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Faculty of Engineering Economics and Management
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ELABORATION AND DESIGN OF PUBLIC-USE RAILWAY INFRASTRUCTURE OPTIMAL DEVELOPMENT MODELS

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THE DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF ECONOMIC SCIENCE

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Engineering Sciences (Telecommunications) is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Justina HUDENKO…………………………….

Date: ……………… 2017.

The Doctoral Thesis has beenwritten in Latvian. It consists of introduction, 4 parts, conclusions, bibliography and 9 appendixes. It includes 38 figures and 14 tables. The volume of the present Thesis is 159 pages. The bibliography comprises 224 reference sources.

The Thesis and its summary are available at Riga Technical University Scientific Library, 5 Paula Valdena Street, Riga.

Comments on the thesis may be send to the secretary of RTU Promotion Council RTU P-09, Prof. *Dr.oec.* K. Didenko, Riga Technical University, 6 Kalnciema Street, Riga, LV-1048, Latvia.
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GENERAL DESCRIPTION OF THE THESIS

Rail infrastructure is one of the most important parts of the national and global economy. Modern and developed railway infrastructure is one of the factors that determine the country's development opportunities. This fact is of prime importance given the global trends in regional specialization. Railway infrastructure provides significant national freight and passenger volumes, transit, export and import flow, by connecting local producers with raw material sources, worldwide production and service markets. So, the rational development of railway infrastructure and the choice of the most perspective direction of its evolution are essential in all countries as well as in Latvia (hereinafter also LR). Comprehensive information on the functioning of the railway infrastructure and its commitment to macroeconomic and microeconomic processes shall be prepared in order to ensure the optimum of the railway infrastructure development while adopting appropriate management decisions.

The development of the Latvian railway infrastructure is determined by a number of policy documents which are harmonized with European Union (hereinafter also EU) transport policy documents (the White Paper, the Lisbon strategy) and with mandatory laws. The Directive 2012/34/EU, which is implemented into the Latvian national legislation, provides that the Member States shall develop their national railway infrastructure by taking into account, the general needs of the EU, including the need to cooperate with neighboring third countries. To this end, Member States shall draw up an indicative development strategy where, based on sustainable financing of the railway system, the vision of mobility needs at the national level shall be included. The strategy shall cover a minimum period of five years and be renewable.

Railway infrastructure and its links to the economy represent a very complex organizational, technical - technological, environmental and socio- economic system that is affected by management decisions on different levels of the economy. A variety of modeling approaches, different types of models and modeling tools are usually used in order to establish development directions of such system. Afterward, different decision-making systems are designed based on the models made. European Commission (hereinafter also EC) issued documents show that modeling is a key tool for sustainable socio-economic development policy-making and point out the three main types of use:

- modeling gives more comprehensive insights into the functioning of economic systems;
- modeling provides forecasting capabilities of the processes;
- modeling allows creating a variety of development scenarios.

It should be noted that, in general, despite the diversity of modeling approaches and abundant practice, railway modeling lacks a holistic approach – models are designed either on microeconomic (or even on a certain process), or industry (selecting a certain transport mode) or national (as well as transnational) levels, but level connection opportunities and social rate of return has not been studied at the academic level.

Adoption of a model developed for another country to Latvia is incorrect in any way due to differences in national historical development, geographical situation, legal requirements and national development peculiarities. Latvian railway infrastructure is a specific case because it was not designed for domestic needs, but mainly Russia's, Belarus' and other former Soviet republics' raw material transportation to the Baltic sea ports. This type of rail infrastructure usage has been preserved to this day. Thus, the most important factors influencing the railway operation occur in response to the global traffic flow instead of the Latvian economy. On the other hand, Latvia had to implement the EU's single railway area policy after joining the EU, where the main objective is the reduction of the transportation costs and environmental impacts. Such a dual dependence and a number of other peculiarities require more attention when making decisions both on macroeconomic and on microeconomic levels. Taking into consideration the notable importance of Latvian railway in the economy (Latvian Railway is one of the largest companies, employers and taxpayers, which provides even a quarter of export earnings), the decisions taken at all levels must be consistent, in other words, the factors influencing the decision-making process must be understandable. Therefore, it is rational to create the original problem-solving methodology for a specific rail infrastructure modeling object.

So the railway infrastructure is a multi-disciplinary object and decision-makers lack a holistic understanding of rail-related economic interaction processes both at the micro level and the macro level. There no common methodology and modeling approach to develop the topical development programs related to the cost and environmental impact of the transport sector with respect to market requirements to provide flexible delivery schedules.

The goal of the thesis

The thesis is aimed at elaborating public-use railway infrastructure optimal development modeling methodology and models and at designing the models to the Latvian public railway infrastructure in order to determine the optimal directions of its development, by using the analysis of the peculiarities and factors that contribute to or restrict railway infrastructure development.

The tasks of the thesis

To achieve the aim, the following tasks are specified:

1) to identify the peculiarities of the Latvian and other public-use railway infrastructures around the world;
2) to structure decision-making on public-use railway infrastructure processes and to establish the links between railway infrastructure and economic processes at the micro- and the macro-level and their interactions;
3) to analyze the railway and other transport modes infrastructure development models around the world, their advantages and disadvantages;
4) to analyze modern theoretical approaches that reflect the impact of the selection of directions and objectives of the public-use railway infrastructure development to the state's economic development;
5) to elaborate the modeling methodology of public-use railway infrastructure development, by the structuring of rail infrastructure test parameters, endogenous and exogenous factors that affect the development of railway infrastructure and their indicators, as well as by creating of development targets optimization approach;
6) to use elaborated principles of rail infrastructure optimal development modeling in order to establish the development directions of the Latvian rail infrastructure;
7) to collect and to analyze information on the development of railway infrastructure in Latvia and other Baltic countries;
8) to develop proposals for the rail infrastructure development program makers and users, and to identify future research areas.

The object of the research

The **object** of the research is public-use railway infrastructure and specifically Latvian public-use railway infrastructure.

The subject of the research

The **subject** of the research is development and management processes, decision-making on development tendencies, development modeling including optimization modeling of public-use railway infrastructure.

Research methods

The research is based on the general theoretical research methods, such as induction and deduction, analysis and synthesis, systematic approach as well as the specific research methods such as mathematical modeling, data grouping, time series analysis, graphic, ANP (Analytic Network Process), expert assessments, etc.

The methodological foundation of the research

The research is based on the theoretical and methodological foundation of foreign scientific works *(J. Bradley, B. de Borger, F. Calvo, M. Fisher, M. Florian, C. Growitsch, K. Jansson, P. Krugman, S. Maffii, C. Nash, J. de Ona, R. Pittman, J. Preston, S. Proost, F. P. Ramsey, W. Roeger, T. Saaty, L. S. Thompson, W. G. II. Waters, H. Wetzel, M. Wickens, C. Woroniuk, Я. А. Дубров, В. Б. Савчук)*, etc. and Latvian (J. Māsāne-Ose, L. Frolova, M. Šenfelde u.c.), theoretical and practical knowledge.

The informative foundation of the research

The information is base on the research of SJSC "Latvian Railway" key indicators, UIC (International Union of Railways) database, Latvian Central Statistical Bureau database, Eurostat and Rosstat data, www.bank.lv, www.lb.lt, www.eestipank.ee, www.cbr.ru balance of payments data, the European Rail Agency's reports, etc. Secondary data and author's calculations also used in the research. The geographical area of indicators used was narrowed in a view of the railway sector technical connectivity (European countries with access to the Baltic Sea).

Scientific novelty

The scientific novelty of the thesis is as follows:

- the peculiarities (organizational, management, technical, financial, usage of resources, costs etc.) of the Latvian and other railway infrastructures around the world that affect the modeling approaches and choice of infrastructure development direction were identified and assessed;
- the optimal railway infrastructure development concept in its broader meaning was summarized and related endogenous and exogenous factors were identified;
- the new theoretical insights of rail infrastructure development targets and the evaluation process of their fixing and optimization were established;
- a critical analysis of the railway infrastructure development and optimization development models around the world was made and limitations of their usage were formulated;
- the factors affecting test parameters and indicators used for a rail infrastructure analysis and elaboration of models and development scenarios were systematized and grouped;

- the elaboration methodology of a public-use railway infrastructure optimal development models based on exploring of various levels and multi-criteria decision-making approaches were created;
- the Latvian public-use railway infrastructure development scenarios (models) were elaborated and assessed when the created methodology was tested.

The substantive hypothesis of the research

In order to define the optimal direction of railway infrastructure development, the appropriate holistic modeling approaches and model elaboration methodology must be used, taking into account the interaction of rail-related economic processes at the macro level and the micro level.

Keynotes

- Rail infrastructure and provided cargo and passenger transportation services is a specific case of the economic theory: it has a heterogeneous structure, it is multi-dimensional, its development is influenced by many interrelated endogenous and exogenous factors related to various decision-making levels. The elaborated modeling approach and methodology can be used for its analysis.
- Railway infrastructure operation's economic contradictions exist at the micro level, while decisions about its development are adopted at the macro-level, therefore, the congruent economic models must be developed and used in order to harmonize the interests of various management level entities and to optimize decision-making.

Practical value and approbation of the obtained results

The results of the thesis have been presented at Latvian and international conferences. The obtained results have been used within the reports to the European Commission organized working groups, the meeting on rail transport issues with OECD and industry representatives, the report to the Latvian Ports, Transit and Logistics Council, the working groups organized by Ministry of Transport, the meeting of Latvian Transit Business Association, the Latvian Chamber's transport infrastructure committee meeting on the review of the rail development guidelines mid-term, the advisory council meetings of the State Railway Administration, working groups of the Joint Stock Company "Latvian Railway".

The research results have been used for the participation in the national research program 5.2. "EKOSOC-LV" project 5.2.1. „Explore the Competitiveness of Latvian Enterprises in Foreign Markets and Make Proposals for its Strengthening" (LR IZM registration No. 02.2-09/13).

Publications

The results have been published in 10 scientific papers:

1. Hudenko J., Ribakova N., Počs R. Cost that is directly incurred as a result of operating the train service on the 1520 mm rail with primarily freight transportation // Transportation Research Procedia. – 2016. – No.16. – 1914–1922 pp.
2. Hudenko J., Počs R. Latvijas dzelzceļa konkurētspēja Baltijas jūras reģionā // Latvijas Universitātes 74. zinātniskā konference: referātu tēzes. – 2016. Rīga: Latvijas Universitāte, 2016. – 1 p.
3. Hudenko J., Počs R. The Discrepancy between the Service Export Incomes of Rail and Sea Transport among Baltic States Transit Corridors // Proceedings of the 19^{th} World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2015). – Orlando: 2015. – 63–68 pp.
4. Hudenko J., Ribakova N. Costs that is Directly Incurred as a Result of Operating the Train Service: The Case of 1520mm Rail // Proceedings of the conference Management Horizons in Changing Economic Environment: Visions and Challenges. – Kaunas, Lithuania: 2015. – 179–192 pp.
5. Hudenko J. Actual Problems of Public-Use Railway Infrastructure Development Modeling // International Conference "New Challenges of Economic and Business Development – 2013": Conference Proceedings. – Riga: 2013. – 292–304 pp.
6. Hudenko J., Počs R. Latvijas uzņēmumu konkurētspējas ārējos tirgos pētīšanas modeļa izvēle // Latvijas Universitātes 73. konference: referātu tēzes. Riga: Latvijas Universitāte, 2015. – 1 p.
7. Hudenko J., Počs R. The Effects of Internal Failures and External Regulations on State Funding of the Public-Use Rail Infrastructure // International Scientific Conference „Economics and Management – 2014" (ICEM-2014): Conference Proceedings. Riga: Procedia - Social and Behavioral Sciences, 2014. – 216–218 pp.
8. Hudenko J., Počs R. Assessment of the Directive 2012/34/EU, Establishing a Single European Railway Area, Impact to the Latvian Rail Sector // Conference CD “55^{th} International Riga Technical University Conference “Scientific Conference on Economics and Entrepreneurship (SCEE’2014). – Riga: RTU, 2014. – 2 pp.
9. Hudenko J., Počs R. The Microeconomics of the Latvian Railway // 54^{th} International Scientific Conference on Economics and Entrepreneurship (SCEE'2013): Proceedings. Riga: Riga Technical University, 2013. – 2 pp.

10. Andrējeva V., Hudenko J. Unification of Public-Use Railway Infrastructure Charging // Riga Technical University 53rd International Scientific Conference: Dedicated to the 150th Anniversary and the 1st Congress of World Engineers and Riga Polytechnic Institute / RTU Alumni: Digest. Riga: Riga Technical University, 2012. – 5 pp.

The results of the thesis have been presented at 16 international scientific conferences and seminars:

1) Report: „Unification of Public-use Railway Infrastructure Charging", RTU the 53rd International Scientific Conference, Riga, 2012.
2) Report: „Actual Problems of Public-Use Railway Infrastructure Development Modeling", New Challenges of Economic and Business Development. Riga, 2013.
3) Report: „The microeconomics of the Latvian Railways". RTU the 54th International Scientific Conference, Riga, 2013.
4) Report: „Actual Problems of Public-Use Railway Infrastructure Development Modeling", New Challenges of Economic and Business Development – 2013, Riga, 2013.
5) Report: „Assessment of the Directive 2012/34/EU, Establishing a Single European Railway Area, Impact to the Latvian Rail Sector" Scientific Conference on Economics and Entrepreneurship (SCEE'2014), Riga, 2014.
6) Report: „The Effects of Internal Failures and External Regulations on State Funding of the Public-Use Rail Infrastructure" International Scientific Conference „Economics and Management – 2014" (ICEM-2014), Riga, 2014.
7) Report: „The Rail and Sea Transport International Charge Level Coherence and Comparison among Baltic States Transit Corridors", the 6th International Conference "Economic Challenges in Enlarged Europe", Tallinn, 2014.
8) Report: „The Selection of a Model for Researching Latvian Business Competitiveness on External Markets", Latvian University the 73rd Scientific Conference, Riga, 2015.
9) Report: „Costs that is Directly Incurred as a Result of Operating the Train Service: The Case of 1520mm Rail", Management Horizons in Changing Economic Environment: Visions and Challenges, Kaunas, 2015.
10) Report: „The Discrepancy between the Service Export Incomes of Rail and Sea Transport among Baltic States Transit Corridors", World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2015), Orlando, 2015.
11) Report "Charging peculiarities on European 1520", InnoRail 2015, Budapest, 2015.

12) Report: «Гибкая тарифная политика в период кризисных явлений в экономике. Опыт Латвийских железных дорог», 3-я Международная конференция по тарифам и ценообразовнию на железнодорожном транспорте, Moscow, 2015.
13) Report: "Estimation of the Latvian Railways Competitiveness in the Baltic Sea Region", Latvian University, the 74th Scientific Conference, Riga 2016.
14) Report: "How much money is needed?" RailTech Conference: Track Access Charges Summit 2016, Bern, 2016.
15) Poster presentation: "Cost that is directly incurred as a result of operating the train service on the 1520 mm rail with primarily freight transportation", Transport Research Arena 2016, Warsaw 2016.
16) Report: «Системная координация и увязка технологических и тарифных решений в перевозках грузов по международным транспортным коридорам», 4-я Международная конференция по тарифам и ценообразованию на железнодорожном транспорте, Moscow, 2016.

Volume and structure of the thesis

The doctoral thesis is an original author's research that is developed and written in Latvian. The thesis consists of 163 pages excluding appendixes. The doctoral consists of introduction, 4 parts, conclusions, bibliography and 6 appendixes. It includes 38 figures and 14 tables. The bibliography comprises 224 entries.

The first part „the Analysis of a Public-use Railway Infrastructure as a Modeling Object" discloses a variety of management, technical and other technological aspects associated with the services provided on public-use railway infrastructure. It describes and evaluates the decision-making levels. It contains the analysis of the management and organizational structure of Latvian railway infrastructure. It provides insights into railway infrastructure usage and railway economical features, including specific services provided on rail infrastructure, opportunities to provide and attract resources as well as railway infrastructure competitiveness dimension and financing issues.

The second part „the Modeling of Public-use Railway infrastructure development" discusses a critical analysis of modeling approaches and models of the public-use railway infrastructure development, reflecting the advantages, disadvantages and application possibilities. It presents the latest results of scientific research in the field of railway infrastructure modeling.

The third part „the Methodology of Elaboration of Public-Use Railway Infrastructure Optimal Development Models" contains the analysis of theoretical railway infrastructure optimization approaches. It sets out the author's proposed methodology for model development, its overall scheme, and the implementation stages. The indicator system selection approach and information providing issues are justified. The model scheme is designed to address Latvian public railway infrastructure development challenges.

The fourth part „the Design of Public-Use Railway Infrastructure Optimal Development Models for elaboration and assessment of development scenarios" declares the results of the proposed methodology and the recommended modeling approaches for elaboration and assessment of the possible development scenarios within the Latvian public-use railway infrastructure, including statistical data, factors, criteria, scenario analysis.

Table of Contents

MAIN RESULTS OF THE SCIENTIFIC RESEARCH

1. THE ANALYSIS OF A PUBLIC-USE RAILWAY INFRASTRUCTURE AS A MODELING OBJECT

This chapter provides insights into railway infrastructure usage and railway economical features, including specific services provided on rail infrastructure, opportunities to provide and attract resources as well as railway infrastructure competitiveness dimension and financing issues. It discloses a variety of management, technical and other technological aspects associated with the services provided on public-use railway infrastructure. It describes and evaluates the decision-making levels. It contains the analysis of the management and organizational structure of Latvian railway infrastructure.

In accordance with the Article 5 of the Railway Law[1], the rail infrastructure is divided into the public-use infrastructure and the private-use infrastructure by the type of use. The public-use infrastructure is open for the freight and international passenger services as well as for the technological processes on the principle of equality.

The World Bank has recognized[2] state monopoly organizational as ineffective and the railway undertaking liberalization processes can be observed around the world. Infrastructure owners can select from the following four organizational forms: a public body (the Ministry), a public company, a state enterprise, a private enterprise.

The public-use railway infrastructure management and management decision making can be categorized into four main levels: global (transnational transport systems and global logistics chains), strategic (national), tactical (industry) and operational (company). Actions related to the development and use of railway infrastructure that occurs at different decision-making levels are not sufficiently aligned. As a result, resources are used inefficiently that reduces the overall validity of rail transport system.

Decisions are taken on a global level (transnational transport systems and global logistics chains) ensure optimal production by using infrastructure solutions to connect the world's most cost-effective resources and to achieve global growth.

Decisions taken on a strategic (national) management level determine the overall rail infrastructure development policies and establish operating systems in a specific country, including identification of infrastructure design solutions and technical system development as well as key resource categories; define the range of services, access conditions, and track assess

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[1] Latvijas Vēstnesis: Dzelzceļa likums / Internets. - http://www.likumi.lv/doc.php?id=47774

[2] World Bank: Railway reform : Toolkit for improving rail sector performance. Internets. - http://documents.worldbank.org/curated/en/616111469672194318/Railway-reform-Toolkit-for-improving-rail

charging policy. A government and invited competent authorities to develop and implement high-level planning and legislative documents at national management level.

Decisions are taken on a tactical (industry) management level related to service assurance solutions put in place responsible ministries and invited interested subjects. Tactical plans are realized by optimizing routes and schedules if the end points are known and transportation dynamics are predictable. Decisions on the route, usage frequency, running directions, service and station facilities' range of services, light running prevention, etc. are taken on industry management level too.

The railway infrastructure manager takes decisions on operational (business) management level in cooperation with specialists or delegates part of functions to subcontractors. The target of this level is profit-making or (if such a purpose is prohibited or limited by the decisions of the highest planning levels) fulfilling of various indicative targets. Although the strategic and tactical decisions affect the operational decisions, the rail infrastructure's total result depends on operational decisions.

The characteristic of the prime importance of railway infrastructure is capacity that is railway infrastructure's technical ability to provide a certain type, frequency, regularity and volume of rail transportation[3]. The railway infrastructure's maximum capacity determines the potential of rail transportation volume. It is a constant in the short term. Capacity usage has a seasonal nature. The intense railway operation at peak times impairs economic performance because it requires additional labor and material resources, slows down traffic and causes congestion. Railways with higher passenger share have uneven services during the day and stations are congested during peak periods. Transportation can also be uneven in different parts of the network. Excessive line loading in one direction and an empty wagon movement in the opposite direction is another peculiarity of the railway infrastructure usage. The usage of railway infrastructure is also affected by climatic and topographical conditions.

The cost structure and usage conditions on the railways, which are mainly engaged in the carriage of goods and railways, which are mainly engaged in the carriage of passengers, are completely different. The quality of services provided by rail infrastructure is determined by compliance with its technical - technological parameters with a type of service (freight or passenger transport) and specifics of supply chain organization. The proposed service quality level scales down when the infrastructure is not specialized for a particular type of transport.

[3] Latvijas Vēstnesis: Dzelzceļa likums / Internets. - http://www.likumi.lv/doc.php?id=47774

Capacity utilization and operating process produce externalities: greenhouse gasses, water pollution, noise, congestion, accidents, land use problems[4] where railways compared with other modes of transport (road and air) have more advantages. The choice between different types of infrastructure use can also affect deforestation, inhabitant relocation, etc.

In order to ensure certain activities, the rail infrastructure attracts considerable labor and capital resources. Railway labor market has a specific legal framework. The labor market cannot respond to demand rapidly enough, therefore the railway infrastructure manager is required to cover cyclical and seasonal downtime costs. The railway infrastructure manager is strongly influenced by railway trade unions, so the average wage in the railway sector is higher than it is in other types of transport companies.

The capital resource is viewed in the promotion work in a broad sense, meaning both fixed capital and working capital. In addition to public funding and revenue from minimum access package charges the following rail infrastructure funding sources are foreseen: income from state-owned land lease; profit from infrastructure manager's service facilities; surpluses from other commercial activities; non-refundable income from private sources. The infrastructure manager can attract investments by increasing share capital, including retained earnings and by increasing liabilities.

The EU started railway infrastructure charging unification by the introduction of Directive 2012/34/EU. The new charging system takes into account the correlation between the charge and the cost that is directly incurred as a result of operating the train service and cost reductions due to the expected growth. A study on the distribution of income in the logistics chain "Latvian Railway – Latvian seaports" (with contribution of the author)[5] concludes that the income distribution is not fair, the total income is redistributed in favor of the more monopolistic or less manageable entity that affects the overall transport corridor and can not be compensated by the market mechanism. This enhances an important role of the establishment of cooperative links between the participants of the logistic chain (competing among them too).

So far the infrastructure managers have used mainly the financial sector resources due to their availability and relatively low price. Since 2013, when the Basel agreement entered into

[4] Demir E., Huang Y., Scholts S. Et al. A selected review on the negative externalities of the freight transportation: Modeling and pricing // Transportation Research Part E. 2015. - Nr. 77. – 95–114 p.

[5] Hudenko, J., Počs, R. The Discrepancy between the Service Export Incomes of Rail and Sea Transport among Baltic States Transit Corridors // Proceedings of the 19th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2015). – ASV, Orlando, 2015.

force, the capital adequacy requirements were increased[6]. Banks refer to the lack of resources in the long term and higher input prices (due to the need to procure more capital) [7].

One of the main financing sources is public investment. State funding is often associated with the need to invest in the transport infrastructure because no country has reached the commercial level, when the State funding is *apriori* not necessary. The infrastructure managers alternatively use other state-guaranteed resources for the railway infrastructure maintenance and development - the Cohesion Fund, the European Regional Development Fund, Community financial aid for trans-European network, the European Commission's program "Marco Polo".

Other production resources (factors) used are the employees' knowledge and technologies. But given that the technical - organizational knowledge level is fixed in a short-term, it was generalized that the rail infrastructure services are exclusively dependent on two main factors – labor and capital.

There is a diverse impact of the state to rail economics: with the general macroeconomic instruments, such as taxes, credit and investment opportunities, the business environment, etc. and with macroeconomic policies such as public services market regulation, as well as with the direct impact considering that the state is the owner of the railway infrastructure, the supplier of main production resource (capital), and one of the main clients. Quite a large rail infrastructure manager's dependence on the single entity causes a number of problems. Firstly, the state must ensure market regulation, contrary to their financial interests. Secondly, the railway economy often depends on the lobbying. Thirdly, since investment in railways has a long-term return that does no meet budget programming period.

The role of the state can be evident as a coordination of rail stakeholders group by creating stakeholder group associations, as discussions on the railway system integration capabilities were started in Europe [8]. UNITE researchers propose [9] the use of the total social cost (TSC) concept, which consists of five categories: rail infrastructure costs, supplier production cost, transport user costs, accident costs, environment costs, as a starting point to merge rail stakeholders. The author suggests to supplement TSC with production factors social costs category.

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6 Slovik P. , Cournède B.. Makroekonomics Impact Bāzele III. OECD Work Paper No.844. - OECD Publishing, 2011.

7 turpat

8 O'Sullivan P.J., Patel T. Fragmentation in transport operations and the case for system integrity // Transport Policy. – 2004. – Nr. 11. – 215–225p.

9 van den Bossche M.A. , Certan C., Gpyal P. et al. Marginal cost methodology // UNITE Deliverable 3, Founded by 5th Framework RTD Programme. – Leeds: Institute for Transport Stidies, 2001.

State Joint Stock Company "Latvian Railway" manages Latvian state public-use infrastructure. This is the state owned concern. The Ministry of Transport implements the state policy in the rail transport according to the Transport policy planning documents - Transport Development Guidelines and the indicative rail infrastructure development strategy approved by the Cabinet of Ministers.

Latvian railway infrastructure and its development strategy has a number of features:

– Management decision-making depends on a number of decision-making bodies;
– Strategic planning documents at all levels have clear priority given to the provision of commercial transit;
– Traffic externalities' issues generally are not included in the national planning documents;
– The state does not participate in the railway infrastructure service qualitative characteristics determination.

Latvian Railway Act [10] provides that the railway infrastructure is a complex engineering structure, where the public railway infrastructure management is separated from the transportation process.

The absolute and relative performance indicators of Latvian public railway infrastructure are shown in Table 1.1.

The Latvian rail capacity is used in a non-uniform way: the main junctions are overloaded, but regional lines are underloaded. The majority of Latvian railway infrastructure capacity (67 %) is used for the provision of transit services in the freight segment, but one-third in the passenger segment. The 55.6 mln.t cargo was transported by Latvian rail in 2015, where 53.9 mln. t (97 %) were international traffic. It was mainly transportation of goods from ports and to them (84 %). Latvian Railways usually transports goods, which Russia, Belarus, Kazakhstan and other countries export via Latvian ports. The largest volume consists of coal, crude oil, fertilizers and other raw materials and export goods. This kind of cargo is characterized by scale technology – accumulating of wagons, composition of maximum long and 3-5 thousand net tontrains, sending to the seaport-side marshaling yards, and delivering to the port terminals.

[10] Latvijas Vēstnesis: Dzelzceļa likums / Internets. - http://www.likumi.lv/doc.php?id=47774

Table 1.1

SJSC "Latvian Railway" main performance indicators

	Performance indicators	1990	1995	2000	2005	2010	2015
Absolute indicators							
1.	Length of track in use, km	2397	2413	2331	2270	1896	1860
	Of which, double and more track	303	304	302	303	320	367
2.	Station or technical track kilometers	1277	1207	1065	896	816	819
3.	Switching points, it	4469	4275	3790	3512	3194	3215
Relative indicators							
1.	Cargo turnover on one track kilometer, *mln.t km/km*	-	4,04	5,71	8,71	9,05	10,16
2.	share of renewed track kilometers, %	n.d.	n.d.	5,6%	n.d.	2,8%	n.d.

Source: SJSC „Latvian Railway" 2011 and 2015 key performance indicators.
(n.d. – no data)

12.3 thousand employees were employed in Latvian railway sector in 2015, that is 1.4 % of the total number of Latvian employees, while a large part of Latvian Railway employees are in supported Latgale region. Railway specialists' work is better rewarded than other transport workers' work.

The table 1.2. shows data on capital resources and their dynamics provided by the Latvian railway infrastructure manager. It can be concluded that the most of Latvian assets required for providing the infrastructure services consist of long-term investments, which annually dynamically increase. Asset financing resources consist mainly of loan obligations, and their share in balance sheet has an increasing trend.

Table 1.2

The capital and the dynamics of capital resources of Latvian Railway in 2012 - 2015

Report year	2012	2013	2014	2015
Assets (EUR)	603 137 316	687 728 596	818 899 098	863 824 011
Of which, long-term assets	508 539 674	619 266 700	724 024 083	840 435 483
Share capital (EUR)	163 417 742	163 528 584	256 720 375	256 720 375
Share of loan obligations	63 %	59 %	64 %	66 %

Source: SJSC „Latvian Railway" annual reports

The competitiveness of services provided by Latvian railway infrastructure depends on the supply chain, where the infrastructure is concerned, as well as the proper supply chain operational efficiency. The competitiveness means the ability to attract more freight (for Latvia especially transit freight) through the ports and passengers in comparison to competing infrastructures in the region. Latvia has won the second place in competitiveness evaluation (with a contribution of the author) among the countries that compete with each other in transit services through the Baltic seaports. Russia has acquired competitive advantages in recent years, where the rail industry cluster was established that provides supply chain harmonious operation and cheaper production resources.

It is concluded that the railway infrastructure is not homogeneous object, performance of which can be measured by a simplified average or individual parameters. A whole system of indicators must be developed.

2. THE MODELING OF PUBLIC-USE RAILWAY INFRASTRUCTURE DEVELOPMENT

The modeling analysis of the research object shows that there are various types and kinds of models used. They are designed for a particular item, a simulated system and circumstances. A variety of modeling approaches is in use. Different solutions are selected taking into account economical, technical and technological conditions, as well as EU framework and national strategic documents and laws. Each decision-making level creates different models, with due attention to both economic and management processes and technological relationships[11]. Each level has its own modeling approach, parameters and indicators analyzed.

Global trade flows are evaluated in order to justify the need to invest in infrastructure, but the worldwide best possible use of resources is often not taken into account when choosing investment options.

Nowadays the general modeling approach on this level is associated with the scenario-building, where the target is to promote a particular region by using transport infrastructure. EC recommends to use Beutel model. The model consists of calculation tables on raw materials usage and production data in the reporting year, including the imported matrix, estimates of each industry's growth and value added and total demand forecasts. There are other characteristics that can be calculated using the proposed input - output tables [12] too. There are two modeling systems used to analyze EU Cohesion Policy (one of the major rail infrastructure development funds) [13]: the QUEST system, used by EC, and the HERMIN system, used in many Member States.

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[11] Jansson K. Optimal public transport price and frequency // Journal of Transport Economics and Policy. –1993. – Nr.XXVII(No. 1). – 33–50 p.

[12] Marcel P. T. The World Input-Output Database (WIOD): Contents, Sources and Methods // WIOD Working Paper. – 2012. – Nr. 10.

[13] Bradley J., Untiedt G. Do economic models tell us anything useful about Cohesion Policy impacts? A comparison of HERMIN, QUEST and ECOMOD // Schütz U., Stierle M.H., Jennings Jr. F.B., Kuah A. Regional Economic Policy in Europe – New Challenges for Theory, Empirics and Normative Interventions. Cheltenham UK: Edgar Elgar, 2008.–159–180 p.

So transnational communities model infrastructure from the supply point of view (political decision). On demand side, the final consumers of railway infrastructure services base their calculation primarily on business advantages and use Kresge [14] model and its specific modification. It was concluded that national and transnational groups are interested in the implementation of much larger railway infrastructure tasks than it is commercially viable. While similar requirements are not imposed to other transport infrastructure, private investors will choose commercially feasible over socially responsible service providers.

The implementation of strategic planning is supported by deployment models (arrangement of the railway line, the distance between stations and service facilities etc.); rail network technical models; regional multimodal planning models; balance approach as well as simulation models.

The transport systems modeling approach is very common at the national level in Europe. The following national-level transport systems models can be considered: Sweden used SAMGODS, Norway used NEMO, Belgian used WFTM, Italian used SISD, Dutch used TEM and SMILE, the British used STEMMA and EU-wide used SCENES, ASTRA and NEAC as well as a Transalpine model for international transport corridors.

The main disadvantages determined reviewing national level models are exploitation of computation that is not available in other decision making levels; not taking into account microeconomic considerations of freight and passenger flows generating consuming parties including limiting factors and seasonality; the need for detailed statistics; possibly subjective interpretation of the data.

LR macroeconomic forecasting is concentrated at Latvian Bank and at the Ministry of Finance, where the HERMIN model 2000 (prior to accession to the EU) for ex-ante evaluation of EU structural politic impact is in use[15]. LATFUN model for evaluation of ex-ante and ex-post funds that Latvia has received since 2004 was established in 2007- 2008. These models are not developed to assess the infrastructure impact on the economy.

On the industry level, the problem of delivering productspassengers to the final consumer/place of residence, subject to various constraints (infrastructure capacity, transportation times, prices, priorities) is solved. This problem is solved with the VRP (vehicle routing problem) models, which are used to justify a particular decision-making on mobility

[14] Kresge D.T., Robert P.O. Techniques of Transport Planning: System Analysis and Simulation Models. – Brookings Institution, Washington D.C., 1971. – 119 p.

[15] Bradley J., Kearney I., Morgenroth E. Ex-ante Analysis of the Economic Impact of Pre-accession Structural Funds: A Model-based Methodology for Latvia. – Dublin: The Economic and Social Research Institute (ESRI), 2000.

plans. For this purpose, the simulation models with direct route target (Monte Carlo method) as well as dynamic and linear programming methods are used. Investment-type and indicative-type models are also applied at industry level where for monitoring needs multi-criteria analysis is used. The Latvian strategic regional transport model (RPMP) [16] was developed to support the mobility plan of Riga and its surrounding area.

Nowadays modeling is more oriented on particular transport mode with less emphasis on comodality (ensuring modal synergies) – the improvement of capacity and coherence of investment projects in logistics chains; more efficient transport mode selection criteria in places where various transport modes infrastructure overlap; multimodal terminals; new transport modes' infrastructure development. Planning horizons of developed models are shorter than the lifecycle of infrastructure. Higher-level modeling tools are not available at the industry level so they can not cover the economic development evaluation results, therefore links to national development plans are not formed. The emphasis is placed on technical infrastructure projects, less emphasis on adaptation of services and technologies.

The simulation and certain processes (financial, technological or economic) modeling tools are commonly used. These kinds of models are mostly confidential and are not publicly available.

The work on the development of single rail optimal operating criteria system which reflects the life cycle costs and externalities can be observed nowadays [17]. For this purpose, URRAN methodology is used in Russia. This is European RAMS methodology analogous. The methodology aims to minimize production systems functioning risks within appropriate thresholds, connected with the economic resources constraints. RAMS currently is used to a limited extent[18,19], moreover this methodology does not provide an assessment of a number of positive and negative externalities.

The overall conclusion is that there is currently no fully approved railway infrastructure manager endogenous business model.

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[16] Satiksmes ministrija: Rīgas un Pierīgas Mobilitātes plāns. Gala ziņojums / Internets. - http://www.sam.gov.lv/images/modules/items/PDF/item_2953_RPMP_gala_zinojums.pdf

[17] Андреев А. Влияние конструкции верхнего строения пути на стоимость жизненного цикла при различных климатических и эксплуатационных условиях / А. Андреев // Известия Петербургского университета путей сообщения. – 2014. № 3, с. 36–39.

[18] van den Breemer J.J.A., Al-Jibouri S.H.S., Veenvliet K.T. et al. RAMS and LCC in the design process of infrastructural construction projects: an implementation case / Internets. – http://essay.utwente.nl/58668/1/scriptie_J_van_den_Breemer.pdf

[19] CENELEC. Railway applications // The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS). Part 1: Basic Requirements and generic process. EN 50126-1. – Brussel: CENELEC, 1999.

There are problems and fragmentation in modeling of interaction between different level models in relation to single-level modeling approach principles. The main problem is the subjective decision-making at various levels, as well as one-way impact assessment mechanism, not including feedback and spin-off effects, which can affect other modes of transport, socio-economic and ecological systems [20]. Modeling of links is also hampered by the different planning horizon - long-term political plans doesn't foresee a variety of effects in the short and medium term. Political documents provide systematic (year to year) movement towards the indicative rate, contrary to the cyclical nature of tactical and operational activities.

It was concluded that the economic entities that influence the development of railway infrastructure at different decision-making levels are hierarchically subordinated and deal with different types of interrelated tasks. There are no piloted modeling techniques that reflect the interconnectedness of all the hierarchical levels.

3. THE METHODOLOGY OF ELABORATION OF PUBLIC-USE RAILWAY INFRASTRUCTURE OPTIMAL DEVELOPMENT MODELS

This chapter consists of the analysis and generalization of modeling approaches, then on the basis of the conclusions, the general methodology of elaboration of public-use railway infrastructure development model is proposed and adapted to the Latvian public railway infrastructure development challenges.

When the railway infrastructure optimization problems and conditions are analyzed, it must be concluded that the complexity of the system does not clearly articulate development objectives and system constraints. This is due to the diversity of relationships, ambiguous and occasional impact of factors, a necessity to harmonize decisions at the different system's functioning and management levels, as well as to the interaction of technical parameters, the number and contradiction of indicators etc. Optimization challenges are faced in very different spheres.

Management objects have a hierarchical structure, where inherent set of criteria is used for each level. There are also uncertain subordination relations between the levels [21]. There are at least three subjects that are involved in railway infrastructure management and service (see. Fig.3.1): the state (local government), the infrastructure manager, infrastructure users.

[20] Rothengatter W. Economic Assessment of EST scenarios. Methods and Approach. – Karlsruhe: Institute for Policy Research, University of Karlsruhe, 1998.
[21] Дубров Я.А. Системное моделирование и оптимизация в экономике. – М, 1976.

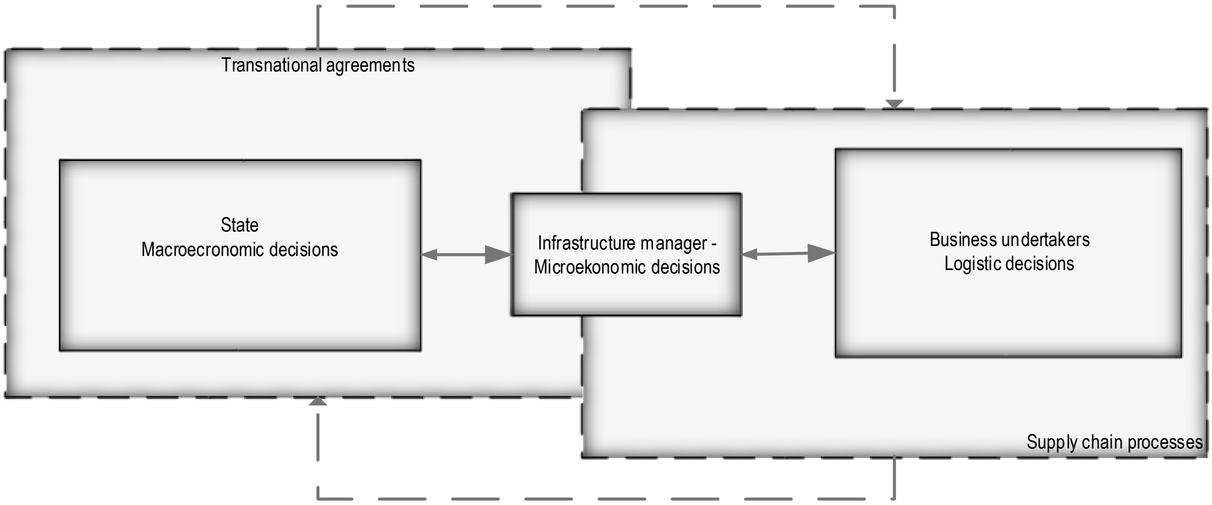

Fig. 3.1 Subjects involved in railway infrastructure management and service and those interactions (designed by the author)
(The dotted line shows the indirect effects of actions)

As it shown in Fig. 3.1, the subjects are connected with different types of links, they have different functions and tasks.

The state's main task is to ensure the optimal proportion of the economy, stability and efficiency of the development, to promote the output growth of various industries, employment, the rational deployment of material resources, regional development, the replenishment of state budget funds, to implement the country's fiscal policy and structural policies [22].

Railway business undertakers' main task is to ensure efficient supply chain activities according to final consumer needs.

The main tasks of the infrastructure manager are to ensure stable raw materials, components etc. supply activities of different entities which are dependent on the effective operation of the railway through the quick and safe transportation in all the links of the global supply chain as well as to adopt appropriate microeconomic decisions at the enterprise level.

Both from the level at which decisions are taken and from the analysis of the existing models follows that:

1) when models are elaborated, it is not possible to cover all decision-making levels in one sitting, so the models and approaches for different development options must first be developed at a certain level and then resumed by coordination process;
2) the multi-conflicting criteria approach must be used for optimization needs.

The unique formulation of the target function is not possible, considering the author's assumption that the railway infrastructure is put in the concept of national economic structural

[22] Šenfelde. M., Makroekonomika. Rīga: Rīgas Tehniskā Universitāte, 2009.

development on the macro level with the target to enhance national welfare by the rational use of the economic resources in existing rail and logistics services market influence patterns.

So the optimization task was stated as follows: the rail infrastructure development optimization is a prioritization of various conflicting economic and social processes in order to enhance national welfare, considering limited, variable and different management level-owned amount of resources, the rail service market failures and different frequency of processes.

In order to find the best solution for the development of systems like rail infrastructure, it is necessary to mark "a compromise area", which includes all solutions that are effective by Pareto [23], meaning those that can not be improved without impairing other criteria. The most viable local solutions, meaning solutions that are effective only by one of the criteria may also include in "the compromises area". "The compromise area" generally can be determined by narrowing down the "conflict set" with the "set of strategic advantage". The set of strategic advantage should have the following characteristics [24] [25]: it depends on the target process; it must be enforceable; it depends on the current economic situation; it can vary only when affected by significant exogenous factors; it links to economic development.

Railway infrastructure effective development model enables to provide an economic "portrait" in order to assist other economic subjects related to railway infrastructure managers to meet their economic challenges, considering the behavior of railway infrastructure manager to use its resources to achieve the maximum validity.

With relation to the theoretical analysis of the optimization problems, the author offers the general methodology for an elaboration of public-use railway infrastructure development models and scenarios upon scheme given in Fig 3.2.

[23] Блауг М. Экономическая теория благосостояния Парето // Экономическая мысль в ретроспективе. – М.: Дело, 1994. – С. 540-561.

[24] ibid

[25] Каплан А.Б. и др. Математическое моделирование экономических процессов на железнодорожном транспорте. М.: Транспорт, 1984.

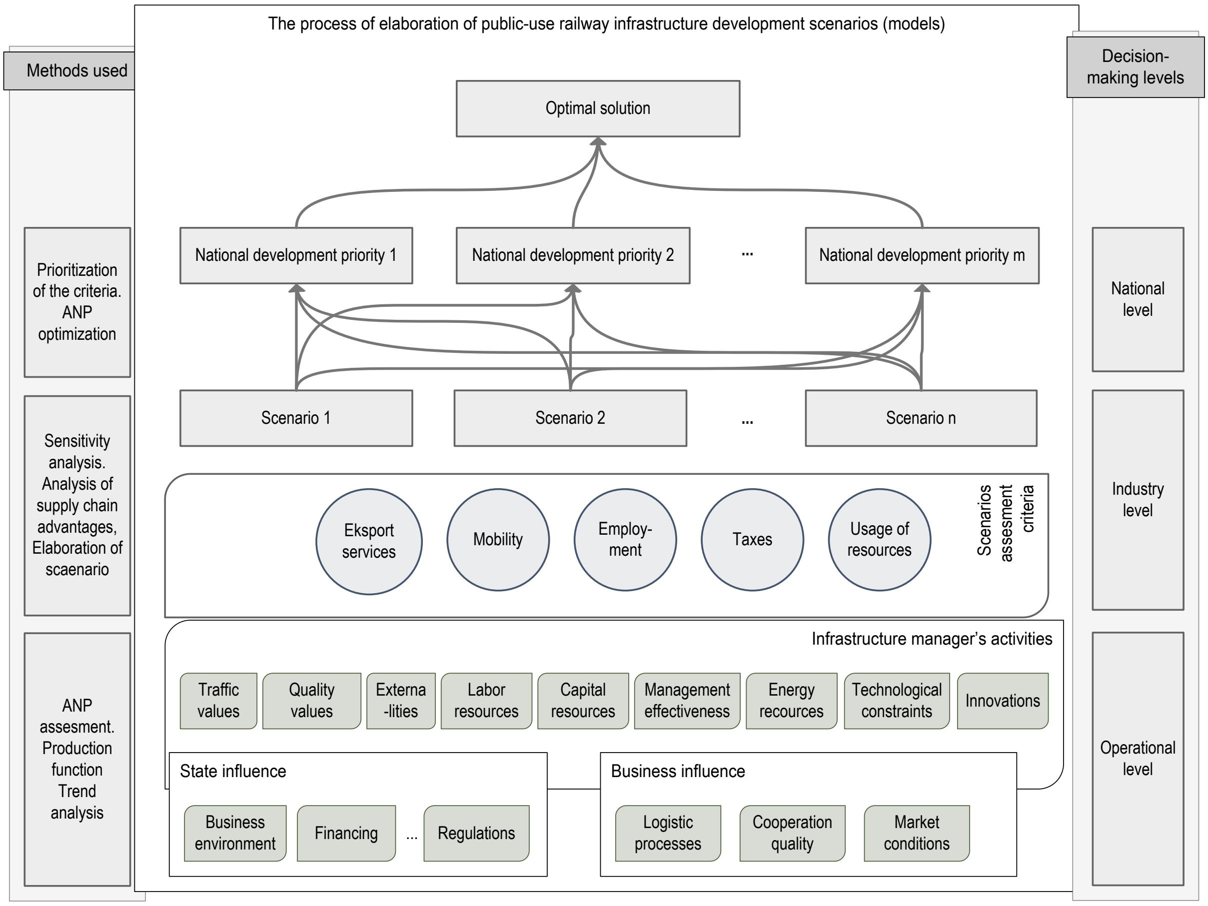

Fig 3.2 The scheme of general methodology for elaboration of public-use railway infrastructure development models and scenarios (designed by the author)

As it shown in Fig.3.2 the methodology provides task solution on several levels. Each level consists of its tasks: determination of indicators and limitations, assessment of the impact of factors; elaboration of possible scenarios; formulation of the set of criteria; prioritization of criteria, optimization using a variety of approaches and methods. The author of the thesis recommends to perform optimization by the "bottom-up" principle in three stages, each of which corresponds to a certain level of decision-making:

1) on the operational decision-making level test parameters of the object (railway infrastructure) are determined and analyzed including analysis of its potential limiting factors and analysis of the factors that characterize its the interaction with the processes that take place in the economy and supply chains;
2) on the industry level the set of optimization indicators and the set of strategic advantage are selected;
3) on the national level scenarios are assessed according to national development priorities, the optimal solution is evaluated and directed to the operational level.

There are main test parameters that must be analyzed on the operational level:

Freight and passenger traffic parameters: passenger turnover (*passenger-kilometers, a number of passengers, average travel distance*); cargo turnover (*tonne-kilometer, transported tons, the average transportation distance*).

Railway infrastructure service quality test parameters: reliability (*number of failures during infrastructure life cycle*); availability (*downtime during infrastructure life cycle*); maintainability (*probability of technical maintenance option*); safety (*probability of unacceptable risk (e.g., death*)) extra passenger service quality indicators (*journey intensity, waiting time, speed, parking facilities, station equipment quality, individual security at stations; stations cleanliness; special needs and senior passenger support*).

Production resources test parameters:

Labor resources parameters: working hours (*h*); a number of employees; labor productivity (*value added per person employed*); labor costs (*wages and employer's social costs per employee*).

Assets' parameters: ensured speed; ensured axle load; train length maximum; track utilization; carrying capacity; traction equipment installed power.

Energy parameters: energy consumption in calories equivalent (*per traffic parameter unit*); electrified line share of a network (*%*).

Financial resources parameters: infrastructure charge level (*currency units*); service facilities charge level (*currency units per average weight train kilometer*); public funding (*share of the full cost*); loans (*share of the investment value*); EU funds (*share of the investment value*); private funds (*share of the investment value*).

Operational level management quality test parameters: life cycle costs of one track kilometer in use (*currency unit*); solvency (*solvency ratio*); profitability (*capital revenue*); efficiency (*assets turnover*); productivity (*administrative costs per employee*).

Railway infrastructure services structure and export indicators: share of transport services in service exports of payment balance (*%*); Balassa index; cargo structure (%).

Competitiveness parameters: World Bank's Logistics Performance Index (*infrastructure, services, border procedures and time and supply chain reliability*); correspondence of cargo structure to the world demand; demand factors of specific cargo groups.

Factors that characterize the interactions among railway infrastructure and affiliated sectors of the economy: value added provided in affiliated sectors of the economy (storage, processing, manufacturing, construction, engineering, etc.) *(% of GDP*); income distribution equity in the supply chain *(% of GDP per traffic parameter unit*); TSC: rail infrastructure costs, supplier production cost, transport user costs, accident costs, environment costs, as a starting point to merge rail stakeholders, production factors social costs *(% of GDP*); export services *(% of GDP*); employment (*share of a total number of employees*); resources and population mobility (*share of inland traffic unit*); nature, labor and other resources' use efficiency (*value added per resource unit*).

Externalities parameters: emissions (*CO2 tonne equivalent par traffic unit*); water, air and soil pollution (*concentration of unacceptable substances (e.g., oil products) per roadbed sq.km and impact to external environment*); noise levels in urban areas; occupied land area - (*sq.km per traffic unit*); congestion - (*delays per time unit*).

The parameters have the specific interdependence and subordination nature. The various management levels, the complexity of technical systems, financial and economic calculations link these parameters into the single system with diverse interrelationships. Changes of separate parameter indicators affect other parameter indicators' changes.

Drivers of the parameters as well as conditions and restrictions of permissible changes such as economic, organizational, technical, legislative, governing regulation circumstances shall be taken into account. These factors may, therefore, supplement a set of parameters' indicators.

The most important factors, limiting parameters and conditions are as follows (denoted by ß and the relevant subscript):

$ß_c$ – construction (topological and technical) failures factor;
$ß_t$ – technological failures factor;
$ß_r$ – national quality requirement ratio;
$ßtk_n$ – the maximum possible amount of cargo n group, tkm;
$ß_n$ – cargo n group demand influencing factor;
$ß_{dp}$ – national labor policy factor;
$ß_{dr}$ – productivity factor;
$ß_a$ – labor market failures factor;
$ß_m$ – infrastructure charging restriction factor;
$ß_v$ – public funding availability and limitations factor;
$ß_k$ – loan restriction factor;
$ß_p$ – private funding availability and limitations factor;
$ß_{as}$ – association factor, indicates income distribution equity in the supply chain;
$ß_{rs}$ – rolling stock availability factor in certain traffic type;

ß$_{ap}$ – different types of services combining factor.

These factors adjust the test parameters (by limits, regulations, etc.) when they are used for further calculations. For example, track utilization is adjusted by track maximum capacity (C_{max}), construction (topological and technical) failures factor ß$_{c,}$ technological failures factor ß$_{t}$. ß$_{c}$ and ß$_{t}$ factor can be evaluated as C_{max} aligning coefficients by using expert method. ß$_{c}$ is influenced by construction restrictions drivers set cv_i {cv_1 – section working and operating speed; cv_2 – section technical equipment; cv_3 - station technical equipment; cv_4 - planned maintenance volume} and considering each driver importance ck_{ij}. ß$_{t}$ is influenced by technological restrictions drivers set tv_i {tv_1 – wagon average spent time in terminals and stations; tv_2 – the locomotives depot average spent time; tv_3 – average daily utilization of locomotive} considering each driver importance tk_{ij}.

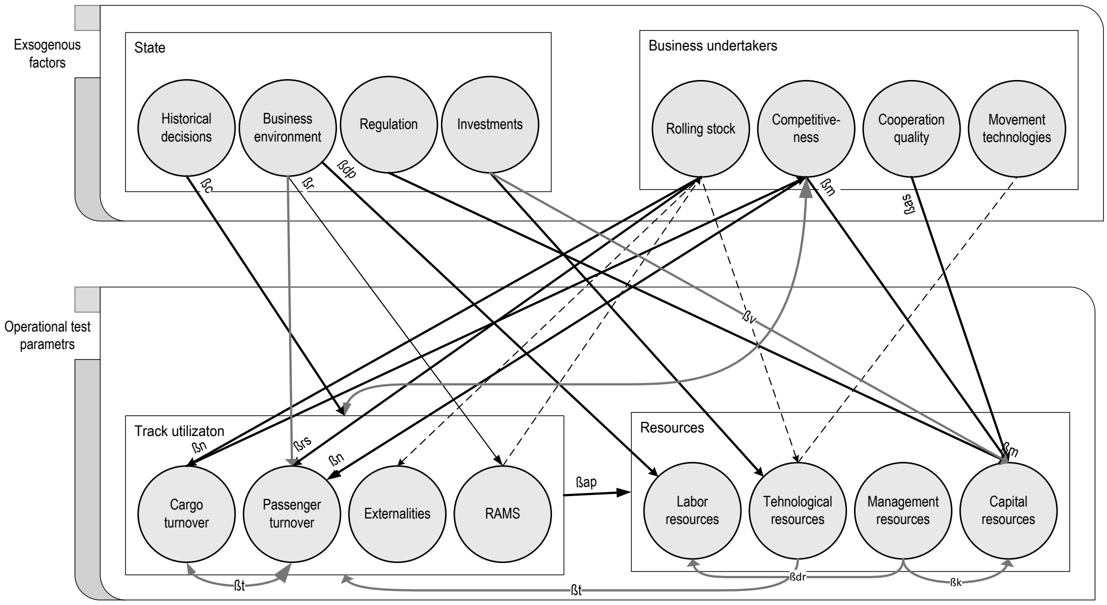

Fig.3.3 Interactions among rail infrastructure test parameters and factors on different decision-making levels (designed by the author)

(The arrows shows the effect of factors, dashed line - hypothetical links)

The same way, freight turnover test parameters are adjusted depending on the transit corridor influencing drivers: correspondence of cargo structure to world demand (*KSTR*); cargo n group demand influencing factor ß$_{n}$; the maximum possible amount of cargo in group, tkm, **ß**tk_n; and competitive advantages of particular supply chain (transit corridor) (CP_k).

The test parameters are affected by more other factors, which appear at the different management level and often even at several levels at once and may have controversial direction. Fig. 3.3 shows the interactions among parameters and factors in a systematized way.

Based on the information analysis development scenarios may be elaborated, and more after evaluated in the light of national development priorities. The sensitivity analysis with regard to each parameter transparency assessment (Table 3.1) may be carried out in order to extract set of strategic advantage.

Table 3.1

Example of parameter transparency assessment

Parameter transparency assessment	Annotation
High	Fluctuations of the parameter can be accurately explained on the basis of the infrastructure manager's information. Parameter's changes can be easily administered at the operational level. Parameter's fluctuations in previous periods are at 3 % range.
Medium	Fluctuations of the parameter are partly or wholly dependent on certain external factors. Parameter's changes can be easily administered at the industry level. Parameter's fluctuations in previous periods are at 3-10 % range.
Low	Fluctuations of the parameter are partly or wholly dependent on unknown factors. Parameter's changes cannot be easily administered. Parameter's fluctuations in previous periods are more than 10 % range.

Designed by author

Sensitivity and transparency values combine into the sensitivity matrix (Table 3.2), in order to extract set of strategic advantage.

Table 3.2

Example of extracting of set of strategic advantage by using sensitivity analysis

Parameter's transparency	Parameter's sensitivity		
	High	Medium	Low
High	I	I	II
Medium	I	II	III
Low	II	III	III
I – shall be added to strategic advantage set, is a subject of quality analysis, breakpoints setting and evaluation and monitoring of affecting factors II – shall be added to local solution group, the whole set of parameters is a subject of quality analysis, breakpoints setting and evaluation and monitoring of affecting factors III – shall be excluded from strategic advantage set, not a subject of quality analysis.			

Designed by author

Sensitivity analysis can prove that there is no indicator that can significantly improve the situation and at the same time indicate that the achieved efficiency is not sufficient. Thus a solution may be found by designing the "blue ocean" strategy[26] in order to include in the production function such kind of indicators that weren't analyzed before. The "strategic canvas" tool can be used for this purpose where on the horizontal axis the factors that are important for competition and where investments made are shown, but on the vertical axis – the level key competing for factors.

[26] Kim W.C., Mauborgne R. Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant. – Boston: Harvard Business School, 2005

In order to identify the factors that are important for improving competition freight turnover through a variety of supply chain, Fisher's supply chain classification can be used [27]:

– the "efficient" supply chain model (provides less possible cost);
– the "fast" supply chain model (is able to update the product portfolio in accordance with the latest trends in the market);
– the "continuous-flow" supply chain model (provides respond to changes in demand, monitors and ensures continuous replenishment of stocks);
– the "agile" supply chain model (providing services to particular customers in accordance with the unique specifications);
– the "custom-configured" supply chain model (offers a unique final product configured in accordance with the needs of the final consumer but from a limited range of basic products);
– the "flexible" supply chain (provides the solution of clients’ problems).

As a result of sensitivity, "blue ocean" and supply chain analysis the "compromises area" which includes all solutions that are optimal by Pareto [28], that is, they can not be improved without impairing the other parameters, can be marked at the industry decision-making level and evaluated on the national decision-making level.

Decision-making on a particular scenario on the national decision-making level may be justified by using ANP (Analytic Network Process) multi-criterion problem-solving method, or it’s simple modification AHP (Analytic Hierarchy Process). The optimal scenario can be chosen, based on funding, financial, investment priorities, environmental protection, spatial planning policies, other economic and social considerations or a critical volume of particular indicator (e.g. congestion level).

Each rail infrastructure is a unique economic entity, so from the recommended test parameters the most appropriate have to be chosen. The following groups of test parameters are important for Latvia:

– production resources test parameters compared to competing states’ rail infrastructure parameters;
– railway infrastructure public importance test parameters, the role in the national economy;

[27] Fisher M.L., Hammond J.H., Obermeyer W.R. et al. Making supply meet demand in an uncertain world // Havard Business Review. –1994. - March/April. 105–116p.

[28] Блауг М. Экономическая теория благосостояния Парето // Экономическая мысль в ретроспективе. — М.: Дело, 1994. — С. 540–561.

– railway infrastructure commercial performance test parameters, including affiliated performance;
– state influence test parameters.

Only those test parameters that can be obtained from the historical statistic data, compared one with another (especially considering restricted access to the Russian databases), grouped and trended, were included in the groups.

The analysis shows that the following test parameters may be included in the analysis at the operational management level in Latvian case:

1) evaluation of production resources usage effectiveness:
– labor costs per employee in the transport and storage sector (R1), indicates relative labor resource advantages comparing to capital resource advantages;
– value added per employee in transport and storage sector (R2), indicates the productivity of labor resource;
– investment indices in transport and storage sector (R3), indicates an availability of capital resource;
– cargo turnover per track length (R4), indicates the utilization of railway capacity;
– van de Velde et al[29] externalities comparative advantage matrix (R5) indicates the railways' impact to the environment, compared to other transport modes' impact.

2) commercial performance, and correspondence to market conditions:
– Balassa index (K1), indicates correspondence of the cargo structure to world demand;
– cargo turnover (mln.t) (K2), indicates market share in the region;
– the World Bank's Logistics Performance Index (K3), indicates comparative advantage of the logistics chain service quality;

3) affiliated performance, place in the supply chain:
– sea and rail total share in exports of services (I1), indicates the cumulative impact of the supply chain part to the balance of payments, and therefore the role in the economy;
– rail net export share in exports of services (I2), indicates railway's ability to cluster its value-added part of the supply chain;

[29] van de Velde D., Nash C., Smith A. et al Rail Economic effects of Vertical Separation in the railway sector // Report to: CER Community of European Railway and Infrastructure Companies EVES, 2012
van de Velde D., Nash C., Smith, A., et al Economic effects of Vertical Separation in the railway sector. – CER, 2012.

– association indicator (author's study[30] developed coefficients) (I3), indicates equity of income distribution in the supply chain;

4) railway infrastructure role in the economy:

– cargo turnover in the largest ports (mln.t) (T1), indicates the related supply chain part market share in the region;
– share in exports of services (T2), indicates the impact of the railway on the balance of payments;
– conventional oil resources kg of 10 thousand gross tonne-kilometers (T3), indicates natural resource productivity;
– domestic passenger transport mode shares (T4), indicates the ability to provide inhabitants' mobility.
– domestic freight transport mode shares (T5), indicates the ability to provide mobility of domestic resources in the growth areas;
– international passenger transport mode shares (T6), indicates the ability to provide international accessibility.

5) state influence on business:

– Doing Business index tax dimension (M1), indicates fiscal environment in the country;
– Doing Business index cross-border trading dimension (M2), indicates the business environment in the country;
– OECD competitiveness indicator (M3), indicates domestic economic environment in the country;
– OECD export performance for goods and services indicator (M4), indicates external economic relations of the country.

In order to mark set of strategy advantage, the assessment of the test parameters on the operational level should be correspondent with the aims of the Latvian National Development Plan 2014 – 2020 (NAP2020).

The model has restrictions on indicator evaluation. Available secondary statistical data make it possible to determine the values of parameters with a certain probability [31], so the results have illustrative quality. Russia related data is taken from the Russian statistical databases,

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[30] Hudenko, J., Počs, R. The Discrepancy between the Service Export Incomes of Rail and Sea Transport among the Baltic States Transit Corridors // Proceedings of the 19th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2015). – ASV, Orlando, 2015.

[31] International Transport Forum: Railway Efficiency – An Overview and a Look at Opportunities for Improvement / Internets. - www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html

where metadata, compared to the information provided by Eurostat, may vary. It is not possible to provide a single rail infrastructure development solution in this study, because the author does not have a clearly defined infrastructure development targets, so it is not possible to put a scenario evaluation scales in ANP matrix.

All other Pareto requirements are provided in calibrated model, showing the economic situation and ensuring the sustainability of alternative scenario testing, as well as showing the interaction with the economy and other exogenous variables.

4. THE DESIGN OF PUBLIC-USE RAILWAY INFRASTRUCTURE OPTIMAL DEVELOPMENT MODELS FOR ELABORATION AND ASSESMENT OF DEVELOPMENT SCENARIOS

This chapter presents the results of the proposed methodology design for the elaboration of possible Latvian public railway infrastructure development scenarios, evaluation application of results, including statistical data, factors, criteria, scenario analysis.

Summarizing the Latvian operational level test parameters' quantitative analysis and trend analysis, it can be concluded that:

1) strategic planning documents at all levels provide a clear priority of transit services;
2) domestic rail services are excluded from a strategic group;
3) assessment of externalities is not included in the national planning documents;
4) the state does not participate in the determination of railway infrastructure service qualitative characteristics;
5) state influence on the railway infrastructure, from a macroeconomic point of view, must be regarded as supportive;
6) the global economic trends show increases in a competition of transit corridors as well as cargo flow redistribution. Most of the trends show negative indications for existing cargo structure;
7) the market structure is beneficial for the railway infrastructure manager and allows to accumulate most of investment in its supply chain part;
8) production factor market development dynamics shows that difficulties to ensure the rail sector with the necessary rolling stock and material resources can be observed in the long run;
9) the costs of labor and capital production factors increase and there is a trend of their deficit.

The export of railway services is so important to Latvia that the interest improve the competitiveness appears on all levels - from the operational to the national. This factor supports traditional competitive strength but can be troublesome when a decision has to be made on any change of strategy - too many stakeholders with contrary interests are involved.

The trends on traditional markets are not optimistic. Forecasts indicate that maintaining the existing economic model can cause a chain reaction: traffic volume reduction → decrease of track utilization → lack of capital (loans, infrastructure charges). Or another alternative: charges increase, due to state lack of response → rail and affiliated companies are driven out from the market → national economy slows down. Thus, it is necessary to create development scenarios for decision-making on railway infrastructure performance optimization.

Currently formulated set of strategic advantages can not be the basis for the formulation of development scenarios, and therefore the sensitivity analysis of the selected test parameters was made. As a result:

- logistics performance indicator (K3) and association of market stakeholder indicator (I3) were tested parameters which have got the highest score, because they are both highly transparent and sensitive.
- domestic freight and passenger turnover indicators (T4, T5); labor resource utilization indicators (R1, R2) performance is conflicting with respect to various stakeholders; railway infrastructure utilization (R4), the structure of cargoes (K1), business environment (M3, M4) indicators have a major impact on the overall performance of the railway, but at the same time the impact of indicators are not under full control of Latvian stakeholder. These indicators can be added to local solutions area;
- other indicators were excluded from the analysis.

Based on the qualitative analysis of the selected sets of strategic advantage and local solutions four scenarios were proposed:

- the 1st baseline scenario – service and logistic chain parts association quality rising strategy;
- the 2nd scenario – domestic turnover support strategy;
- the 3rd scenario – business environment boosting strategy;
- the 4th scenario – innovation process promotion strategy.

The 1st baseline scenario

The set of strategic advantages consists of quality indicators, therefore the SJSC "Latvian Railway" infrastructure services correspondence to the Fisher's supply chain models was evaluated. The results of the analysis show that the Latvian railway infrastructure services must be targeted to the "agile" type of supply chain concept – a small number of customers that operate according to their own qualitative parameters. The results of baseline scenario implementation on the operational level are as follows:

- the cost of labor resources will increase because of the need to maintain a staff that would be able to prove highlevel service;
- expected less capacity utilization, as network operation should be adapted to the customer needs;
- at the same time adaptation only to the specific customer needs will require less capital than it had been necessary to ensure a wide range of services;
- the turnover will become very sensitive to the client cargo exogenous factors;
- there is the need to perfect quality of association with other logistic chain participants in order to ensure a uniform service that meets customer needs, the state participation would be required for the participants' association.

At the national level, it is expected that the raising of the railway infrastructure service quality can result in higher value-added in rail and affiliated sectors. In contrast, the economic potential will not be fully realized (due to decline in capacity utilization) and will depend on market forces and the state's ability to maintain the necessary association links.

The assumption of the **2nd scenario** is that the domestic transport performance indicators (T4 and T5) can be transparently improved by realizing domestic rail transport state support strategy commonly used in European countries. This can be achieved with a foundation of the different transport modes consolidated national State Transport Infrastructure Fund program, where various transport modes' infrastructure would be financed from, according to economic viability, environmental, safety etc. prioritization factors. Aligning of infrastructure funding among competing for transport modes will make rail transport more competitive compared with road and will increase the share of domestic transport services.

Changes of priorities will impact the national economic objectives as follows:

- the attraction of financing promotes domestic services and increases using of rail infrastructure
- rail utilization increase decreases one transport unit costs;
- creation of the externality effects of the country;
- indirectly, a tax collection increase can be predicted, due to the fact that private road transport sector avoids tax payments.

The 3rd scenario test parameters have a high sensitivity but low transparency (R4, K1, M3, M4) improvement is a concept of raising competitiveness in market segments that technologically meets rail transport opportunities. The analysis of the world trade geography and nomenclature led to the conclusion that it maybe nutrition products. Statistical data on the nutrition products transportation in Europe show that rail share is about 3 % only. The nutrition products are mostly transported by road. The carriage constituted 1.2 – 1.7 mlrd.t.

Agricultural products are characterized by a "continuous-flow" supply chain model. Technologically it can be achieved by using the experience gained in Europe in an organization of contrailer train and provision of a big storage area in special economic zones. In order to align Latvian test parameters to this type of supply chain concept it is necessary:

– to raise the level of production resources (R1–R4 group of test parameters' indicators);
– to provide an excellent business environment (M1 and M2);
– to improve the interoperability among the logistics chain (I3);
– railway utilization (R4) may fall – services will provide storage (or processing) nodes.

The impact of the realization of the 3rd scenario on the economic objectives is expected as follows:

– the requirement of capital investment and railways and affiliated logistics chain technological innovation;
– the decrease of railway infrastructure performance, but increase the rail-affiliated logistics chain performance;
– the decrease in rail services export value will require additional public funding;
– the increase in affiliated sector performance, contributing to the local industry economy e.g., processing of agricultural products, as a result the economic pillar of the overall performance will increase (estimated comparative value is 0,40).

In order to assess the viability of the 3rd scenario, it is necessary to carry out an enhanced study, both cargo-specific requirements, associated risks and the necessary investments.

The 4th scenario is associated with the labor resource (R1 and R2) efficiency. Workforce productivity is one of the national priorities too. Latvia, where the provision of transit services has been a traditional national product for centuries, can undertake innovative solutions in the industry. In order to transform severe physical infrastructure to modern "solution", it is necessary to innovate the current economic model or its components.

The first level of innovation can be created within a sector. For example, different financing models can be designed where rail infrastructure is integrated into the local infrastructure, and receive local funding for provided benefits to the local government.

The second level of innovation may be linked to the overcoming of technical contradiction, using techniques which are already being applied in affiliation systems. For example, existing containerized cargo or timber consolidation and storage can be organized till the vessel's arrival time in seaports, or contrailer trains can be collected and consolidated with the ferry lines. Or to arrange a delivery of small packs to/from Riga by regular passenger trains (examining the possibility of sorting during the path time).

The third level of innovation requires significant system changes. It can be a review of the severe type train movement railway system to a railcar type small trains system. The construction of an inland terminal and processing complex on railway stations and nearby. Or introducing changes in rail infrastructure maintenance processes by switching from physical inspection to continuous surveillance by drones or microchip built into the rails.

The fourth level of innovation may result in the creation of a new technical system. For example, conversion to the infrastructure supermanager and control all types of transport infrastructure and traffic interaction in Latvia or in Baltic countries, or to the producer/supplier of the alternative energy, or to the military object, or to the completely robotized cargo/ passenger conveyor Hyperloop or Maglev type, or to the tourism attraction etc.

The fifth level of innovation may result in a fundamentally new industry, as it is currently with drones' development. Rail space can be used as the main air room to provide their traffic control and safety.

After nomination of scenario the public railway infrastructure optimization was done in a view with formulated target to enhance national welfare by the rational use of the economic resources where criteria are: RI - the rational use of the economic resources; TI - the maximization of economic growth; CD - the maximization of human securitability; AR - the growth in supporting areas.

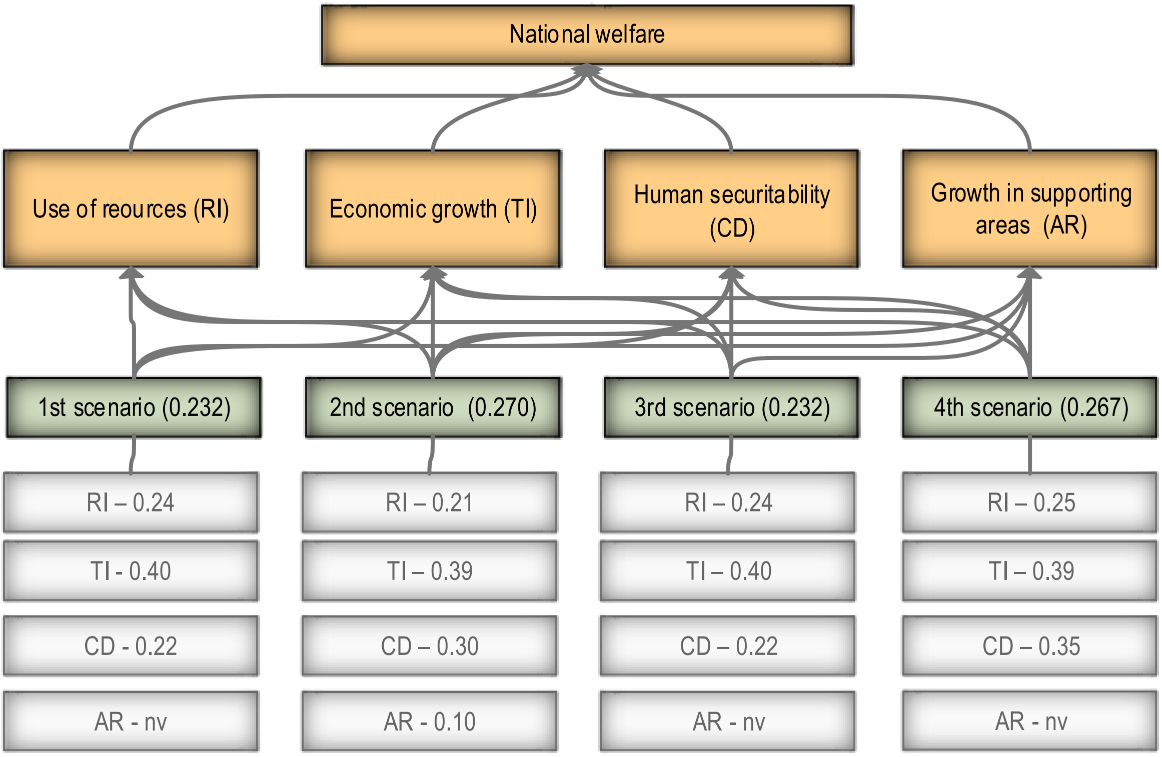

Fig. 4.1 Evaluation of scenario with average weighted *ANP* (designed by author)

(ANP value where average value in group is 25 shown in brackets)

When the alternative scenarios and their test indicators have the same weight, ANP evaluation criteria, returns that the comparative advantage (with the value of .27) has the 2nd scenario – domestic turnover support strategy (see Fig 4.1.). However, the links between the decision-making elements are largely dependent on political decisions, they can not be predicted due to their dependence on exogenous factors and lobbying processes. The thesis with the illustrative example of supermatrix shows abnormalities of optimization due to changes in weighing criteria supermatrix assessment results, that switched the 2nd scenario advantages in favor of the 4th scenario.

After analysis of the railway infrastructure strategy development processes, contributing and limiting factors, as well as the object specifics, it can be concluded that the hypothesis that the railway infrastructure is a multidisciplinary subject where lack of a holistic understanding of the economic process of interaction between micro- and macro-level head off the elaboration of the currently unfolding development programs related to the cost and environmental impact reduction of the transport sector, taking into account the market demand for flexible supply is verified:

- the railway infrastructure is not homogeneous object (can not be applied the averaged values) and a whole system of weighted indicators must be used

- decision making at various levels affects the overall performance of the system - it is necessary to develop and apply specific economic models to support decision-making;
- SJSC “Latvian Railway” railway infrastructure economic model has expressed "asymmetry". Public rail infrastructure is used mainly for commercial services, and less for social (population and resource mobilization) needs.

RESULTS AND CONCLUSIONS OF THE THESIS

Results

1. The analysis of various aspects (organizational, management, technical, economic, financial, etc.) of public railway infrastructure as the modeling object showed that the following aspects must be taken into account when elaborating the models: railway infrastructure’s complex, heterogeneous and multi-dimensional structure, close links to the economy, and effects of management decisions adopted in various economic and regional levels on its development.
2. Latvian public railway infrastructure has a number of peculiarities (a lot of unrelated decision-making entities; transit as a priority of a business, the environmental impact, the monopoly position, income redistribution inequality between the logistics chain stakeholders, etc.), that calls for the creation of special rail infrastructure development models, searching a variety of modeling and decision-making approaches.
3. The analysis of the models developed and used in rail infrastructure development optimization and other models around the world showed that each country's specific circumstances of economic and technical technological conditions, a legislative framework must be taken into account when developing the models.
4. The analysis of the currently developed and applied models around the world showed that they can not be directly used or adapted to the specific Latvian railway infrastructure. They are focused on specific sub-systems, and there is no fully approved railway infrastructure business model at operational management level, there is also the lack of different levels cross-links modeling and approved modeling techniques that reflect the interconnection of all the hierarchical levels are not designed yet.
5. In a view of the public railway infrastructure development target modeling peculiarities (the diversity of links, complex and random impact of factors, a need to harmonize decisions on the different management levels as well as the interaction of test parameters) the development target should be formulated in the wider range. It should

include not only the categories associated with the railway technical empowerment but also such categories as national welfare, the world globalization processes, social and safety aspects, the industry’s impact on the other economic sectors, as well as to the environment.

6. The formulation of the development target should be linked to a more general understanding of the optimization. Rail infrastructure optimization is a prioritization of various conflicting economic and social processes in order to enhance national welfare, considering limited, variable and different management level-owned amount of resources, the rail service market failures and different frequency of processes.
7. The analysis of the modeling object and its existing models showed that the model development methodology must consist of three level. On the operational level the assessment of economic potential and the impact of external factors by using multi-criteria decision-making methods (ANP, AHP, CBA, CEA, trends analysis etc.) must be comprised. On the industry level the set of strategic advantages’ parameters and factors must be extracted by using sensitivity analysis and the latest scenario development methods ("Blue Ocean" strategy approach) and development scenario models corresponding to Pareto optimization principle must be elaborate by using Fisher logistics chains classification. On the national level the optimal scenario must be selected by using ANP analysis and prioritization of the test parameters, scenario and targets.
8. The investigation of the author's proposed methodology by designing it for "Latvian railway" infrastructure needs showed that it can be used for data analysis to obtain the information, to develop relevant scenarios - models and to get their comparative evaluation, to develop recommendations on the optimal and prime direction rail infrastructure developments for decision-makers.
9. The analysis, using the proposed methodology showed that Latvia has lost its competitive position in the region, compared to rail transit corridors positions in Lithuania, Estonia, Russia in recent years, and specifically in the freight market share, in the use of resources, in the correspondence of the cargo structure to world demand, etc.
10. Latvian public-use railway infrastructure development scenario analysis showed that the implementation of the "effective" logistics concept has been compromised and solutions can not be found in traditional markets, as personal costs in Russia are about

a third lower, but the railway intensity two and a half times higher, and there are adverse political economy factors. So the development of new strategic scenarios is necessary.

11. The optimal choice can be done in Latvian case among four scenarios offered by the thesis: 1) service and logistic chain parts association quality rising strategy; 2) domestic turnover support strategy; 3) business environment boosting strategy; 4) innovation process promotion strategy. Pareto solution properties are respected in models while ensuring the sustainability of alternative scenarios.
12. The models development methodology, objectives, criteria, scenario formulations and possible development presented in the thesis were approved in a number of management and expert groups at different levels, in seminars and meetings, where received a positive evaluation, which leads to the conclusion that the results of the study may be recommended for the use in other organizations, countries, regions to meet railway infrastructure development challenges.
13. The proposed methodology indicates rail development-related decisions interaction both at the micro level and the macro level and allows decision-makers to set priorities for different purposes, scenarios and their assessment criteria by themselves.

Suggestions

1. The evaluation of the economic potential, as well as market failures (price distortion, resource restrictions, political decisions and entropy of links between the various decision-making levels of) should be the subjects of planning documents (national development plans, transport development programs, infrastructure entities' strategies, etc.)
2. The Ministry of Transport, the Ministry of Economy, SJSC "Latvian Railway", etc. must ensure a holistic approach at both the micro level and the macro level and a promotion at all levels of decisionmaking when developing the public railway infrastructure planning documents.
3. The indicative development plan developed by the Ministry of Transport should comprise the externalities financing mechanism according to the different modes of transport capacity to contribute to national development plans.
4. In view of unresolved theoretical issues of the railway infrastructure systems functioning and development, the Ministry of Transport is expected/invited/to establish research institutes for technological, economic and political problem solving, the formation of relevant statistical database and facilitating decision-making supporting software.

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