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THE CERTAIN APPROACH TO THE ASSESSMENT OF INTEROPERABILITY OF RAILWAY LINES

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Abstract: *This paper presents the main aspects concerning the systemic approach to the problem of interoperability 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 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 signaling systems, power supply and operation system, to be rich on the safe and not disrupted train running over the different countries (different infrastructure managers). The article indicated the main areas in the railway system which are depends on strongly of the interoperability implementation.*

Key words: *interoperability, railway, assessment of requirements, transport system*

1. Introduction

Commissioned by the European Commission's analysis and the development of Study [17], [18] 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 to reduce cost of transport services [16], [17].

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 [16], [17]. 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 o passenger and freight trains without unnecessary aforementioned restrictions. The European Commission and 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 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 were adopted directives: 2004/49/UE (as. amended.) on the safety of railway traffic [2], 2012/34/EU (originally 2001/14/EC) concerning the allocation of routes [4], 2008/57/UE (as. amended.) on the interoperability of the rail system [3], implementing decisions - Technical Specifications for Interoperability.

Interoperability has many meanings, depending on the discipline in which it is applied. Basically means active participation in the ongoing process to ensure that the systems, procedures and culture of the organization are managed in such a way as to maximize opportunities for exchange and re-use of information, both internally and externally. The concept of interoperability has emerged as a result of increased customer expectations with regard to the compliance of devices and systems in order to increase the availability and attractiveness of the product. Generally, interoperability is defined as: “a property of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, without any restricted access or implementation [3].

Interoperable adj. - able to operate in conjunction (Concise Oxford Dictionary)

In rail transport, the concept of interoperability appeared along with the implementation of European Directives relating to the establishment of the rail market and increase the possibility of transfer of the transport by rail between countries in European Union [16], [19], [20], [21]. Implementation of this idea, however, is charged exceptional complexity and difficulty, specific to each country.

Although these systems have the same goal, i.e. the movement of people and goods, it is organize in a variety of administrative - legal and technical conditions (other command control-command and signaling and signaling systems, traction power supply, gauge, etc.). Measures taken in order to eliminate the differences became the primary order to integrate "individual" the railway systems and it is meaning as the fulfillment the requirements of the interoperability for the rail system [3], [12].

The definition of interoperability of railway terminology is given in Directive 2008/57/EC, as follows: „Interoperability means the ability of a rail system to allow the safe and uninterrupted movement of trains which accomplish the required levels of performance for these lines. This ability depends on all the regulatory, technical and operational conditions which must be met in order to satisfy the essential requirements".

2. 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 [31].

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 [12].

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:

LK = {nrl: nrl = 1 ,…, NRL}, which NRL is the number of line.

Taking into account the interpretation of [3] 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 lk(*nrl*):

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

Because the subject of certification and the verification WE the subsystem and its authorization, obtain only the structural subsystems [3], [12], therefore, an assessment of the railway line to adapt to the requirements of interoperability can be simplified structural subsystems, and we write:

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

In order find the moment "t" ($t \in T$, T – set of moments), while same subsystem met the interoperability requirements the Cartesian multiplex form for subsystems *nrl* line and set of moments T should be evaluate by θ1 as elements of multiplex in to set {0,1}, e.g..:

$\theta 1\left(\mathbf{PS}^{\boldsymbol{I}}(nrl), t\right) =$

$$\begin{cases} 1, \; for\, interoperability\, subsytem\, in\, moment\ "t" \\ 0, \; for\, not\, interoperability\, subsystem\, in\, moment\ "t" \end{cases}$$

Similar, for other subsystems: PS^E (nrl) i PS^S(nrl) put evaluate: θ2, θ3.

So the interoperable of the line we can consider, if all structural subsystems are interoperability (LK^q – it is set of numbers lines which are interoperable, $\mathbf{LK^q} \subseteq \boldsymbol{NRL}$, that means everyone met the interoperability requirements:

$$\forall t \in \mathbf{T}\ \ nrl \in \mathbf{LK^q} \Leftrightarrow \theta 1(\mathbf{PS}^{\boldsymbol{I}}(nrl), t) \cdot \theta 2(\mathbf{PS}^{\boldsymbol{E}}(nrl), t) \cdot \theta 3\left(\mathbf{PS}^{\boldsymbol{S}}(nrl), t\right) = \mathbf{1} \qquad (1)$$

3. Interoperability vehicle (train)

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 [3]. 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 [5], [6], [9], [11].

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 follows:

SR = {nps: nps = 1 ,…, NPS}, which NPS is the number of type vehicle.

Taking into account the interpretation of [3] 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 st(nps):

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

Because the subject of certification and the verification WE the subsystem and its authorization [12], 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∈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 μ1 as elements of multiplex in to set {0,1}, e.g..:

$\mu 1\left(\mathbf{PS}^{\boldsymbol{T}}(nps), t\right) =$

$$\begin{cases} 1, \; for\, interoperability\, subsytem\, in\, moment\ "t" \\ 0, \; for\, not\, interoperability\, subsystem\, in\, moment\ "t" \end{cases}$$

similar, for subsystem $\mathbf{PS^{ST}}$(*nps*) put evaluate μ2.

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:

$$\forall t \in \mathbf{T}\ nps \in \mathbf{PS^q} \Leftrightarrow \mu 1(\mathbf{PS}^{\boldsymbol{T}}(nps), t) \cdot \mu 2\left(\mathbf{PS}^{\boldsymbol{ST}}(nps), t\right) = \mathbf{1} \qquad (2)$$

4. 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 [3]. Directive of the European Parliament and of the Council 2008/57/EC and the associated Technical Specifications for Interoperability (TSI) [5], [6], [7], [8], [9], [10], [11], [13], [15] 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 [2], 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 [3] to decision of UE member. With such a possibility also benefited Poland [31], [34], 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 [16], [18], [21] 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 $\mathbf{TEN}^{\boldsymbol{B}} \subseteq \boldsymbol{NRL}$), we write as follows: $\mathbf{TEN^B} = \{nrl: \varphi(nrl) = 1,\ nrl \in \boldsymbol{NRL}\}$,

which: $\varphi(nrl)$ is binary function describe the contain line to the core net TEN-T:

$\varphi(nrl) = 0$ – the number *nrl* line do not contain in the core net TEN-T,

$\varphi(nrl) = 1$ – 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 ($\mathbf{TEN}^{\boldsymbol{K}} \subseteq \boldsymbol{RL}$), 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: $\delta(nrl)$ is binary function describe the contain line to the comprehensive net TEN-T:

$\delta(nrl) = 0$ – the number *nrl* line do not contain in the comprehensive net TEN-T,

$\delta(nrl) = 1$ – 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 = 2050 y.), so interoperability is the condition of the rail network can be formulated as follows:

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

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

$$\sum_{nrl \in \mathbf{TEN}^{\boldsymbol{K}}} \theta 1\left(\mathbf{PS}^{\boldsymbol{I}}(nrl), 2050\right) \cdot \theta 2\left(\mathbf{PS}^{\boldsymbol{E}}(nrl), 2050\right) \cdot \theta 3\left(\mathbf{PS}^{\boldsymbol{S}}(nrl), 2050\right) = \overline{\overline{\mathbf{TEN}^{\boldsymbol{K}}}} \tag{4}$$

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

5. Interoperability 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 [12], 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:

$$\mu 1\left(\mathbf{PS}^{\boldsymbol{T}}(nps), t\right) \cdot \mu 2\left(\mathbf{PS}^{\boldsymbol{ST}}(nps), t\right) \cdot \theta 1\left(\mathbf{PS}^{\boldsymbol{I}}(nrl), t\right) \cdot \theta 2\left(\mathbf{PS}^{\boldsymbol{E}}(nrl), t\right) \cdot \theta 3\left(\mathbf{PS}^{\boldsymbol{S}}(nrl), t\right) = 1 \tag{5}$$

6. Transformation of the 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 [17]. As stated in [27], [28] for the physical realization of the movement of goods or persons are 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 [27] is **S = < A, R >,** 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 [3] 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 [4], [18], [20].

7. Aggregation of technical areas in subsystems

As defined in [3] and in the transposition of the Law on Railway Transport [31] *"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.

7.1. The existing rules for admission of railway vehicles

On the basis of a RIC and 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.

7.2. 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 command-control signals subsystem [11] which is connected with the conformity assessment applied technical solutions to the requirements of the Technical Specifications for Interoperability, inter alia, [5], [6], [7], [8], [9], [10], [11], [13], [15]. 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) [3].

7.3. 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 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 [3], security management with the integration of system components [2], the use of technical requirements for functional subsystems [10], [13], [15],

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) [2] and the availability of the rail network for rail carriers the European Union [4] (Fig. 1 and Fig 2).
The scope of changes give 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.

8. Determinants of interoperability implementation

The implementation plan for interoperability on the railway network depends mainly on obtaining answers to the following questions:
How to determine the plan of the modernization the railway lines in order to adapt them to the requirements of the interoperability, taking account the importance of the railway line, the railway network consistency and availability of financial resources?
The railway line should be adapting to the requirements of interoperability, or not ? How to do assessment for this railway lines?
International commitments regarding the TEN-T corridors and international freight corridors indicate the lines which should be a priority in the implementation plan for interoperability [13].

In addition, the TSIs are dedicated to railway lines located in the corridors of the TEN- T, particularly defining, how to conduct the migration of structural subsystems and what are the time frame for the full application of the TSI (for [7], [8] until 2021y.)
Because, in the case of railway lines located outside the TEN –T, there is no clear interpretation of the legal and technical as the timing and scope of the implementation of the interoperability, it is necessary to identify those factors that enable them to determine the priority of individual railway lines, taking into account adaptation to the requirements of interoperability for the entire rail network.
Such factors are closely related to the modalities provided for in Directive 2008/57/UE and Technical Specifications for Interoperability. Basically to evaluate the railway line should indicate:

1) Membership of the railway corridor TEN-T;
2) Estimated demand for interoperable trains on the railway line;
3) Co-financing of the modernization of the railway line from the EU;

The economic effect resulting from the difference in revenue resulting from the size of the number of interoperable trains for passenger and freight traffic to the costs arising from the modernization and adaptation to the requirements of interoperability line [29].

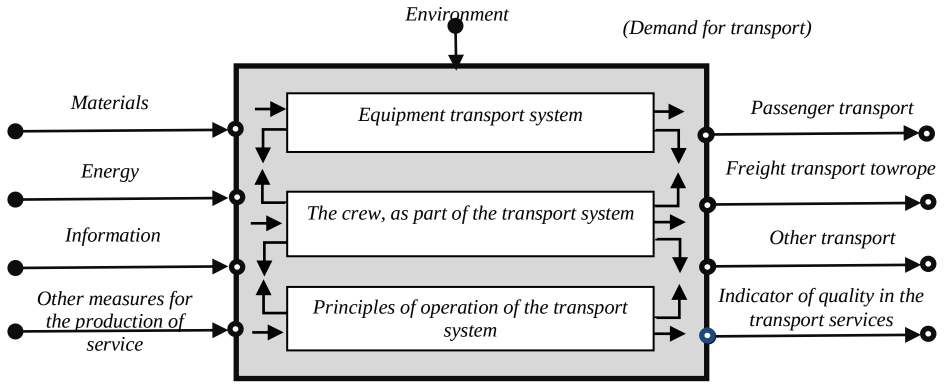

Fig. 1. Existing railway system - transformation inputs to outputs
Source: based on [3].

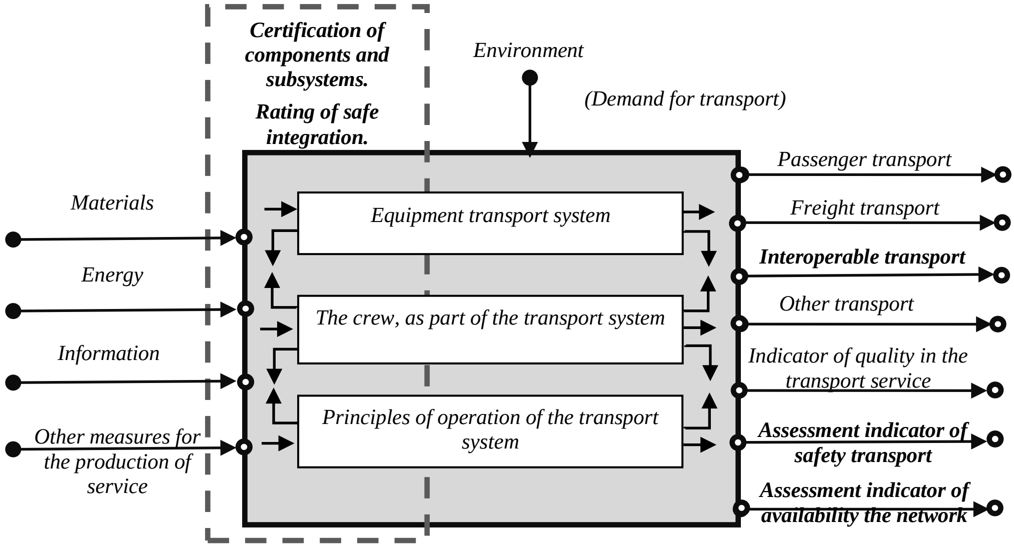

Fig. 2. New railway system – transformation inputs to outputs
Source: own work and based on [3], [12].

Taking into account national circumstances, type of surface (truck bed), including traction power network and control-command and signaling devices can be concluded that, although the structural subsystems of infrastructure and energy does not require significant changes so much as the control-command and signaling subsystem (track-side) require a quite new, expensive ETCS system (and GSM -R) [1][16].

Therefore, if the lines are located in the corridors of the TEN-T upgrading of these subsystems may be "easier" to implement, whereas installing ERTMS outside TEN-T corridor - can give rise to serious doubts [1].

In this context, questions is about the economic justification for the changes, the analysis does not indicate the offer, the demand for interoperable train on the railway line. In this case, it is also difficult to expect a positive NPV, i.e. the advantage benefits over costs for the investment in a given time [29].

Railway undertakings pursuing traffic on this rail line would not to be interested to investing in interoperable rolling stock. For this reason, adjusting the line to interoperability cannot justify the financial effect on the railway line, undermining the whole point of the allocation of funds for its reconstruction [29].

Such considerations may provoke to the reflection on the assessment of the determinants of railway lines (not belonging to the TEN-T), in terms of adapting their to the requirements of interoperability. For such determinants can indicate restrictions:

1) Appropriate transport offer for interoperable trains

Limited due to the minimum number of interoperable train forming for the transport offer - attractive from the point of view the passenger travel time or the frequency of this services. Given that the interoperable trains, in the strict sense definition, should not be detained in other cases than for the purposes of commercial activities, may obtain the time which value will be the shortest, depending on the maximum travel speed.

Obtaining the correct frequency of services mean as the ability to secure routes for interoperable train at different times of the day. If we take into account the fact that the interoperable trains are moving at the longer rout than the national trains, and thus the travel time between a start and end

stations can take more than a few hours, even distribution of intervals time in train paths can increase the attractiveness of the service [16], [18], [22], [35], [35].
The above benefits relate basically to the Railway Undertakings that will have the incentive to invest in interoperable rolling stocks, as well as, to the use of data rail line [26].

2) Justifications for the economic modernization of the line
Limited due to economic efficiency should be considered from the point of view of financial benefits for the lines of the commercial (outside the TEN -T). This is a different point of view in relation to the "corridor", where the benefits must also be considered in a wider scope and scale, among others taking into account social, environmental and political one [17], [18], [19], [20], [21], [23].
In order to determine the economic effects constraints should be compared with the expected number of interoperable trains on the line, retraining of existing trains into the interoperable as freight trains and passengers trains, etc. With this increase will be the benefit of reducing operational costs.
In other case, the question of the size of the necessary financial resources for the change the structural sub-systems, in particular the implementation of the type ERTMS system [1], [24].
Analysis of the size required to capital expenditures incur should refer to relevant aspects of traffic and operating, obtaining the minimum headway time between trains, the buffer time which will compensate the delays (primary and transmitted to other trains), and adequate the traffic on the railway line [22], [33], [35], [35].
The economic effect will therefore be a difference between the benefits of the minimum number of interoperable trains running on the line and the minimum cost necessary to keep the requirements of interoperability.

3) Additional interoperable train
The limit of the capacity of the railway line is defined as the maximum achievable number of additional interoperable train routs with the introduction of appropriate buffer time “window” for existing train routs, which are reclassified into interoperable trains.
The maximum value can be determined on the basis of the density of trains on the rail line, and the probability of negative impact as a result of the emergence of deviation of the train running from the scheduled route [4], [22], [33], [35], [35].

$$Nadd = \frac{N^{\frac{-z_0}{z_m}}}{e^{\frac{tn+z_0}{z_m}} - 1} \qquad (6)$$

$z_m = i_m - tn$ -average buffer time, $i_m =$ disposable time/number of trains in day, tn – headway time, z_0 - the minimum buffer time between trains.
4) The terms for interoperable train, buffer time with "coming" train routes in the existing the timetable.
Limitation in buffer time depends on the run distance of interoperable train and from the requirement of its "undisrupted" movement. If takes into account the way of the interoperable train, consisting of several sections of the railway line, passing over the different railway nets (infrastructure managers), as well as movement disorders generated in nodes and in junctions, it is necessary to take into account of the temporary buffer time for interoperable train. So the trains could move from one line to the other one without collisions.
The “window” time can be interpreted as the time dilatation (time implications of the train increased by extra time), allowing the suppression of interference by the absorption of the primary delays train to a scheduled time for the next train routes [21], [16].
It remains to determine the dilatation of time of trains and how many train routes will be altered as a result of the emergence of the initial disturbance. Such analyzes require to examine and evaluate how does the distribution of train paths, so the whole day or in the rush hour [33], [35], [35].
It is important question: is that the intensity of entry of the trains, as well as the time of running, are the shifted exponential distribution or based on completely random phenomenon [22], [33], [35], [35]?

Above mentioned restriction specifies the possibility of obtaining maximum movement of trains with the involvement of interoperable trains with the fluency of their run and the possibility to the absorption of the primary delays [35].

On the basis of the so -defined priority issues can develop a model [23], [27], [28] for the assessment of railway lines in adapting to the requirements of interoperability.

As a result, it will be possible to develop a list of railway lines, compiled chronologically according to their priorities for the implementation of interoperability.

9. 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 allow to conclude 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. Although almost all of the requirements have been formulated and given in the EU documents (e.g. regulations TSI), questions remain about the railway lines which are not part of TEN-T net (the different technical characteristics and movement, different categories and levels of maintenance infrastructure, with large share of traffic of local trains, etc.

Given the above, it is justified to develop a simulation model [26], [27], [28] which will based on various determinants as: investment costs and benefits of the interoperability's traffic, required scope of change in order to met the interoperability requirements, high of the capacity of line, point of view of interoperability stakeholders

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