the Baltic Sea and the North. According to a study [25] streamlining of transport infrastructure, in particular service sea ports by rail, is and will be a priority of transport policy objectives of the Ministry of Transport Netherlands. The study [25] indicated that for freight on the Danish network, the most competitive in the case of mass transport to and from the ports have rail, compared to other modes of transport.

Shippers and logistics operators expressed interest in a variety of transport options, which will

enable them to maintain uninterrupted transport chain.

The new approach proposed (the concept) – synchromodal – is an ability to change the means of modal transport at any time, regardless of the circumstances.

Typing this idea, – as reported [25] – the Dutch government is considering support intermodal system in order to remove the restrictions, developing knowledge and innovation, application of the relevant legal and administrative rules within stimulation of the rail transport development. The purpose of these activities are, inter alia, prepared by the infrastructure manager applications for new connections, which must guarantee: service adequate for the goods volume, the terminals availability for all operators, openness for new operators and third entities, good capacity for international freight traffic.

Political activities will also be synchronized with the development of trans-European transport network (TEN-T). The development of European freight corridors, where the Dutch government supports the development of the first corridor (Rotterdam – Genoa), the second corridor (Rotterdam – Lion / Basil) and eighth corridor (Rotterdam – Warsaw), and bilateral cooperation with Poland and with the Czech Republic to remove "bottlenecks" in the railway infrastructure.

The assumptions regarding the development of rail corridors [13], as well as the orders of the European Parliament and of the Council [17] and Decisions [12] show the intentions of the EU in the range of recanalization of major transport corridors (TEN T).

As part of these activities defined 5 groups of the most important issues:

a) the missing "link", in particular cross-border sections, constituting a serious obstacle to the free movement of goods and persons between different Member States and between them and neighbouring countries,
b) significant and lasting differences in the quality and availability of infrastructure between individual Member States and within them ("bottlenecks"),
c) transport infrastructure between the different modes of transport is fragmented. In terms of multi-modal connections implemented many European freight terminals, passenger stations, inland ports, seaports, airports and urban junctions does not meet expectations,
d) investments in transport infrastructure should contribute to achieving the objectives of reducing greenhouse gas emissions from transport by 60% by 2050,
e) member States still have different regulations and operational requirements, particularly in terms of interoperability, which is another obstacle in the transport and contributes to the formation of "bottlenecks".

In order to solve the above problems [17] EU transport policy is focused on the establishment and development of the complete TEN-T in a two-level approach, including: a comprehensive network to be set up to December 31st in 2050 y. and the core network, which is expected to create up to 31st December in 2030 y. The core network is strategically the most important part of the comprehensive network, the backbone of multi-modal mobility network, focusing elements with the highest added value for Europe.

Expected key changes in railway infrastructure include:

- implementation of interoperability requirements, and fitted the railway with the new CCS system ERTMS,
- open access to rail terminals for all operators,
- at least one terminal logistics platform open to all operators,
- freight terminals and logistic platforms will be available in a non-discriminatory, with transparent rules for charges,
- passenger stations provide access to information, ticket sales and commercial activities to the needs of rail traffic across the comprehensive network and in appropriate cases, access to information on the local and regional transport, in accordance with the regulations [11].

On the basis of impact assessments of market opening for rail freight [16], the options analyses for quantitative and qualitative measures aimed for a freight traffic. The result was the decision to

introduce a regulation [15] concerning the synchronization of activities in the field of investment management on the dedicated to international freight corridor lines. The establishment of its governing body – overseen by the Ministry of Transport of individual countries – with the objective of traffic management in the hallway along with underwriting and provision of routes for freight trains in international traffic.

The assumptions and intentions of the above entering the stage of the investment now, among others, imposing on operators in the rail market duty to apply the requirements of interoperability, as described in [2, 4-9].

3. Transformation of the railway system

3.1. Structure of railway system

The transport system is a system of technical, organizational and human resources related to each other in such a way that it can effectively carry out the movement of people or goods, in time and space [22]. As stated in [21] for the physical realization of the movement of goods or persons is used:

- solid objects with characteristics given (e.g. railways, railway stations),
- means of transport such as rail vehicles (including trains),
- people forming crew of transportation system, who used elements of technical equipment to the movement of persons or goods,
- vehicles technologies,
- management system to proper use of technical transport equipment.

The structure of the system:

$$S = < A, R >, \tag{1}$$

where:

A – a set of distinguished elements in the object,

R – set of relations defined on the elements of the system and some elements of the system and the environment.

According to [22] the overriding objective of the transport system is the movement of people or goods resulting from the nature, number and characteristics of moving objects, as well as the relationship of carriage and quality parameters (safety, speed, comfort, etc.).

The realization of this goal is the transformation of the input streams to the output streams from the system at the appropriate equipment of the system. A detailed description of the issue is presented in the papers [18-20].

3.2. Changes in the selected area of railway system

Problems affiliated with transformations in the field of rail transport require a detailed characterization of changes in the scope:

- *Aggregation of technical areas in subsystems*

As defined in [2] and in the transposition of the Law on Railway Transport „subsystem is a part of the rail system of a structural or functional, for which established separate the essential requirements for the interoperability of the rail system".

In order to simplify the concepts and technical issues rail transport system is subdivided into structural and functional subsystems.

- *The existing rules for admission of railway vehicles*

On the basis of a RIC, RIV, and certificates of release to service previously allowed to the placing on the market railway rolling stock specific manufacturer.

Freight and passenger, on the basis of existing agreements such as RIC and RIV, may be admitted to the rolling stock in the countries of the beneficiaries of the agreement. The condition

for the joint exploitation of the registration of wagons and passenger cars with UIC members, who in turn take on the maintenance of rolling stock. With the implementation of the requirements of interoperability and safety management provisions of RIV / RIC were replaced authorization to subsystems issued by the NSA (National Safety Administration), inter alia, certificate of EC verification of structural subsystems. In other cases, applied a new private and voluntary agreement (General Contract of Use for Wagons, GCU).

Previous admission traction carried out on the basis of the certificate of approval for the operation of the railway vehicle.

– *New rules for the admission of railway vehicles*

The introduction of new EU rules for exploitation requires the manufacturer, carrier or other entity that owns the vehicle obtaining the certificate of EC verification of structural subsystem rolling stock and control – which is connected with the conformity assessment applied technical solutions to the requirements of the Technical Specifications for Interoperability, inter alia, [7], [9]. In the case of older vehicles already authorized to operate in the EU, the so-called procedure is foreseen the mutual recognition "Cross Acceptance" as a result of which are checked only those parts and vehicle systems for which it is feared another of their operation than on the infrastructure of the first release, to are done the performance tests and tests. The subsystems are subject to verification of conformity with the essential requirements before they are allowed to operate under the decision of the NSA (National Safety Administration).

– *Changes in the technical and operational area*

Projected changes in the technical area are related to the implementation of the interoperability requirements. On the basis of the Technical Specifications for Interoperability [4-6, 9]for key parameters, performance of the subsystem can be considered: kinematic gauge, the maximum allowable speed train on the railway line, axle loads, train length, the required power output of the power system cooperation with catenary pantograph, change the system of the train, railway line capacity, information and passenger service areas, etc.

The range of expected changes in the assessment of input streams, the introduction of certification for structural subsystems, security management with the integration of system components, the use of technical requirements for functional subsystems, including the procedures and rules of conduct during the operation and maintenance of railway traffic, as well as training and qualification of the crew, allows for value-added service capabilities in the form of interoperable trains. It also allows the use of indicators to assess the safety (to a greater extent than previously realized) and the availability of the rail network for rail carriers the European Union (Fig. 1 and Fig 2).

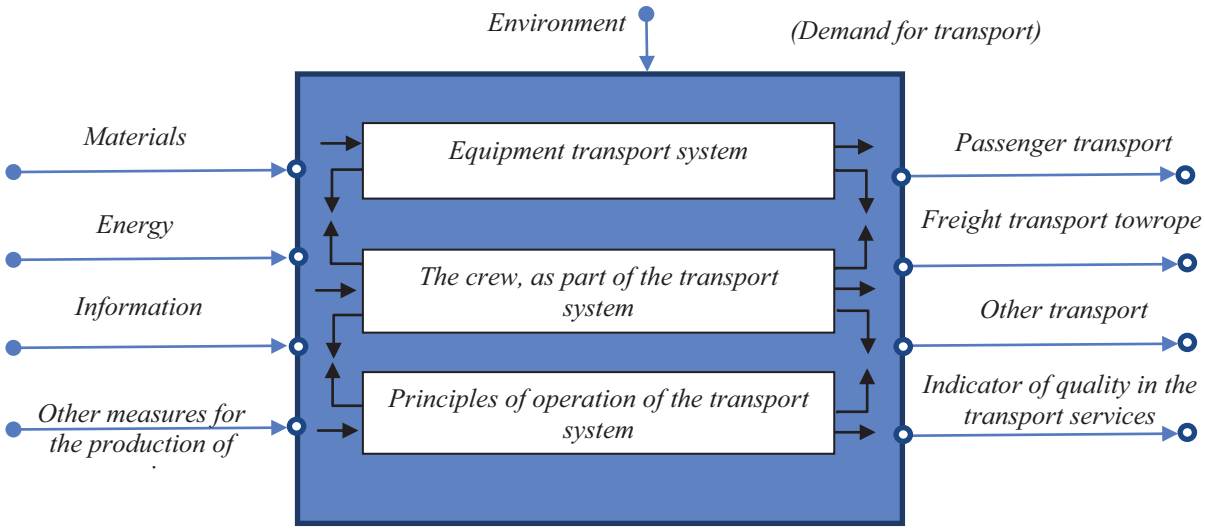

Fig. 1. Existing railway system – transformation inputs to outputs [22]

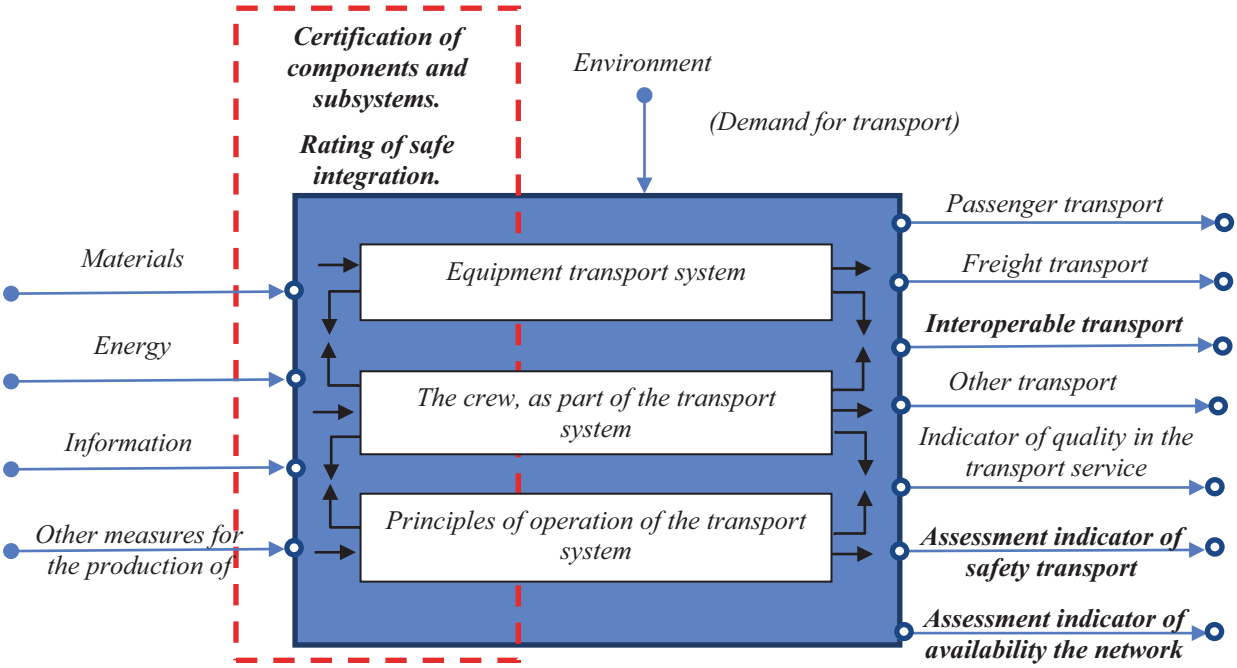

Fig 2. New railway system – transformation inputs to outputs [1. 2]

The scope of changes gives us the conclusion that the implementation of safety requirements (Directive 2004/49/EC) and interoperability requirements (Directive 2008/57/EC) have a dimension of transformation the railway system.

4. Interoperability of railway transport

4.1. Interoperability of railway line

Rail transport system is composed of a network of railway lines, and as defined in the Act on rail transport – railway line is a train "rout" having a beginning and an end, along with an adjacent strip of land, which consists of line segments, as well as buildings, structures and equipment for rail traffic along the land occupied by them.

For the geographical scope of railway line, it have the specific number and consist of segments of various technical and operational characteristics, e.g. consist of sections of single-track and double-track, electrified and non-electrified, with a self-locking linear and sections where traffic is carried on the basis of semi block line, etc. In this case, to meet interoperability requirements on the all railway line can be very complex or impossible. Follow the EC verification for each of the subsystem and authorization.

In the article the author will deliberately tie the concept of interoperability to meet, the conditions set railways, without dividing them into sections (as mentioned above). Such an assumption is necessary for the sake of clarity considerations for interoperability. It should therefore be aware that used in the rest of the article the term „railway line" refers to a segment line, which is restricted junction stations, and therefore does not have a strict sense of the definition currently used railway line.

For clearly the lines describing, the line set in the number of index *nrl.*

The set of numbers of lines will be define as follows:

$$\mathbf{LK} = \{ nrl: nrl = 1, \ldots, \mathrm{NRL}\},$$

which NRL is the number of line.

Taking into account the interpretation of [2] concerning the understanding of the railway line as a set of subsystems, we can write:

$PS^{I}(nrl)$ – structural subsystem „Infrastructure”,
$PS^{E}(nrl)$ – structural subsystem „Energy”,
$PS^{S}(nrl)$ – structural subsystem „Control – Command and Signaling (track)”,
$PF^{R}(nrl)$ – functional subsystem „Operating”,
$PF^{M}(nrl)$ – functional subsystem „ Telematics”,
$PF^{U}(nrl)$ – functional subsystem „Maintenance”,
so any railway line can be represented as a set of subsystems $\mathbf{lk}(\boldsymbol{nrl})$:

$$\mathbf{lk}(\boldsymbol{nrl}) = [\mathbf{PS^{I}}(nrl),\ \mathbf{PS^{E}}(nrl),\ \mathbf{PS^{S}}(nrl),\ \mathbf{PF^{R}}(nrl),\ \mathbf{PF^{M}}(nrl),\ \mathbf{PF^{U}}(nrl)]. \quad (2)$$

Because the subject of certification and the verification WE the subsystem and its authorization, obtain only the structural subsystems, therefore, an assessment of the railway line to adapt to the requirements of interoperability can be simplified structural subsystems, and we write:

$$\forall\ nrl \in \mathbf{NRL}\ \mathbf{lk}(\boldsymbol{nrl}) = [\mathbf{PS^{I}}(nrl),\ \mathbf{PS^{E}}(nrl),\ \mathbf{PS^{S}}(nrl)], \quad (3)$$

without the functional subsystems: $\mathbf{PF^{R}}(nrl)$, $\mathbf{PF^{M}}(nrl)$, $\mathbf{PF^{U}}(nrl)$.

In order find the moment “t” ($t \epsilon \mathbf{T}$, $\mathbf{T}$ – set of moments), while same subsystem met the interoperability requirements the Cartesian multiplex form for subsystems *nrl* line and set of moments $\mathbf{T}$ should be evaluate by $\theta 1$ as elements of multiplex in to set {0,1}, e. g.:

$$\theta 1(\mathbf{PS^{I}}(nrl), t) = \begin{cases} 1, for\ subsystem\ in\ moment\ t\ as\ it\ is\ interoperability, \\ 0, for\ subsystem\ in\ moment\ t\ as\ it\ is\ not\ interoperability. \end{cases}$$

Similar, for other subsystems: $\mathbf{PS^{E}}(nrl)$ and $\mathbf{PS^{S}}(nrl)$ put evaluate: $\theta 2$, $\theta 3$.
So the interoperable of the line we can consider, if all structural subsystems are interoperability ($\mathbf{LK^{q}}$ – it is set of numbers lines, which are interoperable, $\mathbf{LK^{q}} \subseteq \boldsymbol{NRL}$), that means everyone met the interoperability requirements:

$$\forall\ t \in \mathbf{T}\ nrl \in \mathbf{LK^{q}} \Leftrightarrow \theta 1(\mathbf{PS^{I}}(nrl), t) \cdot \theta 2(\mathbf{PS^{E}}(nrl), t) \cdot \theta 3(\mathbf{PS^{S}}(nrl), t) = \mathbf{1}. \quad (4)$$

4.2. Interoperability of trains

The part of railway transport system contain thermal or electric trains, traction units heat energy or electricity, passenger coaches or freight, special vehicles for the construction and maintenance of railway infrastructure [2]. The interoperability of the rail vehicle provides interoperability of the conditions for the subsystem „rolling stock” and subsystem „Control – equipment on board”. For vehicles without power – passenger carriages and freight wagons – assessment of interoperability relating to the subsystem „Control – board equipment” need to check only that the vehicle operation does not interfere with other subsystems. The scope of parameters and rule for testing this subsystem include in [2, 7, 9].

For clearly the mean of transport describing, the type of vehicle is set in the number of index *nps*. The set of numbers of mean of transport will be define as $\mathbf{SR} = \{nps: nps = 1, \ldots, NPS\}$, which NPS is the number of type vehicle.

Taking into account the interpretation of [2] concerning the understanding of the railway line as a set of subsystems, we can write:
$PS^{T}(nps)$ – structural subsystem „Tabor”,
$PS^{ST}(nps)$ – structural subsystem „Control – Command and Signaling (on board)”,
$PF^{RS}(nps)$ – functional subsystem „Operating”,
$PF^{MS}(nps)$ – functional subsystem „ Telematics”,
$PF^{US}(nps)$ – functional subsystem „Maintenance”,
so any type of vehicles *nps* can be represented as a set of subsystems $\mathbf{st}(\boldsymbol{nps})$:

$$\mathbf{st}(\boldsymbol{nps}) = [\mathbf{PS^{T}}(nps),\ \mathbf{PS^{ST}}(nps),\ \mathbf{PF^{RS}}(nps),\ \mathbf{PF^{MS}}(nps),\ \mathbf{PF^{US}}(nps)]. \quad (5)$$

Because the subject of certification and the verification WE the subsystem and its authorization, obtain only the structural subsystems, therefore, an assessment of the railway vehicle to adapt to the requirements of interoperability can be simplified structural subsystems, and we write: $\forall$ *nps* $\in$ **SR st(*nps*)** = [$\mathbf{PS^T}$ (*nps*), $\mathbf{PS^{ST}}$ (*nps)*].

In order find the moment "t" ($t \epsilon \mathbf{T}$, **T** – set of moments), while same subsystem met the interoperability requirements the Cartesian multiplex form for subsystems *nps* type of vehicle and set of moments **T** should be evaluate by $\mu 1$ as elements of multiplex in to set {0,1}, e.g.:

$$\mu 1(\mathbf{PS^T}\ (nps), t) = \begin{cases} 1, for\ subsystem\ in\ moment\ t\ as\ it\ is\ interoperability \\ 0, for\ subsystem\ in\ moment\ t\ as\ it\ is\ not\ interoperability, \end{cases}$$

similar, for subsystem $\mathbf{PS^{ST}}$ (*nps*) put evaluate $\mu 2$.

So the interoperable of the vehicle we can consider, if all structural subsystems are interoperability ($\mathbf{PS^q}$ – it is set of number of type vehicles, which are interoperable, $\mathbf{PS^q} \subseteq \boldsymbol{SR}$), that means everyone met the interoperability requirements:

$$\forall\ t \in \mathbf{T}\ nps \in \mathbf{PS^q} \Leftrightarrow \mu 1(\mathbf{PS^T}\ (nps), t) \cdot \mu 2(\mathbf{PS^{ST}}(nps), t) = \mathbf{1}. \quad (6)$$

4.3. Interoperability of the rail network

Determination of the railway network of the Member State of the European Union, as interoperability, requires the establishment of the determinants of allowing such a statement [18]. Directive of the European Parliament and of the Council 2008/57/EC and the associated Technical Specifications for Interoperability (TSI) indicate a close relationship to meet interoperability requirements from the fact of belonging to a railway line under the TEN-T. Any major change in the structural subsystems, in particular, may affect negatively the level of safety on the railway line of the TEN-T, implies the need for the implementation and application of the requirements of the TSI.

The possibility to extend the interoperability requirements for all the rail network is given by directive 2008/57/UE [2] to decision of UE member. With such a possibility also benefited Poland, introduced in 2011, amendments to the Law on Railway Transport (Chapter 4a, conditions to ensure the interoperability of the rail system on Polish territory) imposed unavoidable duty of implementing interoperability also on lines outside the TEN-T network.

In authors of the article opinion, finding the interoperability of the rail network should, however, be related to resulting from Route establishing the European Community relating to the obligations of the Member State concerned to the application and implementation of the Directives and Regulations of the EU.

According to [15] and [17], the individual Member States are obliged to implement interoperability on the core net TEN-T to 2030 and comprehensive TEN-T to 2050.

If the set of railway lines belonging to the TEN-T ($\mathbf{TEN^B}$ **-** set of numbers of rail lines in core net $\mathbf{TEN^B} \subseteq \boldsymbol{NRL}$), we write as follows $\mathbf{TEN^B} = \{nrl: \varphi(nrl) = 1, nrl \in \boldsymbol{NRL}\}$, which:

- *φ(nrl)* is binary function describe the contain line to the core net TEN-T,
- *φ(nrl)* = 0 – the number *nrl* line do not contain in the core net TEN-T,
- *φ(nrl)* = 1 – the number *nrl* line contain in the core net TEN-T,

and symbol $\mathbf{TEN^K}$ that mean set of numbers of railway lines in comprehensive net TEN-T ($\mathbf{TEN^K} \subseteq \boldsymbol{RL}$), so the set of railway lines which include in in comprehensive net TEN-T: $\mathbf{TEN^K} = \{nrl: \delta(nrl)=1, nrl \in \boldsymbol{NRL}\}$, which:

- *δ(nrl)* is binary function describe the contain line to the comprehensive net TEN-T:
- *δ(nrl)* = 0 – the number *nrl* line do not contain in the comprehensive net TEN-T,
- *δ(nrl)* = 1 – the number *nrl* line contain in the comprehensive net TEN-T,

and determine the time frame for the implementation of the interoperability of the railway lines

contain in core net (t = 2030 y.) and comprehensive net (t = 2030 y.), so interoperability is the condition of the rail network can be formulated as follows:

$$\sum_{nrl \in \mathbf{TEN}^{B}} \theta 1(\mathbf{PS}^{I}\ (nrl), 2030) \cdot \theta 2(\mathbf{PS}^{E}(nrl), 2030) \cdot \theta 3(\mathbf{PS}^{S}(nrl), 2030) = \overline{\overline{\mathbf{TEN}^{B}}}, \quad (7)$$

which: $\overline{\overline{\mathbf{TEN}^{B}}}$ – the number of railway lines contain in the core net TEN-T,

$$\sum_{nrl \in \mathbf{TEN}^{K}} \theta 1(\mathbf{PS}^{I}\ (nrl), 2050) \cdot \theta 2(\mathbf{PS}^{E}(nrl), 2050) \cdot \theta 3(\mathbf{PS}^{S}(nrl), 2050) = \overline{\overline{\mathbf{TEN}^{K}}}, \quad (8)$$

which: $\overline{\overline{\mathbf{TEN}^{K}}}$ – the number of railway lines contains in the comprehensive net TEN-T.

4.4. Interoperability between superstructure and infrastructure

The integration of rail transport subsystems can be considered structural subsystems of the railway and transport meet all the requirements of interoperability, which is confirmed by the certificate of EC verification of structural subsystems and the decision of NSA (National Authorization Body) to authorize the placing in service of structural subsystem:
so for: $t \in \mathbf{T}$, $nps \in \mathbf{SR}$, $nrl \in \mathbf{NRL}$, we could save the following condition:

$$\mu 1\left(\mathbf{PS}^{T}\ (nps), t\right) \cdot \mu 2\left(\mathbf{PS}^{ST}(nps), t\right) \cdot \theta 1\left(\mathbf{PS}^{I}\ (nrl), t\right) \cdot \theta 2\left(\mathbf{PS}^{E}(nrl), t\right) \cdot \theta 3\left(\mathbf{PS}^{S}(nrl), t\right) = \mathbf{1}, \quad (9)$$

5. Conclusions

Market analysis and research for services and for rail transport, despite the „crisis" and economic stagnation in rail transport, indicate the potential growth and increase tendency for the railway traffic, as a result of 'integration' the rail systems, implementation of interoperability and, consequently, the removal of existing barriers and limitations: technical, operational and legal – administrative.

The interest in rail transport in international traffic results from the demand for this mode of transport as globally as well as in the area of European Union countries. EU intentions are focused on clearing the railway lines to the ports and industrial regions or distribution of goods and cargo areas, the connections between large cities and major conurbations, cross-border connections between macro-regions with different levels of economic development. The expected range of changes in rail transport allows concluding that these changes are dimension of scope as transformation of the railway system. It is focused on a new approach to the operation of railway transport, including meeting the expectations of stakeholders about the opportunities to participate in the open market of services and rail transport in the European Union countries.

The time frame and geographic scope of the implementation of interoperability are measurable, and the process of implementation of the requirements is already started. As a result of the transposition of the provisions of the EU, directives and national legislation to entities associated with the operation of the rail system are legally obliged to implement the new requirements, in particular in the field of interoperability.

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