Economic Commission for Europe
Inland Transport Committee
Working Party on Transport Trends and Economics

Thirty-fifth session
Geneva, 5–7 September 2022
Item 4 (b)
Benchmarking Transport Infrastructure Construction Costs

Final report of the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs

Submitted by the Governments of Croatia, Cyprus, Finland, Russian Federation, Poland, Polish National Rail Infrastructure Manager (PKP PLK S.A.) and Türkiye

I. Introduction

The present document consists of the final report of the Group of the of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4) which has fulfilled its mandate during fifteen sessions that were held over the last six years (from 2016 – 2022). The document consists of nine annexes each presenting a substantive part of the final report. The final report has been prepared by the Governments of Croatia, Cyprus, Finland, Russian Federation, Poland, Polish National Rail Infrastructure Manager (PKP PLK S.A.), and Türkiye:

- Annex I – Executive Summary
- Annex II – Chapter 1 – Introduction, mandate, and modus operandi of the Group
- Annex III – Chapter 2, section A – Benchmarking literature review – definitions, concepts and methodologies
- Annex IV – Chapter 2, section B- National approaches in benchmarking of road, rail and inland waterways infrastructure construction costs
- Annex V – Chapter 3 – Glossary on construction costs
- Annex VI, – Chapter 4, section A – Benchmarking analysis of road transport infrastructure construction costs in the ECE region
- Annex VII – Chapter 4, section B – Benchmarking analysis of rail and inland waterway transport infrastructure construction costs
- Annex VIII – Chapter 5, section A – Conclusions and recommendations/ sustainability options
- Annex IX – Chapter 5, section B – Conclusions and recommendations
Annex I

Executive Summary

I. Background

1. At its annual session in September 2014, the Working Party on Transport Trends and Economics (WP.5), which serves as the think tank of the ECE Sustainable Transport Division agreed that “The benchmarking of transport infrastructure construction costs is a critical requirement for Governments to be able to come up with realistic cost estimates, moreover it increases cost predictability and transparency and thus creates a stable national infrastructure investment programme”. At its subsequent annual session in September 2015, the Working Party mandated the establishment of a Group of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4) which following approval by the Inland Transport Committee (in February 2016) and the ECE Executive Committee (in May 2016) commenced its activities as of November 2016.

2. Based on its Terms of References, the Group of Experts, which at the height of its success gathered fourteen Governments, convened, over a period of six years (from October 2016 – May 2022) fifteen meetings. The Group gathered representatives of ministries in charge of transport and public works, infrastructure managers and operators, national railway authorities, investment agencies and other stakeholders.

3. As per its mandate, the Group focused its deliberations on:
   • Identifying and listing terminologies used in the ECE region for construction costs of inland transport infrastructure and creating a glossary of agreed terminologies and related explanations.
   • Identifying and describing models, methodologies, tools, and good practices for evaluating, calculating, and analysing inland transport infrastructure construction costs.
   • Collecting and analysing data to prepare a benchmarking analysis of transport infrastructure construction costs across the ECE region for each inland transport mode – road, rail, inland waterways – including intermodal terminals, freight/logistics centres and inland ports.

4. Representatives of the following ECE Member States have been involved in all, or selected parts of the endeavour, with some Governments taking the lead and forming the analytical core of the effort including Croatia (on inland waterways), Cyprus, Finland, Poland (on railways), Russian Federation and Türkiye (on road transport). Other ECE member States, including Austria, Bulgaria, Czechia, Estonia, Germany, Iceland, Latvia, Lithuania, Republic of Moldova, Norway, Slovakia, Slovenia, Serbia, and Sweden provided information on national best practice examples and/or submitted filled out questionnaires on construction cost data. For the railway sector, data sets from Azerbaijan, Kazakhstan, Tajikistan, and Turkmenistan were collected and shared in the framework of a technical assistance project co-implemented by ECE, the Economic Cooperation Organization (ECO) secretariat and the Islamic Development Bank (IsDB).

5. The Working Party is invited to consider this report and adopt it. It may also wish to request the secretariat to issue this report as a United Nations publication in the three ECE working languages.

II. Key achievements

6. The Group’s key achievements can be summarized as follows:
   • The development of seven mode specific questionnaires aimed at collecting national benchmarking data on transport infrastructure construction costs on road, rail, intermodal terminal infrastructure, inland waterway, and port construction.
infrastructure. Upon its last extension the Group has developed two additional questionnaires with a focus on transport infrastructure maintenance and operation costs for the rail and road sectors. The templates of these seven questionnaires are available as an annex to this report.

- The development of a **consolidated list of terminologies** on benchmarking of road, rail, inland waterway, and intermodal terminals construction costs, including also on benchmarking of maintenance and operation costs.
- A benchmarking literature review providing a comprehensive overview of definitions concepts and methodologies as well as many national case studies and best practice examples showcasing how different ECE member States:
  
  (a) Go about calculating, forecasting, and evaluating their transport infrastructure construction costs.
  (b) Compare their transport infrastructure construction costs over time and normalize these costs by region.
  (c) Use their benchmarking efforts as a cost control mechanism; and
  (d) Use different cost calculation and evaluation methodologies for construction in different modes or not

### III. Data gathering

7. The questionnaires were shared with delegates in the various mode-specific Working Parties including Road Transport (SC.1), Rail Transport (SC.2), Inland Water Transport (SC.3) and Intermodal Transport and Logistics (WP.24). In parallel, the Group has also reached out to other relevant organizations in the field of benchmarking of transport infrastructure construction costs, including TEM and TER Projects, the International Union of Railways (UIC), the International Road Federation (IRF) and European Union networks of road and rail infrastructure operators.

### IV. Challenges

8. The Group faced several challenges in the conduct of its work, including during its final extension:

**A. The quantity and quality of road and railway data**

9. The data received was often sparse and scattered. In some cases, there were misrepresentations or omissions in the datasets provided by respondents. The first challenge was to turn the data into a workable format which could later be analysed. For that purpose, all the questionnaires with missing or inaccurate data had to be removed from the final dataset.

**B. Delays in data collection for intermodal terminals, inland waterways, and ports**

10. In particular, the data collection efforts for ports, intermodal terminals and inland waterways were delayed and the data received was often insufficient or inaccurate. The present study has therefor mostly focused on road and rail sectors.

### V. Sustainability options

11. At its thirteenth session in February 2022, the Group decided that rather than asking for an additional extension of its mandate or establish a new Group to continue the work, its
efforts could be continued in the framework of the TEM and TER projects. The Group also decided that uploading its analysis and data findings onto a Geographic Information System (GIS) International Transport Infrastructure Observatory (ITIO) may be the best way to ensure that its work becomes sustainable and would in addition to resulting in a written report also live on in a virtual/ GIS based environment. Moreover, the Group noted that ITIO could offer an automated user dashboard function that would allow Governments, in a secured IT environment, to continue sharing transport infrastructure construction cost information with one another.

VI. Findings of the Group

12. Benchmarking the cost of infrastructure construction remains a challenge due to the inherent characteristics of the cost. Plenty of factors affect cost. Most important cost factors of transportation infrastructure construction are: availability and costs of material, labour, geography, financial conjuncture (for example; availability of finance, inflation rate, risk), involved parties’ condition (for example; capacity of contractors in terms of machine park, finance and qualified staff), intended project characteristic, etc. Benchmarking of transportation infrastructure construction cost is challenging even within an organization and therefore it is more challenging benchmarking infrastructure construction cost internationally.

VII. Road specific

13. Conducting a road transport infrastructure construction cost benchmarking analysis is more complex when it is undertaken at international level instead of within a country. Differences among countries turned this benchmarking analysis quite complicated. The comparability problems were technical in some cases but more fundamental in other cases. Specifically for road infrastructure, the needs, expectations and conditions of the countries tend to be quite variable. While some countries do not need new infrastructure projects at all, as they have completed their highway infrastructure network, other countries require smaller-scale projects or are building mega projects. The size of the road projects is a very important factor when conducting a cost benchmarking analysis. However, during this exercise, it was not known how many countries provided data on small-sized projects and how many of them provided data on mega sized projects and this impeded part of the analysis.

14. This study conducted a cost benchmarking analysis focusing on national projects implemented over a period of 10 years. Economic stability and other related socio-economic factors of the countries involved in the course of this 10 year period was an important element in the conduct of this benchmarking analysis. The study concluded that some construction costs of road infrastructures are not comparable across ECE member States. This result shows that mutual understanding is still a challenge. Data and results need to be further calibrated. Regarding other benchmarking parameters such as GNP per capita and population density a correlation between actual cost and the size of economies and of countries was not established. This may in part be due to limited data availability because of which the data boxplot analysis could not be applied.

VIII. Rail and inland waterways specific

15. For the purpose of this report Azerbaijan, Bulgaria, Croatia, Finland, Kazakhstan, Poland, Serbia, Slovenia, Tajikistan, Türkiye, and Turkmenistan kindly provided data on their investment projects in the railway sector. Some of this data was collected within the ECO-ECE-ISdB GIS project. Data was also received from the ECE Trans-European Railway (TER) project.

16. Considering that the railway is a complex system with many different elements, parameters and characteristics, and since each railway line requires a different approach, the costs are difficult to be compared. The analysis was made not only for the new construction,
but also for upgrade and renewal, as the last two are of crucial importance for the railway investment process.

17. Inland waterways is an important, environmentally friendly and energy efficient mode of transport, and can therefore greatly contribute to socio-economic development of the whole transport system. At the same time due to specifics of inland waterways navigation and rivers per se, most of the data received was difficult to compare as it involved many different and often location-specific infrastructure works and projects.
Chapter 1
Introduction, mandate, and modus operandi of the Group

I. Background

1. During the twenty-seventh session of the Working Party on Transport Trends and Economics (WP.5) (Geneva, 8–10 September 2014) a workshop was organized on “Good practices and new tools for Financing Transport Infrastructure”. During the workshop it was agreed by the participants that the benchmarking of transport infrastructure construction costs is significant for having realistic construction costs and a stable investment program with no unforeseen costs. The Working Party requested the secretariat to draft a formal document based on inputs received by the experts on benchmarking of transport infrastructure construction costs where proposals for possible further actions to be taken by the Working Party on this issue were to be included. (ECE/TRANS/WP.5/56, paras. 10 and 12).


3. These Terms of Reference (ECE/TRANS/2016/4) were subsequently adopted by the Inland Transport Committee at its seventy-eighth session (Geneva, 23–26 February 2016) (ECE/TRANS/254, para. 21) and by the Executive Committee during its May 2016 session.

Box 1
At a joint, Euro-Asian Transport Links (EATL) project - Trans-European Motorways (TEM) and Trans-European Railway (TER) projects – and Working Party on Transport Trends and Economics, workshop on “Financing Transport Infrastructure”, Geneva, September 2013

Participants:
• Recalled that financing of transport infrastructure includes the planning for and building of new infrastructure, as well as the planning for and realization of rehabilitation and/or maintenance of existing one.
• Agreed on the need to prepare feasibility studies where the economic viability will be analysed by taking into consideration the social aspects of such investments such as road safety and environmental costs.
• Agreed on the need to identify and harmonize, if possible, the cost per unit of investment, i.e. cost of constructing 1 kilometre of road or the cost of constructing 1 kilometre of railroad or high-speed railroad.
• Observed the need to harmonize the technical standards of transport infrastructure and referred to the technical standards included in international agreements serviced by ECE e.g. AGR¹, AGC², AGTC³ and AGN⁴ as best practices to be followed.
• Noted that an observatory for exchange of information and lessons learned from implementing public private partnership (PPP) schemes as a transport infrastructure financing tool could be beneficial.
• Observed that the development of investment plans and especially their harmonization is an efficient step forward to finance transport infrastructure. Also noted the work developing investment plans during the EATL phase II and agreed on the need to focus on funding these projects.

¹ European Agreement on Main International Traffic Arteries
² European Agreement on Main International Railway Lines
³ European Agreement on Important International Combined Transport Lines and Related Installations
⁴ European Agreement on Main Inland Waterways of International Importance
• Observed that improvements should also take place on non-physical obstacles – border crossings facilitation, etc. — in parallel with the physical ones such as transport infrastructure.

II. Scope of issues and achievements expected:

4. Based on its ToRs it was agreed that the Group of Experts should focus its work on the following issues:
   • Identify models, methodologies, tools and good practices for evaluating, calculating and analysing inland transport infrastructure construction costs.
   • Identify and list terminologies used in the ECE region for construction costs of inland transport infrastructure; if possible, create a glossary of agreed terminologies and related explanations.
   • Collect and analyse data in order to prepare a benchmarking of transport infrastructure construction costs along the ECE region for each inland transport mode – road, rail, inland waterways – including intermodal terminals, freight/logistics centres and ports; Analyse and describe the conditions / parameters under which these costs have been calculated on.

5. It was also decided that the Group of Experts should base its considerations on previous work of ECE in this field, in particular the work on:
   • Cost benefit analysis of transport infrastructure projects, 2003.5
   • A methodological basis for the definition of common criteria regarding the identification of bottlenecks, missing links and quality of service in infrastructure networks, 2009.6
   • The Trans-European North-South Motorway (TEM) Project standards and Recommended Practice, 2002.7
   • The TEM and TER revised Master Plan – Final Report, 2012.8
   • The Euro Asian Transport Linkages Project studies, 2008/2012.9, 10

III. Methods of work

6. Participation in the Group of Experts was opened to all concerned United Nations member countries and experts. Concerned intergovernmental and non-governmental organizations, as well as concerned road, railway and inland waterways administration authorities and companies, freight and forwarding industries, intermodal terminals, freight and logistics centres as well as ports authorities are invited to participate and provide expert advice in compliance with United Nations rules and practices.

7. It was agreed that translation of documents and simultaneous interpretation of its sessions in English, French, and Russian shall be provided by ECE for all sessions held at the Palais des Nations in Geneva.

8. Representatives of the following ECE Member States participated in the first session and to varying degrees remained involved in the subsequent sessions: Austria, Croatia, Cyprus, Czechia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Slovakia, Sweden and Türkiye.

---

9. At a later stage representative of the Russian Federation engaged in the work of the Group as well.

IV. Time-frame

10. The initial mandate of the Group of Experts was for two years but it has been extended twice, most recently on the occasion of the eighty-third session of the Inland Transport Committee (February 2021) until 2022, with the aim to hold at least two sessions annually in 2021 and 2022 with interpretation in the three ECE official languages and to continue and revamp its data collection efforts across all modes resulting in a more data rich final report.

11. In the course of these six years the Group of Experts met on the following occasions:

   • First session: 31 October 2016 – 1 November 2016
   • Second session: 10–11 April 2016
   • Third session: 10–11 July 2016
   • Fourth session: 16–17 October 2017
   • Fifth session: 30–31 January 2018
   • Sixth session: 1–2 May 2018
   • Seventh session: 28 June 2018
   • Eighth session: 15–16 July 2019
   • Ninth session: 29 September – 1 October 2019
   • Tenth session: 30–31 January 2020
   • Eleventh session: May 2020 cancelled due to COVID-19 (replaced by shorter virtual sessions on 14 May 2020 and 18 June 2020 respectively)
   • Eleventh session: 8-9 April 2021
   • Twelfth session: 22-23 November 2021
   • Thirteenth session: 10-11 February 2022

12. The final, fourteenth session of the Group was held on 23-24 May 2022.

V. Work plan/ Sequence of work

13. The Group conducted its activities based on a prepared work plan in order to ensure its smooth implementation.

14. The following work phases are to be distinguished:

   • Development of specific questionnaires:
     • Questionnaire on Benchmarking Road Transport Infrastructure Construction Costs
     • Questionnaire on Benchmarking Rail Transport Infrastructure Construction Costs
     • Questionnaire on Benchmarking Intermodal Terminal Infrastructure Construction Costs
     • Questionnaire on Benchmarking Inland Waterway Infrastructure Construction, Upgrading and Maintenance Costs
     • Questionnaire on Benchmarking Inland Waterway Port Construction, Upgrading and Maintenance Costs
     • The development of a set of 4 open questions on different national benchmarking models and approaches in use across the ECE region
• Upon its last extension and as suggested by the Government of Türkiye, the Group has developed two additional questionnaires with a focus on transport infrastructure maintenance and operation costs.

• Development of a consolidated list of terminologies on benchmarking of road, rail, inland waterway and intermodal terminals construction costs, including also on benchmarking of maintenance and operation costs.

• Dissemination of these questionnaires among delegates participating in WP.5 which is the GE.4 parent body.

• Dissemination of the questionnaires among delegates in mode-specific Working Parties including SC.1 on Road Transport, SC.2 on Rail Transport, SC.3/WP.3 Inland Water Transport and WP.25 on Intermodal Transport and Logistics.

• In parallel, reaching out to and building partnerships with other relevant organizations in the field of benchmarking of transport infrastructure construction costs, including TEM and TER Projects, the International Union of Railways (UIC), the International Road Federation (IRF) and European Union networks of road and rail infrastructure operators.

• The following GE.4 members acted as lead countries for the drafting process of the final report:
  • Türkiye: conducted a benchmarking literature review and provided substantive inputs to the road transport terminology and the analysis of data for the road sector.
  • Poland: provided substantive inputs to the rail transport terminology and conducted the analysis of data for the rail sector.
  • Russian Federation: provided substantive inputs to the road data analysis and contributed to the compilation of national benchmarking approaches and methodologies.
  • All other members of the Group actively participated in the drafting process of the final report and contributed through the provision of national case studies and data on benchmarking.

VI. Challenges experienced and opportunities identified by the Group

15. The Group faced several challenges in the conduct of its work, including during its final extension:

(a) The quantity and quality of road and railway data
The data received was often sparse and scattered. In some cases, there were misrepresentations or omissions in the datasets provided by respondents. The first challenge was to turn the data into a workable format which could later be analysed. For that purpose, all the questionnaires with missing or inaccurate data had to be removed from the final dataset.

(b) Delays in data collection for intermodal terminals, inland waterways and ports
In particular the data collection efforts for ports, intermodal terminals and inland waterways were delayed and the data received was often insufficient or inaccurate. The present study has therefore mostly focused on road and rail sectors.

16. Given however that the available analysis proves to be of great value added it is worthwhile to continue data collection efforts of the Group across all modes. In doing so, efforts need to be made to make sure that there is a better understanding among ECE member States wishing to submit additional data regarding the exact requirements. At its thirteenth session in February 2022, the Group decided that rather than asking for an additional
extension of its mandate or establish a new Group to continue the work, its efforts could be continued in the framework of the TEM and TER projects.

VII. Sustainability options for the work of the Group

A. Synergies with the International Transport Infrastructure Observatory

1. Integrating data and analytical findings of the Group into the International Transport Infrastructure Observatory (ITIO)

17. At its twelfth session (November 2021), the Group received more information about the recently established Geographic Information System (GIS) based International Transport Infrastructure Observatory (ITIO). The secretariat provided a detailed description of the Observatory, its purpose, functions, user groups and operational modalities. The Group requested the secretariat to prepare ahead of its next session a short note providing food-for-thought on the potential that this GIS platform offers to host and visualise benchmarking analytical data and information on national and regional benchmarking best practices. Section VII of the present document provides such an overview.

2. Main objectives of the International Transport Infrastructure Observatory and the services it provides

18. The Observatory offers a multi-stakeholder, web-based Geographic Information System (GIS) platform which hosts data on a large variety of transport infrastructure networks and nodes across different modes including road, rail, inland waterways, ports, airports, intermodal terminals, logistics centres and border crossing points. A geographic information system (GIS) is a system that creates, manages, analyses, and maps all types of data. GIS connects data to a map, integrating location data with all types of descriptive information. This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making. (Esri, 2021).

19. The main objectives of the Observatory are:

   (a) Support the implementation of pillars 1, 2 and 4 of the ITC Strategy until 2030, envisaging the role of the ITC as: a United Nations Platform for regional and global inland transport conventions, a United Nations Platform for supporting new technologies and innovations in inland transport and a United Nations Platform for promoting sustainable regional and interregional inland transport connectivity and mobility, respectively.

   (b) Support the implementation of Sustainable Development Goal (SDG) 9 on “Building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation”; SDG 11 on “Making cities and human settlements inclusive, safe, resilient and sustainable; SDG 13 on “Taking urgent action to combat climate change and its impacts”; and SDG 17 on “Strengthening the means of implementation and revitalizing the global partnership for sustainable development”.

   (c) Offer to the United Nations system and Governments an innovative and inclusive tool that further facilitates transport infrastructure financing and enhances regional and interregional connectivity.

20. The main pillars of services that the observatory provides are being summarized below:

   (a) Offering an electronic repository of ECE inland transport conventions, project outputs, and deliverables of designated Groups of Experts:

      • More specifically, the observatory provides an electronic platform that will be catalytical for the ongoing digitalization of different United Nations inland transport
agreements and conventions, especially those covering infrastructure (AGR\textsuperscript{11}, AGC\textsuperscript{12}, AGTC\textsuperscript{13} and AGN\textsuperscript{14}) but also border crossing facilitation instruments such as TIR\textsuperscript{15}/eTIR (customs systems location).

- Furthermore, it offers a digital environment that helps visualize specific outputs and deliverables, such as the work done in the framework of the TEM\textsuperscript{16}, TER\textsuperscript{17} and EATL\textsuperscript{18} projects but also the tangible outputs produced by the Group of Experts on Assessment of Climate Change Impacts and Adaptation for Inland (GE.3) and the Group of Experts on Benchmarking Transport Infrastructure Construction Costs (GE.4).

(b) Promoting sustainable regional and interregional connectivity: the observatory provides the possibility to all regional and interregional organizations to create their own maps illustrating their transport infrastructure initiatives, corridors, projects, reports and studies and anything else they consider useful for the purpose of further enhancing regional connectivity. This will enhance cooperation among the different transport infrastructure initiatives in Europe, Asia, and Africa.

(c) Financing transport infrastructure: the observatory operates as a marketplace for financing transport infrastructure by providing an electronic interface between Multilateral Development Banks and Governments. Governments can upload their transport infrastructure projects in need of funding as well as select which MDBs they wish to reach out to. By adding or removing GIS layers, data on transport infrastructure networks can be combined with data about the national and/or regional ratification and implementation rate of specific transport legal instruments or with the impact that climate change may have on planned infrastructure projects. For MDBs, the observatory functions as a clearing house granting them direct access to a centralized information platform assisting them to decide which projects to consider for funding. A secured electronic communication platform will be provided enabling all users to reach out to each other and exchange information.

3. **User categories, profiles, and functionalities**

21. Four user groups are foreseen in the observatory:

   (a) Governments

   (b) Multilateral Development Banks

   (c) Regional Cooperation Organizations

   (d) The wider public

22. Each of these user groups have access to a distinct set of functionalities, services, and possibilities. For Governments, MDBs and Regional Cooperation Organizations (RCOs) access will be granted to officially nominated/accredited representatives only. A username and password will be provided only after receipt of nominations by the secretariat. The public, academia, private sector, independent experts, and others will not have to register but will only have access to high-level data and information. Upon entering the observatory, they may be invited through an optional online survey to provide some background and profile information for statistical purposes (reasons for using the observatory, their location, professional affiliation etc.).

---

\textsuperscript{11} European Agreement on Main International Traffic Arteries

\textsuperscript{12} European Agreement on Main International Railway Lines

\textsuperscript{13} European Agreement on Important International Combined Transport Lines and Related Installations

\textsuperscript{14} European Agreement on Main. Inland Waterways of International. Importance

\textsuperscript{15} Convention on International Transport of Goods Under Cover of TIR Carnets

\textsuperscript{16} Trans-European Motorways project

\textsuperscript{17} Trans-European Railways project

\textsuperscript{18} Euro-Asian Transport Links
4. Next steps

23. Develop additional functionalities for the ITIO, including related to visualising the benchmarking data and analysis prepared by the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4/WP.5).

24. Benefits to the ITIO include:

   • Transport infrastructure construction cost data either at national/country level (i.e. average for a 10-year period) or at specific project level are of high interest both to Government users as they can compare and evaluate the costs of their own infrastructure projects with the associated costs in countries in their immediate (sub-)region as well as to International Financial Institutions (IFIs) and Multilateral Development Banks (MDBs) who may be interested in funding national and or (sub-)regional projects and want to understand how a given project proposal compares to project proposals from other countries.

   • Adding a GIS layer to the ITIO that would provide such information would increase the attractiveness and usability of the platform and would also add value to Governments and MDBs since the benchmarking of transport infrastructure construction costs is a critical step for having realistic construction costs and a stable investment program without unexpected cost increases. The use of benchmarking of construction costs could also be useful for cost estimates as well as for control of projects’ costs.

25. Benefits to GE.4:

   • As the Group by May 2022 will have concluded its mandate, uploading its analysis and data findings onto the ITIO may be the best way to ensure that the work of the Group becomes sustainable and would in addition to resulting in a written report also live on in a virtual/ GIS based environment.

   • Moreover, the ITIO could offer an automated user dashboard function that would allow Governments, in a secured IT environment, to continue sharing transport infrastructure construction cost information with one another.

26. Short overview of benchmarking visualisation options:

   • GE.4 has gathered and analysed two types of transport infrastructure construction cost datasets: i) Multiple year country averages and ii) Specific project data (including information on a geographical start and end point of a specific infrastructure project). The latter option provides better options for visualisation in a GIS environment as the infrastructure segment that is subject of a planned or ongoing construction project could be shown on a map. The former could be illustrated at national/ country level through a pop-up window which would illustrate average cost data.

B. Continuation of benchmarking of transport infrastructure construction cost efforts in the framework of the Trans-European Motorways and Trans-European Railway projects

27. At its thirteenth session in February 2020, the Group decided that rather than asking for an additional extension of its mandate or establish a new Group to continue the work, its efforts could be continued in the framework of the TEM and TER projects.

28. The TEM and TER Master Plans, reflecting the priority transport infrastructure needs of 21 Central, Eastern, and South-Eastern European countries identify the backbone road and rail networks in those countries and present a realistic investment strategy to gradually develop these networks. As many as 491 projects with an aggregate estimated cost of EUR 102 billion have been evaluated and prioritized so far. The Group deems TEM and TER projects as very well-placed framework to continue and further extent its benchmarking efforts.
Annex III

Chapter 2  
Section A - A benchmarking literature review – definitions, concepts and methodologies

I. Introduction

1. As requested by the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs at its twelfth session in November 2021, this document is submitted as Chapter II of the final report of the Group. It builds further on the information contained in ECE/TRANS/WP.5/2020/6 and is a further revision of ECE/TRANS/WP.5/GE.4/2022/3. It provides an overview of benchmarking definitions, concepts, and methodologies. As requested by the Group at its thirteenth session, additional information has been added by the representatives of Türkiye and Poland on concepts surrounding the benchmarking of transport infrastructure maintenance and operation costs.

II. Benchmarking Concept and Description

2. Benchmarking as a Verb refers to a process of comparing agencies’ operations and performance against recognized standards and improving those operations to enhance the effectiveness. According to Merriam Webster’s Collegiate Dictionary, tenth edition, a benchmark as a Noun refers to the numerical target or reference point for taking measures against. This word has migrated into the business world, where it has come to mean: “A benchmark is a measured best-in-class achievement recognized as the standard of excellence for that business process”.

3. According to Merriam Webster’s Collegiate Dictionary (1994), the word benchmark defines as (1) mark on a permanent object indicating elevation and serving as a reference in topographical surveys and tidal observations, (2) point of reference from which measurements may be made. Its origin comes from geographic surveying. The International Clearinghouse for Benchmarking (1992) defined benchmarking as the “process of continuously comparing and measuring an organization with business leaders anywhere in the world to gain information that will help the organization act to improve its performance”.

4. In literature there are plenty of definitions and most of them describe benchmarking as the process of comparing something or someone with best practice. On the other hand, best practices are collections of activities within an organization that are done very well and ultimately, are recognized as such by others. It is referred to as a learning process, a performance process and a strategic activity.

5. Since benchmarking is referred to as a strategic activity, it requires a lot of research and analysis. To make it efficient, the company must be clear about the type of related strategy it must adapt to treat a specific problem area (Priya, 2018).

6. Benchmarking is the process of continuously improving business or organizational processes by evaluating the scope for improvement, comparing the current position with that of the previous one or with the business practices of relevant competitors, thereby establishing standards to be achieved (Priya, 2018). Typically, measured dimensions are quality, time and cost. Benchmarking is used to measure performance using a specific indicator (cost per unit of measure, productivity per unit of measure, cycle time of x per unit of measure or defects per unit of measure) resulting in a performance metric that is then compared to others.

7. It is an important continuous improvement tool which empowers companies and organizations to enhance their performance by identifying, adapting and implementing the best practice (Ryus, et al, 2010). Benchmarking is the process of systematically seeking out best practices to strive towards. It thus is a continuous learning and improvement process.
III. History of Benchmarking

8. Benchmarking is an evolving concept that has developed since the 1940’s towards more sophisticated forms. The history of benchmarking as described by Watson (1993) has been categorized under five generations of benchmarking. The first generation was reverse engineering, which was an engineering-based approach to product comparisons that included teardown and analysis of technical product characteristics. The second generation was competitive benchmarking which Xerox refined starting in 1976. This type of benchmarking went beyond product-orientation comparisons to comparing processes with competitors. In the 1980s, the third generation of benchmarking was process benchmarking, which included searching for best practices across industry boundaries. The fourth-generation benchmarking was strategic benchmarking; where it was used to fundamentally change the business, not just alter the processes. Lastly, the fifth generation was global benchmarking, where international trade, cultural and business process distinctions among companies are abridged and their implications for business process improvement are understood. In the 1980s and 90s benchmarking became a popular management tool in organizations to achieve quality and to learn best practices. Later it has been used by several companies like General Motors, Hewlett Packard, Dupont, Motorola, Royal Mail and others.

Figure I
Five Generations of Benchmarking

IV. Scopes of Benchmarking

9. Benchmarking aims to improve an organization’s performance and competitiveness by learning from and/or with others towards the best practices (Kyrö, 2003).

10. Scott cited Meade’ (1998) benchmarking theory is formed by ten principles. These are:

   (a) Improves practices, services or products;
(b) Involves learning about ‘best practices’ from others;
(c) Accelerates the rate of progress and improvements;
(d) Contributes to continuous quality management;
(e) Is an ongoing process;
(f) Promotes fresh and innovative thinking about problems;
(g) Provides hard data on performance;
(h) Focuses not only on what is achieved, but on how it is achieved;
(i) Involves the adaptation, not merely adoption, of best practices; and
(g) Results in the setting of specific targets.

11. Since the specifics of benchmarking relate to best practices, the starting point of benchmarking is either to learn from others’ outstanding performances, or to create them with others.

12. While benchmarking and action research both aim to improve practices, but benchmarking also has its specifics:
   (a) Focuses on best practices to identify next practices;
   (b) Strives for continuous improvement;
   (c) Partnering to share information;
   (d) Needed to maintain a competitive edge;
   (e) Adapting based on customer needs after examination of the best;
   (f) Lead to competitor research.

V. Types of Benchmarking

13. Literature review shows that there are many types of benchmarking and many ways of categorizing these types. Authors seem to capture different categories of benchmarking. Some terms are used by different authors with different meanings. Each type seems useful for a particular situation. The most important overarching principle however regardless of the benchmarking approach that is used is that the aim of the benchmarking exercise needs to be clear and achievable, and that the choice of partner organization needs to be aligned with the aims.

14. Lutfullayev, cited Alstete (1996) identifies five types: internal, external competitive, external collaborative, external trans-industry (best-in-class), and implicit benchmarking. He also cited Jackson and Helen (2000) classified benchmarking types according to referencing processes:
   (a) Implicit or explicit benchmarking;
   (b) Independent or collaborative benchmarking;
   (c) Internal or external focused benchmarking;
   (d) Vertical or horizontal benchmarking which is focused on the whole process;
   (e) Quantitative and qualitative approach benchmarking;
   (f) Input-process-output focused benchmarking.

15. Four types of benchmarking namely internal, competitive, non-competitive, and best practice/world class were identified by Cook (1995). On the other hand, Vlăsceanu, Grümborg, and Pârlea. (2004) identify the three prevalent benchmarking types as strategic benchmarking (focusing on what is done, on the strategies organizations use to compete), operational benchmarking (focusing on how things are done, on how well other organizations perform, and on how they achieve performance), and data-based benchmarking (statistical
benchmarking that examines the comparison of data-based scores and conventional performance indicators). They mentioned also internal/external and external collaborative/trans-industry/implicit benchmarking types. They say, within different types, benchmarking may be either vertical (aiming at quantifying the costs, workloads, and learning to improve productivity of a predefined program area) or horizontal (looking at the costs of outcomes of a single process that cuts across more than one program area).

16. Achtemeier and Simpson (2005) mention process benchmarking, metric benchmarking and goals and milestones. Process benchmarking involves identifying a problem area within one’s own institution, identifying another not necessarily similar institution with exemplary performance in this area, and sending a team of people who work in this area to the exemplary institution to learn how it achieves its outstanding results. The team then adapts these best practices to improve the home institution. Metric benchmarking means the comparison, among several institutions, of data for selected indicators in order to determine an institution’s relative performance (Smith, Armstrong, & Brown, 1999). Goals and milestones represent another way to understand benchmarking. One identifies internal targets to indicate an institution’s process, and these may be chosen without any external reference by which to measure (Zairi, 1996).

17. Alstete (1996) gives two types of benchmarking approaches, which is strategic benchmarking and operational-level benchmarking. With strategic approach, the organization looks at its overall competitive products and services to understand and develop competitive products and strategies (Camp, 1995). Operational benchmarking is used to understand specific customer requirements and the best practices to achieve customer satisfaction by improving internal organizational processes.

18. Yarrow and Prabhu (1999) differentiate three forms of benchmarking: metric, process, and diagnostic. Metric benchmarking seems to be the simplest and most straightforward in that it compares the performance data of businesses. Though efficient and simple, the metric process requires that the businesses are comparable, and it focuses only on superficial manifestations of business practices. Process benchmarking refers to an expensive, time consuming endeavor in which two or more organizations complete an in-depth comparison of specific business practices in order to achieve better results. Diagnostic benchmarking, on the other hand, is more akin to a ‘health check’ for the company, helping to identify which practices need to be changed and the nature and extent of performance improvements to be followed (Yarrow and Prabhu, 1999).

19. At an overarching level, there are two types of benchmarking. These are internal and external benchmarking as given in the following Figure-3.
A. Internal Benchmarking

20. Internal benchmarking refers to efforts aimed at comparing organizational performance over time. The performance of the organization is compared either to its previous performance or to the performance of its competitors, i.e., companies belonging to the same industry (Priya, 2018).

21. As illustrated in Figure II, ‘Best Practice Benchmarking’, ‘Performance Metrics’, ‘Financial Benchmarking’ and ‘Functional Benchmarking’ are various strategies falling under this category.

22. SWOT: In this benchmarking strategy, the strengths, weaknesses, opportunities and threats of the company are listed and analyzed by the management.

23. Best Practice Benchmarking: The management itself studies and identifies the strategies and practices of the other companies who are the market leaders, to plan the desired course of action.

24. Performance Metrics: This strategy is based on statistical metrics derived through the analysis of the client’s preference and the comparison made with competitors. The company can find out the loopholes in its performance and come up with a strategy to address those.

25. Financial Benchmarking: The management compares the financial forecast of the organization with the actual results or financial reports in an attempt to identify areas of shortcomings and take corrective actions.

26. Functional Benchmarking: The company compares its performance and products with those of other related industries to innovatively improve its functioning.

B. External Benchmarking

27. In external benchmarking, the company compares its performance with that of its competitors in the industry or across the globe (Priya, 2018). Typically, this is done by comparing data collected through sectoral or industrial associations or third parties.

28. As illustrated in Figure II, ‘Collaborative Benchmarking’, ‘Process Benchmarking’, ‘Product Benchmarking’, ‘Corporate Benchmarking’, ‘Strategic Benchmarking’ and ‘Global Benchmarking’ are various strategies falling under this category.

---

19 Strengths, Weaknesses, Opportunities and Threats
29. Collaborative Benchmarking: To improve the performance standards, the companies belonging to a particular industry collaborate in the framework of industrial associations. These associations provide the benchmarking data on best practices and a comparative analysis of all the companies, which in turn facilitates the improvement of the underperforming companies.

30. Process Benchmarking: In process benchmarking, the company analyzes the competitor’s methods, tasks, techniques of production, means of distribution, etc. It also studies the standard mechanisms of performing specific functions, to modify its ways accordingly.

31. Product Benchmarking: This strategy focuses on the in-depth analysis of the competitor’s product to know its features and composition. The company uses this strategy to improve and redesign its own products.

32. Corporate Benchmarking: The company compares its various departments like finance, production, distribution, marketing, human resources, etc. with those of its competitors to enhance the efficiency of each division.

33. Strategic Benchmarking: This strategy is usually adopted when the company plans to implement a new policy or idea or modify the existing one. The team compares the company’s approach with that of the other successful companies in the industry before bringing it into practice.

34. Global Benchmarking: It is similar to strategic benchmarking, the only difference is that here the company compares its strategies with those of its other branches or the various competitors spread across the globe, to take corrective actions.

35. In the following figure types of benchmarking are given.

**VI. Models and Methodologies of Benchmarking**

36. There is no single benchmarking process that has been universally adopted, instead, numerous benchmarking models co-exist and are used in parallel. In general terms, benchmarking can be defined as a continuous and systematic process of comparing products, services, processes and outcomes with other organizations or exemplars, for the purpose of improving outcomes by identifying, adapting, and implementing best practice approaches. Since benchmarking is the practice of comparing business processes and performance metrics to industry leaders and best practices from other companies, the most often measured performance dimensions are quality, time and costs.

37. Benchmarking is used to measure performance using a specific indicator (cost per unit of measure, productivity per unit of measure, cycle time of x per unit of measure or defects per unit of measure) resulting in a metric of performance that is then compared to others.
38. There is no single benchmarking process that has been universally adopted. The wide appeal and acceptance of benchmarking has led to the emergence of a variety of benchmarking methodologies. Benchmarking process models and methodologies can vary from four steps to up to 30 steps. The four-step approach which is suggested by Alstete (1996) consists of: “Plan, Do, Check and Act” (PDCA) as illustrated below in Figure 4.

Figure IV
Alstete’s Benchmarking process

39. Robert Camp developed a 12-stage approach to benchmarking.

40. The 12-stage methodology consists of:
   • Selecting a subject
   • Defining the process
   • Identifying potential partners
   • Identifying data sources
   • Collecting data and selecting all partners
   • Determining the gap
   • Establishing process differences
   • Targeting future performance
   • Communicating
   • Adjusting goals
   • Implementing
   • Reviewing and recalibrating

41. On the other hand, the Figure below identifies seven steps of effective benchmarking.
42. As illustrated in the below figure, any benchmarking process is mainly divided into two branches: standards and practices.

Figure VI
Benchmarking Process

43. A typical benchmarking methodology is given as an example in the following paragraphs:

- Identify problem areas: Because benchmarking can be applied to any business process or function, a range of research techniques may be required. These include informal conversations with customers, employees, or suppliers; exploratory research techniques such as focus groups; or in-depth marketing research, quantitative research, surveys, questionnaires, re-engineering analysis, process mapping, quality control variance reports, financial ratio analysis, or simply reviewing cycle times or other performance indicators. Before embarking on comparison with other organizations it is essential to know the organization’s functions and processes; base lining performance provides a point against which improvement efforts can be measured.
• Identify other industries that have similar processes: For instance, if one were interested in improving hand-over in addiction treatment one would identify other fields that also have hand-over challenges. These could include air traffic control, cell phone switching between towers, transfer of patients from surgery to recovery rooms.

• Identify organizations that are leaders in these areas: Look for the very best in any industry and in any country. Consult customers, suppliers, financial analysts, trade associations, and professional magazines to determine which companies are worthy of study.

• Survey companies for measures and practices: this involves the deployment of detailed surveys of measures and practices used to identify business process alternatives and leading companies. Surveys are typically masked to protect confidential data by neutral associations and consultants.

• Visit the "best practice" companies to identify leading edge practices: Companies typically agree to mutually exchange information beneficial to all parties in a benchmarking group and share the results within the group.

• Implement new and improved business practices: Take the leading-edge practices and develop implementation plans which include identification of specific opportunities, funding the project and selling the ideas to the organization for the purpose of gaining demonstrated value from the process.

44. A benchmarking roadmap is shown in the following figure.

Benchmarking Roadmap

45. To benchmark anything, first of all quantitative data availability is the most important issue to study. This implies breaking down internal processes to calculate performance metrics. Quantify everything, because only quantifiable information can be accurately compared.
VII. Benchmarking in Construction Industry

46. Benchmarking is a new tool to be used in the construction industry. The database created by the Houston Business Roundtable (HBR), one of the first attempts to develop a plan of benchmarking in construction, only contains information on global results of the projects allowing the parties to compare their performance with that of the other projects in this database (Alarcon and Serpeli). The data in this study was developed following a questionnaire that was submitted to company representatives to determine if there was any interest in benchmarking, and if so, what parameters should be used. According to Alarcon and Serpeli the following were the parameters proposed by the participating construction companies:

- Authorized vs. actual costs
- Authorized vs. actual time schedule
- Actual labor vs. estimated
- Scope change vs. original scope

47. The proposed parameters reflect an interest in comparing measured results rather than identifying the deficiencies in practices which affect the results. Actually, such an approach is more of a competitiveness than a benchmarking analysis (Muniz, 1995).

48. Benchmarking project results (cost, schedule, etc.) has a limited value since, at most, it identifies high-level problem areas but does not help to define a possible improvement strategy. With such an approach a company can understand if its planned schedule or cost performance is met, but it cannot know the source of the problems that exist, nor can it know why its competitors are more successful in achieving its results. This can only be achieved analyzing the factors which lead to a successful performance.

49. Benchmarking the results of a project leaves a company part way in the utilization of this improvement tool, since it arrives only at the first stage (Watson 1994) “To understand own processes and to detect its weaknesses and strengths. It however does not accomplish the following stages:

(a) To understand the leaders of industry or competitors; to identify, to understand and to compare the better practices.
(b) To incorporate the best; to copy, to modify or to incorporate the better practices in its own processes.

(c) To gain superiority by combining its own strengths with better existing practices.

50. These last three stages constitute the basis of benchmarking as an improvement tool.

Modeling in Construction Industry

51. Statistical analysis serves as a traditional tool for developing models from empirical information. However, other options exist and may be even more attractive (Alarcon & Ashley 1992, 1996). Alarcon has recently developed a methodology to evaluate project management strategies whose principal components are indicated below:

- A general methodology for the acquisition and modeling of expert knowledge for evaluating decisions in projects.
- A mathematical model based on concepts of cross-impact analysis and statistical inference.
- A representation scheme to support communication and problem structuring during the modeling process.
- A prototype Computer implementation to automatize capturing and processing of information to analyze a model.

52. The methodology consists of a conceptual, qualitative model structure and a mathematical model structure. The conceptual model structure, called the General Performance Model (GPM), is a simplified model of the variables and interactions that influence project performance. The mathematical model uses concepts of cross-impact analysis and probabilistic inference to capture the uncertainties and interactions among project variables. The structure of the GPM is summarized in the following Figure.

Figure IX
General Performance Model (Alarcon and Serpeli)

53. The computational scheme utilized within the model allows for different execution strategies to be compared on a relative basis. Preferred strategies are ranked either based on combined performance or on any single chosen criterion. Sensitivity analyses help determine the robustness of any highly ranked strategy, as well as which drivers or processes have greater impacts on outcomes.

54. This work provides a conceptual and theoretical framework for modeling decision situations that will serve as a basis for the development of the proposed models.

55. In the following table proposed project performance parameters are listed.
<table>
<thead>
<tr>
<th><strong>Table 1</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proposed Project Performance Parameters (Alarcon and Serpeli)</strong></td>
<td><strong>Results</strong></td>
<td><strong>Parameters</strong></td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td><strong>Units</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Cost Variation</td>
<td>Actual Cost/Budgeted Cost</td>
</tr>
<tr>
<td><strong>Scheduled Duration</strong></td>
<td>Schedule Variation</td>
<td>Actual Duration/Planned Duration</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>Rejection of Work</td>
<td>% Sample Rejections</td>
</tr>
<tr>
<td><strong>Scope of Work</strong></td>
<td>Change in Scope of Work</td>
<td>Change Orders/Budgeted Cost</td>
</tr>
<tr>
<td><strong>Procurement</strong></td>
<td>Delivery Time</td>
<td>Delivery Cycle Time</td>
</tr>
<tr>
<td></td>
<td>Compliance W/Specs</td>
<td>% Compliance W/Specs</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>Labour (MH)</td>
<td>Actual Labour MH vs. Planned MH</td>
</tr>
<tr>
<td></td>
<td>Productivity</td>
<td>Actual vs Planned</td>
</tr>
<tr>
<td></td>
<td>Rework</td>
<td>Rework MH/Total MH</td>
</tr>
<tr>
<td></td>
<td>Material Waste</td>
<td>% Material Waste</td>
</tr>
<tr>
<td></td>
<td>Equipment</td>
<td>% Stand by Hours.</td>
</tr>
<tr>
<td></td>
<td>Activities at Planned Rate</td>
<td>% Activities Working at Planned Rate</td>
</tr>
<tr>
<td><strong>Planning</strong></td>
<td>Planning Effectiveness</td>
<td>% Planned Activities Completed</td>
</tr>
<tr>
<td><strong>Engineering Design</strong></td>
<td>Design Changes</td>
<td>Number of Changes/ Total Number of Drawings</td>
</tr>
<tr>
<td></td>
<td>Errors /Omissions</td>
<td>Number of Errors/ Total Number of Drawings</td>
</tr>
<tr>
<td><strong>Other variables</strong></td>
<td><strong>Parameters</strong></td>
<td><strong>Units</strong></td>
</tr>
<tr>
<td><strong>OH&amp;S</strong></td>
<td>Accident Frequency</td>
<td>Number of Accidents* 100/ Total Number of Workers</td>
</tr>
<tr>
<td></td>
<td>Risk Rate</td>
<td>Number of Days Lost* 100/ Annual Average of Workers</td>
</tr>
<tr>
<td><strong>Subcontracts</strong></td>
<td>Subcontracted MH</td>
<td>% MH Subcontracted</td>
</tr>
<tr>
<td></td>
<td>Subcontracted $</td>
<td>% of Cost Subcontracted</td>
</tr>
</tbody>
</table>

56. The collection of information on these performance parameters will allow, as the database grows, to statistically study the existing correlations among results, characteristics and intermediate processes of projects and to develop models to explain the existing causalities, all of which will help to identify the sources of success and failure in construction projects. In this way it will be possible to focus on more accurate studies of operational benchmarking to identify best practices for the industry to improve as a whole.
57. In Table-2 performance indicators for another study are given. The median of these indicators was used.

Table 2
Performance Indicators (Alarcon and Serpeli)

<table>
<thead>
<tr>
<th>Area</th>
<th>Indicator</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Deviation of Cost by Project</td>
<td>(Real Cost - Budgeted Cost) / Budgeted Cost</td>
</tr>
<tr>
<td>Due Date</td>
<td>Deviation of Construction Due Date</td>
<td>(Real Due Date - Initial Due Date Budgeted) / Initial Due Date Budgeted</td>
</tr>
<tr>
<td>Scope of Project</td>
<td>Change in Amount Contracted</td>
<td>Sale Final Contract / Sale Initial Contract</td>
</tr>
<tr>
<td>Safety</td>
<td>Accident Rate</td>
<td>(Number of Accidents) * 100/ Total Number of Workers</td>
</tr>
<tr>
<td></td>
<td>Risk Rate</td>
<td>(Number of Days Lost) * 100/ Yearly Average of Workers</td>
</tr>
<tr>
<td>Labour</td>
<td>Efficiency of Direct Labour</td>
<td>Direct Hours Budgeted / Direct Real Hours</td>
</tr>
<tr>
<td></td>
<td>Productivity - Performance</td>
<td>Budgeted Cost Direct Hours / Cost Real Direct Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sale Final Contract / Direct Real Hours Labour at Construction Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sale Final Contract / Relevant Units Executed</td>
</tr>
<tr>
<td>Subcontracts</td>
<td>Rate of Subcontract</td>
<td>Amount Sub-Contracted / Sale Final Contract</td>
</tr>
<tr>
<td>Quality</td>
<td>Cost Client Complaints</td>
<td>Cost Client Complaints / Total Cost of Project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost Client Complaints /Number of Complaints Per Client</td>
</tr>
<tr>
<td>Procurement</td>
<td>Urgent Orders</td>
<td>Number of Urgent Orders / Total Number of Orders</td>
</tr>
<tr>
<td>Planning</td>
<td>Effectiveness of Planning</td>
<td>% Completed Activities (PCA) = Number of Activities Completed / Number of Activities Programmed</td>
</tr>
</tbody>
</table>

VIII. Application of Benchmarking in Transport Infrastructure

58. Transport infrastructure is a key most component of economic development and social well-being. It is indispensable for social and personal life. It supports, and also ensures personal well-being and national economic growth.

59. The transport sector is an important component of the economy and a common tool used for development. Transportation infrastructures are among essential public assets in many countries.

60. Transportation assets are vitally the most important public assets for the accessibility and mobility of the people and freight. Improvements of these assets are to ensure important benefits to the citizens, taxpayers or users through access to health centres, schools, works, markets, tourism centres by improved comfort, speed, safety and lower vehicle operating costs (in case of the road infrastructure) (WB, 2005). They also support overall economic development by ensuring access of freight transport to logistics centres.
61. To achieve these benefits, a well-planned and timely scheduled transport infrastructure system must be built, maintained and upgraded on a regular basis. A relation between the quantity and quality of transport infrastructure and the level of economic development is apparent. High-density transport infrastructure and highly connected networks are commonly associated with high levels of development.

62. As important as developing the transportation infrastructure and constructing new lines, extending network, increasing capacity is, it is equally important to maintain and improving the system regularly.

63. Maintenance processes are essential to sustain the capacity of transport infrastructures to provide multiple public services for the customers and stakeholders as defined above. To achieve this, it is necessary to carry out relevant treatments towards assets to keep their performance on the level as much as possible close to initially provided when originally constructed. Appropriate maintenance allows to protect adjacent resources and user safety, and to provide efficient, convenient, and safe travel along the route.

64. Unfortunately, maintenance is often neglected or improperly performed resulting in rapid deterioration of the assets and eventual failure from both climatic and vehicle use impacts. The aim of the maintenance is to preserve the asset not to upgrade. Maintenance activities should be done regularly and contains – for example in the road sub-sector - “activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the road margins as near as possible to their as-constructed or renewed condition” (PIARC, 1994).

65. Benchmarking is a strategic tool that helps users make decisions that improve the efficiency and effectiveness of transport assets. Benchmarking is closely associated with measuring costs and performance at the project level in the transportation sector as well as infrastructure sector (RICS, 2020). The most difficult part of benchmarking is data collecting and managing, data sharing, mutual understanding and defining benchmarking programme (What to benchmark, what levels to benchmark, what timescale to use, where). In a large body of literature on transport infrastructure, process of benchmarking is given as in the following figure.

Figure X
Steps in the benchmarking process (NCHRP, 2004)

66. There are five main process steps, as follows: selecting partners, establishing measures, measuring performance, identifying best performances and practices, and implementing and improving continuously.

67. In transport sectors partners are generally state/nation agencies, local agencies, cities, counties, turnpike/motorway authorities, private sector firms, organizations in different industries and organizations in other countries (NCHRP, 2004).
68. “A benchmarking partner and a benchmarking unit are not necessarily the same—for example, a state maintenance organization could be a benchmarking partner with benchmarking units consisting of districts, counties, areas, or garages. Private companies could be benchmarking partners, and their benchmarking units could consist of districts. County government or municipalities could both be partners, while having subunits that are benchmarking units” (NCHRP, 2004).

69. As a result of benchmarking to achieve good results the units to be benchmarked must have some expected characteristics and show this intention. These are: initial agreement what to benchmark, cooperation and willingness to share information, willingness to create common measures, commitment to data and measurement quality, commitment on time, effort, and resources.

70. A National Cooperative Highway Research Program (NCHRP) research cited as report identified two general approaches towards benchmarking in the infrastructure industry as independent (or internal) benchmarking and external benchmarking or benchmarking within a network of similar organisations (RICS, 2020).

71. To identify the levels of benchmarking once the context of benchmarking is established. The levels of benchmarking are identified as international, system, network, asset and project. Appropriate metrics should be developed to measure the performance. To achieve international benchmarking, international standards should also be adapted. The most common measures used to benchmark cost is spatial measures as $/m, $/m2, $/m3 (CabinetOffice, 2012).

72. Benchmarking is closely associated with measuring costs and performance in the infrastructure sector. ICMS (International Construction Measurement Standards) and ICMS Data Standards are good tools to perform infrastructure benchmarking on international level. Cost benchmarking is used as a more reliable platform for predicting the cost of new projects, so benchmarking is also useful in improving cost estimation in the transport sector.

73. “The benefits of benchmarking in the infrastructure sector have been documented by several global research studies, including the NCHRP in the US, and IPA, Centre for Transport Studies (CTS) at Imperial College London and benchmarking tunnelling costs and production rates in the UK” (RICS, 2020).

A. Transport Assets Maintenance Benchmarking

74. Transportation agencies have recognized that continuous improvement is essential to manage the maintenance organization effectively in the face of growing demand, tight budgets, and limited staff. There are different methods and techniques to improve the efficiency and effectiveness of the delivered maintenance products and services. All agencies look for the continuous improvement and best way of doing maintenance works cost effective, efficient, timely by identifying best practice. As defined early benchmarking is the process to identify the best performance, best way doing something and a learning process. It is also a kind of measurement technique.

75. For maintenance products and services one of the benchmarking in literature is customer-driven benchmarking. Four types of measures are used in customer driven benchmarking: Outcomes, outputs, resources, and hardship factors (NCHRP, 2004). These are defined as follows.

(a) Outcomes: Outcomes are the results of performing maintenance activities that are important to customers. Examples of outcomes are smooth roads, edge markings that are easy to see in poor weather, and traffic signals.

(b) Outputs: Outputs are measures of accomplishment or production. Examples of outputs are linear m of ditches cleaned, the number of bags of litter collected, and acres of grass mowed.

(c) Resources: Resources consist of labour, equipment, materials, and financial costs.
(d) Hardship factors: These are factors outside the control of the maintenance organization that make it more difficult to satisfy customer desires and needs. Examples of hardship factors are weather, terrain, and population density.

76. Customer-driven benchmarking combines all four measures to give analysts and managers a broad perspective on how well various organizations are achieving outcomes that matter to customers in a manner that uses the fewest possible resources while considering the level of production and uncontrollable factors such as weather (NCHRP, 2004). Organizations that do this the best, as determined through measurement, are sources of practices that agencies should consider adopting. It is recommended to further analyse the potential measures for benchmarking of the maintenance services in the railway sub-sector and in the inland waterways sub-sectors. Although some of the costs may be treated as internal or even confidential, perhaps it is possible to find a few of indicators which relates to the total costs of ownership of transportation infrastructure assets and to carry out benchmarking to feed the efficiency management in the country and/or particular road, rail, inland waterways managing organization.

B. Understanding the Importance of Maintenance

77. Many developed countries already established their transportation network. Trends in transport sector is not building new infrastructures but providing efficient transportation system. However, transportation professionals face important challenges: to provide efficient transportation with an aging infrastructure, to meet growing public and legislative demands for accountability, and to manage the rapid pace of change (TRB, 2006). The major trends affecting maintenance are:

- Infrastructure growth is slowing therefore maintenance, rehabilitation, improvement and preservation of transport assets are becoming more important.
- Traffic volumes continue to grow.
- Transport assets are getting aged and operators and managers of the organizations must respond this problem on time and in efficient manner.
- Technology is growing so rapidly also digital age is presenting solutions by also creating some problems.
- Climate is changing, that climate change makes maintenance and development of transport systems more important.
- Environmental concerns are becoming more and more important.
- Investing in maintenance at the right time saves significant future costs.
- Maintenance investment must be properly managed.

C. Road Transport

78. Without an emphasis on maintenance, highway and bridge infrastructure aged more rapidly than it could be reconstructed or rehabilitated (TRB, 2005). Currently, new attitudes toward maintenance prevail as understanding and awareness grow. Preservation of assets and mobility are high-priority challenges for a highway system that is essentially in place.

79. Categories of road maintenance costs should be aligned with the overall categories of maintenance, which in the case of the road sub-sector are as routine, periodic and urgent.

80. Routine maintenance, which comprises small-scale works conducted regularly, aims “to ensure the daily pass ability and safety of existing roads in the short-run and to prevent premature deterioration of the roads” (PIARC, 1994). Frequency of activities varies but is generally once or more a week or month. Typical activities include roadside verge clearing and grass cutting, cleaning of silted ditches and culverts, cleaning and repairing traffic signs and signals, patching, and pothole repair (WB, 2005). For gravel roads it may include regrading every six months. In addition, the purpose of winter maintenance is maintaining
the roads safe and passable during severe winter conditions by means of using all effective operation and management techniques and solutions to keep away snow and to prevent frost on the road surface. Roads are maintained regularly and their operability is ensured. Routine maintenance restores serviceability.

81. According to World Bank periodic maintenance covers activities on a section of road at regular and restively long intervals and aims to preserve the structural integrity of the road. These operations tend to be large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and sometimes even a design. Activities can be classified as preventive, resurfacing, overlay and pavement reconstruction.

82. Urgent maintenance is undertaken for repairs that cannot be foreseen but require immediate attention such as collapsed culverts or landslides that block a road.

83. Authorized agencies responsible for maintaining roads are local and national/state authorities and works are performed by these local i.e. municipalities and national agencies. Road agencies engage with Ministry of Finance and present their annual roads maintenance budget needs to get funds. If the roads are not constructed and operated by any techniques as PPP budget generally comes from central budget. Once maintenance needs have been estimated, the road agency finalizes and submits its annual budget for consideration to a funding source. At the central level that would be the Ministry of Finance or a road fund; at the regional or local level, it would be the funding authority at that level. Each country’s institutional and financial systems affect how the budget submission is presented.

84. In the case of roads, maintenance and operations can be outsourced to private organizations or carried out using force accounts (inhouse units and equipment) or both as hybrid model. Responsible road agencies need competent maintenance program management, a good monitoring system, and clear and transparent procurement procedures. During last 10-20 years periodic maintenance done by in-house labour is being replaced by more contracts with the private sector worldwide.

85. There are several types of road maintenance contracts. Contracts can be classifying by size of contracts and type of work as length worker, community contractor, petty contractor, microenterprise, small scale contractor, medium- and large-scale contractors (TRL and DFID, 2003). Some contracts are short term (6-12 months or 1-2 years) and some of them are long-term (2-3 or 3-5 years) contracts. Some of the contracts are lump sum contract or depends on unit prices and some of them depends on performance-based or hybrid (mixture of performance contract and unit price contract). Generally routine maintenance contracts are often short-term contracts. Many countries use domestic although local contractors to implement maintenance works. Some contracts just compromise routine maintenance works but some of them include periodic maintenance also.

86. The cost of the maintenance depends on conditions of the region and country, conditions of the roads. Routine maintenance cost varies by climate, topography, used equipment and machines as sophisticated or conventional, market prices, labour costs, GDP of the country, traffic loads and other factors. In addition, type of the maintenance contracts changes unit costs. According to WB Transport Notes (WB, 2005), unit routine maintenance cost of two-lane bituminous highway is between 656-5,580 US$/km and the average is 2,199 US$/km with 2000-unit prices. According to study done in NZ in 2012 maintenance and operation cost of local roads is 2,870 NZ$/km and for state highway it is 29,318 NZ$/km (Hatcher, Hunter and Mitchell, 2012).

87. The maintenance management is an organized method that controls what work needs to be done, determines the timeframe of the work, labour, equipment, and material resources, and projects the cost of the work to be done. Proper maintenance management can reduce costs up to 20% per year (Hagood, 2014). In general maintenance management consists of four stages: planning, organizing, directing, and controlling. All these stages presented in the following figure.


D. Railway Transport

88. In the case of railway sub-sector costs may fall into two broad categories, which in the case of the Polish railway infrastructure manager are:

- Costs of maintenance and renewal of railway infrastructure
- Costs of operation of the train service

The first category is similar to the road sub-sector and contains, inter alia:

- Regular repairs
- Major repairs
- Winter services
- Operations
- Emergency interventions

89. These costs are directly incurred as a result of infrastructure maintenance and renewal were calculated using the so-called binary method which involves an assessment of the individual types of economic events in terms of their direct relation to train movements. The titles of economic events that are classified as direct costs and noneligible costs are specified and commented in the List of Controlling Items. The figure below shows an example of how economic events are divided into direct and noneligible costs for operations on mainline tracks, which generate 84% of direct costs.
### Table 3

Examples of categories of costs in the case of the Polish railway infrastructure management

<table>
<thead>
<tr>
<th>Costs directly incurred as a result of train movement</th>
<th>non-eligible costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mainline tracks</strong></td>
<td></td>
</tr>
<tr>
<td>Costs by nature only consumption of non-traction liquid fuel, consumption of materials, maintenance related services, renewal related services, remunerations, social insurance contributions</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
</tr>
<tr>
<td>- replacement of damaged connectors and installation of missing connectors, tightening screws and bolts</td>
<td></td>
</tr>
<tr>
<td>- supplementing ballast</td>
<td></td>
</tr>
<tr>
<td>- restoring rail profile by grinding</td>
<td></td>
</tr>
<tr>
<td>- horizontal and vertical adjustments of tracks</td>
<td></td>
</tr>
<tr>
<td>- replacement of single components of the superstructure, final repairs of cracked rails, etc.</td>
<td></td>
</tr>
<tr>
<td>- ongoing rail replacement,</td>
<td></td>
</tr>
<tr>
<td>- ongoing sleeper replacement,</td>
<td></td>
</tr>
<tr>
<td>- ongoing cleaning, supplementing and thickening of ballast, etc.</td>
<td></td>
</tr>
<tr>
<td>- removal of snow and ice from tracks from November to March</td>
<td></td>
</tr>
<tr>
<td>- depreciation.</td>
<td></td>
</tr>
<tr>
<td>- keeping the areas in good order.</td>
<td></td>
</tr>
<tr>
<td>- lease payments.</td>
<td></td>
</tr>
<tr>
<td><strong>Winter operations</strong></td>
<td></td>
</tr>
<tr>
<td>- replacement of single components of the superstructure, final repairs of cracked rails, etc.</td>
<td></td>
</tr>
<tr>
<td>- ongoing rail replacement,</td>
<td></td>
</tr>
<tr>
<td>- ongoing sleeper replacement,</td>
<td></td>
</tr>
<tr>
<td>- ongoing cleaning, supplementing and thickening of ballast, etc.</td>
<td></td>
</tr>
<tr>
<td>- removal of snow and ice from tracks from November to March</td>
<td></td>
</tr>
<tr>
<td>- depreciation.</td>
<td></td>
</tr>
<tr>
<td>- keeping the areas in good order.</td>
<td></td>
</tr>
<tr>
<td>- lease payments.</td>
<td></td>
</tr>
<tr>
<td><strong>Operation</strong></td>
<td></td>
</tr>
<tr>
<td>- plans, measurements and diagnostic analyses.</td>
<td></td>
</tr>
<tr>
<td>- troubleshooting reports</td>
<td></td>
</tr>
<tr>
<td>- visual inspections of infrastructure in accordance with instructions, etc.</td>
<td></td>
</tr>
<tr>
<td>- ad-hoc protection or elimination of damage restoring unobstructed traffic flow or the required technical and operational parameters to enable safe rail traffic operations.</td>
<td></td>
</tr>
<tr>
<td><strong>Emergency repairs</strong></td>
<td></td>
</tr>
<tr>
<td>- damage due to thefts and acts of vandalism, and costs of maintenance, regular and major repairs, and preparations for winter operations, which are not direct costs</td>
<td></td>
</tr>
</tbody>
</table>

---

20 according to the agreement between PKP PLK S.A. and PKP S.A. for handing over the railway lines along with other immovable property required to manage these railway lines for paid use
90. The second category (of operation of the train service) are calculated to determine the unit rates for the minimum access to railway infrastructure are generated by:

- Train dispatchers, signallers, and points operators,
- Level-crossing attendants,
- Production planning dispatchers and line dispatchers,
- Staff needed for preparing train timetables.

91. The cost that is directly incurred because of train movement is the cost incurred during the active working time of the above staff members. The active working time is the time used for operations related to train movement and shunting.

92. The direct costs include the costs of salaries and social insurance contributions that are paid by the employer, which are the costs of the active working time of train dispatchers, signallers and points operators, level-crossing attendants, production planning dispatchers, line dispatchers, and the staff needed for preparing train timetables. The noneligible costs are the costs related to train movements, which, however, are not direct costs, in particular the costs of readiness to operate train service stations in the absence of train movements, annual, additional, training and sick leaves, time off work for renewal examinations and medical check-ups. The followings are samples on transportation infrastructure benchmarking from literature.

E. Infrastructure Benchmarking Report, Australia

93. The Transport Infrastructure Council published a booklet named “Infrastructure Benchmarking Report” in Australia. This report covers the findings of the initial benchmarking and outlines plans for continued and improved future monitoring of infrastructure procurement performance and construction costs (TIC, Australia). The analysis was undertaken by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) for the Infrastructure Working Group of the Transport and Infrastructure Council in Australia.

94. Analysis of the procurement processes found the majority of the projects in the pilot study sample met most timeliness targets and most qualitative and quantitative performance measures specified by Infrastructure Australia. The majority of projects also complied with planned quantitative and qualitative performance benchmarks, however, with two exceptions:

- Almost 80 per cent of sampled projects reported at least one addendum for project changes or missing information; and
- Approximately 57 per cent of sample projects reported at least one material change to terms or scope at the Request for Proposal phase.

Benchmarking Construction Costs

95. The infrastructure construction cost benchmarks presented are of a strategic nature, as recommended in the Productivity Commission’s Public Infrastructure inquiry report. The results cover a sample of 65 separate road construction projects undertaken since 2010, drawn from across all eight states and territories. Thirty of the projects in the sample have been completed, 26 are currently in delivery and nine projects are at pre-delivery phase. Only completed projects and projects currently in delivery have been included in the benchmarks. New South Wales and Queensland account for just over half of all projects in the sample.

96. The main findings of the cost benchmarking analysis are:

(a) road class is the most significant factor influencing average project costs – average costs of urban and rural freeways/highways are around $6.0 to $6.5 million per lane kilometer, while lower standard rural arterials average around $3.0 million per lane kilometer (Figure IX, Table 4);
(b) project management costs typically comprise around 7 per cent of total costs while design and investigation costs typically comprise around 5–6 per cent (Figure II); and

(c) the project sample provides no clear evidence of any time trend in average project costs over the last five years.

Figure XII
Summary Cost Benchmarks – Project Cost Per Lane Kilometer, By Road Reference Class

Table 4
Construction Cost Benchmarks, by Component and Road Reference Class

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Unit</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 6</th>
<th>Class 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average project cost</td>
<td>($/lane km)</td>
<td>6.45</td>
<td>4.13</td>
<td>2.86</td>
<td>7.76</td>
<td>6.44</td>
</tr>
<tr>
<td>Average project cost (excl. land</td>
<td>($/lane km)</td>
<td>6.06</td>
<td>3.72</td>
<td>2.70</td>
<td>5.85</td>
<td>4.07</td>
</tr>
<tr>
<td>acquisition &amp; supplementary items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average construction cost</td>
<td>($/lane km)</td>
<td>5.46</td>
<td>3.40</td>
<td>2.47</td>
<td>5.06</td>
<td>5.11</td>
</tr>
<tr>
<td>Average pavement costs</td>
<td>($/sq. m)</td>
<td>902.7</td>
<td>981.9</td>
<td>230.4</td>
<td>995.3</td>
<td>891.1</td>
</tr>
<tr>
<td>Average bridge costs</td>
<td>($/sq. m)</td>
<td>159.1</td>
<td>158.5</td>
<td>79.1</td>
<td>201.8</td>
<td>164.3</td>
</tr>
<tr>
<td>Average bulk earthworks costs</td>
<td>($/cu m)</td>
<td>5090</td>
<td>4150</td>
<td>3880</td>
<td>3610</td>
<td>3650</td>
</tr>
</tbody>
</table>

a. The average cost benchmarks reported in the table are based on the sample mean. The data set included only three Class 7 (Urban) road projects, so the reported benchmarks may not be representative of broader selection of Class 7 road projects.

b. Austroads functional road classification definitions: Class 1 – Principal rural highways and freeways connecting major regions and capital cities; Class 2 – Principal rural arterial roads; Class 3 – Main rural arterial roads, not in Class 1 or Class 2; Class 6 – Urban motorways and freeways; Class 7 – Primary urban arterial roads.

Source: BITRE estimates based on state- and territory-supplied data.
97. The first national cost benchmarking was a significant step to inform efficient and effective project delivery and identify areas of best practice. Experience from this study initial benchmarking highlighted the need to collect additional information about projects (such as project type, construction methodologies, terrain, pavement type) to better understand the causes of cost variations, particularly for the small number of projects that had costs that differed significantly from averages for the class of road.

98. Preliminary international comparison provided mixed results – suggesting that average Australian road project costs were found below equivalent project costs in the United Kingdom, but above project costs in four continental European countries.

F. Study named “Road Works Cost per Km” World Bank Report

99. This research prepared by Rodrigo Archondo-Callao in 2000 April. The objective of this report is to create a database of actual maintenance, rehabilitation and construction work costs per km. In this report information from World Bank completed highways projects, from 40 countries between 1995 to 1999, was reviewed. 93 work costs per km were found or estimated.

100. The descriptions given to the road works on World Bank reports are very general (for example: rehabilitation, strengthening, periodic maintenance, reconstruction, improvement, construction, etc.). Most of the time no detailed information was found, such as road width, terrain, traffic, overlay thickness, regravelling thickness, rehabilitation surface, improvement type, etc. It was only possible to estimate average costs and costs statistics for a series of road work classes based on the general descriptions.

1. Road Works Classes

101. Paved Roads - Seals (reseals, surface dressings) - Functional Overlays (thickness $\leq 5.0$ cm) - Structural Overlays (thickness > 5.0 cm) - Rehabilitation (strengthening, reconstruction) - Construction (widening, new construction)

102. Unpaved Roads - Regravelling - Rehabilitation - Improvement - Paving

2. Average Works Costs per Km

103. Paved Roads - Seals 20,000 $/km - Functional Overlays 56,000 $/km - Structural Overlays 146,000 $/km - Rehabilitation 214,000 $/km - Construction 866,000 $/km.
104. Unpaved Roads - Regravelling 11,000 $/km - Rehabilitation 31,000 $/km - Improvement 72,000 $/km - Paving 254,000 $/km.

3. Range of Works Costs per Km

105. Paved Roads - Seals 5,000 - 32,000 $/km - Functional Overlays 30,000 - 107,000 $/km - Structural Overlays 74,000 - 198,000 $/km - Rehabilitation 45,000 - 700,000 $/km - Construction 142,000 - 1,832,000 $/km.

106. Unpaved Roads - Regravelling 9,000 - 13,000 $/km - Rehabilitation 17,000 - 47,000 $/km - Improvement 11,000 - 114,000 $/km - Paving 62,000 - 609,000 $/km.

4. Number of Observations and Standard Deviation of Works Costs per Km

107. Paved Roads - Seals (7) 10,000 $/km - Functional Overlays (12) 24,000 $/km - Structural Overlays (6) 42,000 $/km – Rehabilitation (33) 144,000 $/km - Construction (13) 567,000 $/km.

108. Unpaved Roads - Regravelling (4) 2,000 $/km – Rehabilitation (4) 17,000 $/km - Improvement (6) 37,000 $/km - Paving (10) 153,000 $/km.

Figure XIV
Average and Range of Roads Works Costs (1000) US $ per km (Archondo-Callao)

G. Routine Maintenance Benchmarking of Turkish Motorways, State and Provincial Roads

109. In Türkiye motorways, state roads and provincial roads (excluding urban roads) which is about 68,526 km are under responsibility of General Directorate of Highways (KGM) as end of 2021. KGM is a national road transport authority and has 18 regional directorates. There is central office in Ankara which is dealing with mega projects and governance. All maintenance works are done at regional directorates by maintenance chief offices and maintenance houses. Except ring roads motorways are toll roads and toll roads maintenance are performed by maintenance and operation chief offices as same method as state and provincial roads but for assigned motorway sections as average 110 km. However, for special tunnels (i.e. Bolu Mountain’s Tunnel) and special bridges (i.e. Bosphorus Bridges) maintenance and operation chiefs offices are just assigned for that special infrastructures. In addition, not all regional directorates have motorway network.

110. In Türkiye there are also motorway sections and special transportation infrastructures constructed and operated under PPP method. Motorways and special road transport infrastructures which has been constructed under PPP method has also been managed,
operated and maintained by private firms. Routine maintenance benchmarking is only performed for publicly owned and operated roads under KGM (General Directorate of Turkish Highways) responsibility.

111. Under each regional directorate there are nearly 7 maintenance chief offices which is responsible from state and provincial roads covering almost one or at most two provinces. Each maintenance chief offices are responsible nearly 500 km state and provincial road network and each regional directorate is responsible nearly 3,500 km state and provincial road network (Motorways are not included). There are also regional directorates that does not have motorway network.

112. Routine maintenance works are performed using hybrid model in Türkiye that is by force account and contracts together. Contracts are generally based on unit prices.

113. Routine maintenance expenditures and unit costs totally and by work types (TL (Turkish Lira)/Km) are benchmarked by central office in Ankara internally in terms of subdivisions of each directorate and by different years and externally in terms of each regional directorate annually.

114. This benchmarking analysis is done in order to,
   • Calculate realized cost and ranges
   • Find out which parameters are important to specify maintenance cost
   • Determine necessary budget for the following year for maintenance purpose
   • Reduce the cost of delivering maintenance products and services or both
   • Use for benefit-cost analysis
   • Improve efficiency
   • Increase customer satisfaction
   • Ensure continuous improvement, etc.

115. The road maintenance benchmarking study is performed every year. There is a database called KBOS (Organizational Information Automation System) where all inputs, outputs, outcomes, resources are recorded in this automation system. All data is uploaded on time and controlled and checked by system itself warning the person entering data and by central office in Ankara. Leader of this benchmarking is General Directorate. Data quality is the essential element of benchmarking. This benchmarking analysis is documented and published as a book and shared each year on KGM web page with all partners and customers, however some confidential data and outcomes is not shared. Measures are expenses (TL-Turkish Lira) and unit costs (TL/Km).

116. The results are mainly given as;
   • Expenditures
     • Labor expenditures (TL)
     • Material expenditures (TL)
     • Invoiced expenditures (TL)
     • Expenditures under maintenance works contracts (TL)
   • Unit Costs
     • Routine maintenance unit costs (TL/Km)
     • Winter maintenance unit costs (TL/Km)
     • Traffic safety issues unit costs (TL/Km)
     • Toll collection unit costs (Just for motorways) (TL/Km)

117. At the end of each year not only unit maintenance cost has been calculated and benchmarked, but also productivity analysis has been performed and productivity indicators has also been benchmarked. Cost overruns reasons for maintenance cost also have been
researched. Benchmarking is also performed every 5 years to benchmark different years performances and products.

118. Two different routine maintenance works benchmarking analyses are done every year, one is for state and provincial roads and the other one is for motorways. These benchmark analyses are done in detail however a very short summary of the result for 2020 is given below.

119. In 2020, 62,140 km state and provincial roads were maintained. Total expenditures for this network are totally 972,770,200 US$ including winter maintenance expenditures. The breakdown of this expenditure is given in the following graph. As a short summary from this analysis, unit cost of routine maintenance works of state and provincial roads is 3,930 US$/LanexKm in 2020-year prices including winter maintenance.

Figure XV
Routine Maintenance Expenditures Breakdown of Primary and Secondary Roads (%) (2020 Prices)

120. On the other hand, in 2020, 2,610 km motorways, were maintained and operated. Total expenditures for this network 142,708,603 US$ including winter maintenance and toll expenditures. The breakdown of this expenditure is given in the following graph. As a short summary from this analysis, unit cost of routine maintenance works of toll roads is 12,633 US$/LanexKm in 2020-year prices including winter maintenance and toll collection.

121. For motorways not only, costs and performance indicators are benchmarked but also ratio between Revenues to Expenditures are also benchmarked since motorways are tolled roads in Türkiye.
122. Benchmarking steps as a simple flowchart for motorways, state and provincial roads is given in the following figure.

Figure XVII
Benchmarking Steps of Routine Maintenance of Roads Under KGM Responsibility
IX. Advantages and Disadvantages of Benchmarking

A. Advantages of Benchmarking

123. Benchmarking is essential for organizations to sustain high-level competition and to keep up with the customer’s requirement and needs.

124. Benchmarking improves Learning Methodology: Benchmarking paves the way for generating new ideas and for sharing of proven business practices which can be seen as a learning experience for the companies.

125. Initiates Technological Upgrading: Through this strategy, the companies get to know about the new technologies and techniques which have been adopted by the market leaders. Companies can accordingly plan for upgrading their technologies to remain competitive.

126. Improve Company’s Standards: The company analyses and studies the standards of the competitors. This facilitates the company to raise its own standard of production and products accordingly.

127. Enhances Work Quality: It leads to organizational growth since it improves the overall quality of the output and reduces the chances of errors due to the standardization of business operations.

128. Cope with Competition: Knowing about the competitors’ business and their strategy, helps the company to design its strategies efficiently. It also facilitates the company to remain up-to-date with recent technological developments and trends and remain competitive.

129. Improves Efficiency: The overall efficiency of the employees increases with this practice since standardization of work motivates them to perform better without making mistakes.

130. Improved Quality: Benchmarking helps organizations to continuously improve the quality of their products and services. Organizations observe the current standard, and then try to surpass that.

131. Better performance: Benchmarking helps organizations overcome complacency. They continuously strive to improve their performance standards in order to stay relevant in the market.

132. Increases Customer Satisfaction: Through benchmarking, the company collects sufficient data on customer’s needs and requirements. This information helps the company to enhance the customer experience and satisfaction level.

133. Help Overcome Weaknesses: These strategies help the company in finding out its shortcomings and overcome them to get the desired results.

134. Cost efficiency: Benchmarking provides organizations with valuable data on latest technologies, and business processes. These are aimed at increasing productivity while reducing cost. For example, a manufacturing company might learn about a certain machine used by its competitor, which can do the work of five workers. This company might then choose to adopt a similar technology to lower its labour cost.

135. Prioritizing areas of improvement: While organizations understand the importance to develop continuously, they might be unsure at times about where to start the improvement from. Benchmarking helps organizations to identify the areas where the gap between their own standard and that of the industry is the largest. This helps organizations to prioritize the areas they need to work on.

B. Disadvantages of Benchmarking

136. Benchmarking requires a lot of expertise and a vast collection of data that may not be readily available in any organization.
137. Lack of Information: Sometimes, the company is unable to gather adequate information for benchmarking. This leads to an improper or inadequate comparison of the company’s performance with that of its competitors.

138. Increases Dependency: The companies tend to depend on other companies’ strategies to become successful. In this process of following the market leaders, companies sacrifice their individuality and uniqueness by following the practices of others in the industry.

139. Lack of Understanding: At times, companies adopt benchmarking for the sake of doing so, rather than understanding the many benefits it can bring. Instead of using the benchmarking process to better identify and remedy its own weaknesses some businesses may only be interested in the functioning of their competitors.

140. Copying Others: Some organizations do not understand the actual purpose of this strategy and start copying their competitors in every aspect. This may even impede the very survival of the company.

141. Incorrect Comparison: comparing of organizational performances needs to be focused on relevant business process aspects, otherwise it may result in irrelevant or poor benchmarks.

142. Costly Affair: It requires a team of experienced personnel who have excellent analytical skills and expertise in the area. It may thus increase the administrative expenses of the company.

X. Conclusion

143. It is observed that companies at times might be reluctant to use benchmarks. One of the most popular reason for this is the belief that they are their own organization, and hence, do not need to emulate any other organization. This is where it is critical to underline the fact that benchmarking does not mean blindly ‘copying’ what competitors do.

144. Benchmarking is the simplest way to understand where an organization stands, and how far it needs to go before it reaches the top. While earlier benchmarking was a ‘good to do’ initiative, today it has become critical for organizations in order to stay relevant and gain a competitive edge.

145. Not only private sector but also public sector started to use benchmarking starting from 1990s.

146. Specific benchmarking approaches are not easily replicable, instead organizations must adapt the information to fit their needs, their culture, and their system. And, if organizations do simply reproduce a specific approach, they will only be as good as their competitor, not better. Benchmarking among companies or organizations is not about stealing ideas and approaches, on the contrary, it is an open, fair and transparent study of another organization’s business practices. Benchmarking is a continuous process that requires constant calibration.

147. Benchmarking is not just looking for a better way to do things, it is about identifying the best approach.

XI. List of References


Lutfullayev, P. “Research on benchmarking in higher education: an overview”, core.ac.uk/download/pdf/162007595.pdf


PIARC (World Road Association), (1994). International Road Maintenance Handbook: Practical Guidelines for Rural Road Maintenance, Volume I of IV. Roadside Areas and Drainage. Financed and coordinated by ODA and TRL.


TRL (Transport Research Laboratory) and DFID (U.K. Department for International Development), (2003). Management of Rural Road Network. Overseas Road Note 20. TRL Limited, Crowthorne, Berkshire, UK.


Annex IV

Chapter 2
Section B - National approaches in the benchmarking of road, rail and inland waterway infrastructure construction costs

Introduction

An important pillar of the mandate of the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4) was to identify models, methodologies, tools, and good practices for evaluating, calculating, and analysing inland transport infrastructure construction costs. The Group prepared and distributed a set of four open questions to gather the required information. The present document has been prepared as Chapter 2/section B of the final report as requested by the Group at its twelfth session (November 2021).
Appendix

Responses of relevance for road, rail and inland waterway transport infrastructure per country

I. How do you go about calculating, forecasting and evaluating transport infrastructure construction costs?

A. Croatia

1. Development of the transport infrastructure network is based on the Transport Development Strategy of the Republic of Croatia 2017–2030. As large infrastructure projects are often co-financed under European Union funds, feasibility studies and a Cost Benefit Analysis (CBA) are mandatory. Ex-ante and ex-post evaluation are performed taking into consideration the prepared feasibility study and CBA. Moreover, cost estimates of infrastructure projects are based on market studies and experience with similar projects.

2. Moreover, construction of transport infrastructure is subject to open international procurement/tender procedures. The tender is awarded to the tenderer with the lowest tender price.

B. Cyprus

3. Cost data are collected from the previous years constructed/completed projects for all different type of works in structures, highway (including various works: earthworks, drainage, traffic management, health and safety etc.); consequently, a data bank has been created based on the cost data.

Figure I
Flow chart indicating the process for the evaluating, calculating and analyzing the road transport infrastructure construction cost along with the tendering procedure

```
Cost data collected from Previous years Constructed projects

Creation of a data bank for the costs of all different types of works

Preparation of a detailed bill of quantities for the different type of works for the new project

Estimating the budget of the new project based on the detailed bill of quantities prepared
```
Preparation of the tender documents of the new project to be procured (condition of contracts, drawings, technical specification, special terms of condition of contract)

Public invitation for tenders for the new project

Evaluating the received tenders based on the prices of the detailed bill of quantities prepared by public works department

Provided that all the tender document requirements are fulfilled, then the tender is awarded to the tenderer with the lowest tender price

If there is a major deviation (plus or minus) on the total tender price received, with the one prepared by public works department then based on provisions/ regulations of the law ruling the procurement/tendering procedure the tendering process is cancelled and the tender process is repeated

Before the new tender process begins the public works department investigates the factors/reasons which have influenced the tender price deviation. All the necessary remedial measures will be taken before the new tendering procedure begins again

C. Latvia

4. The procedure how the executors of construction works must calculate construction costs for all types of structures including engineering structures is stipulated in the Resolution of the Cabinet of Ministers No. 239 “Regulations on Latvian Construction Norm 501-17 “Order of Determining Construction Costs”. Construction costs include costs for construction materials, work costs, rent of construction equipment and machinery, labour costs, wear of equipment (depreciation), overhead costs and profit, as well as, other costs related to construction (e.g. clearing of construction site, relocation of utilities).

5. Planned construction costs are determined based on the prices of similar works defined in other concluded construction contracts, forecasts of macro-economic development indexes, changes in the construction market of transport infrastructure and related development forecasts.
D. Poland

6. The planned cost of construction work is calculated using the index method as the sum of the products of the price index and the number of reference units, according to the formula:

\[ WRB = \sum WC_i \times n_i \]

where:
- \( WRB \) - value of planned cost of construction work;
- \( WC_i \) - price index of the \( i \)-th cost component;
- \( n_i \) - the number of reference units for the \( i \)-th cost component.

7. The basis for calculating the planned value of construction work is:
   (a) statement of work;
   (b) price indices.

8. Cost components are determined considering the structure of the classification system of Common Procurement Glossary, using, depending on the scope and type of construction work covered by the contract, the groups, classes or categories of work referred to in the Common Procurement Glossary.

9. If the work contract includes construction within the scope of the Construction Law, the cost components must correspond at the very least to the groups of work covered in the Common Procurement Glossary and include:
   (a) cost of site preparation work;
   (b) cost of construction work for basic facilities;
   (c) cost of installation work;
   (d) cost of finishing work;
   (e) cost of work related to land development and construction of ancillary facilities.

10. The price index of a given cost component is determined based on market data or in the absence of such data - based on commonly used catalogues and price lists.

11. The number of reference units is determined based on the statement of work.

12. Where there is not a single suitable price index, these costs should be calculated to produce an individual cost estimate.

13. When preparing the cost estimate, you can make use of currently available publications.

14. The estimate may also be prepared based on a cost analysis of a completed order or parts thereof and thus based on individual analyses.

15. Sources of information for individual data collection can be:
   (a) concluded agreements or contracts;
   (b) prices from current publications, guides, catalogues, and offers;
   (c) prognostic data in the area of shaping prices.

E. Russian Federation

16. The Urban Planning Code of the Russian Federation defines the mandatory application of estimated standards, as included in the federal registry of estimated standards, and estimated prices of construction resources. To date, the fundamental methodological document on pricing in construction is the "Methodology for determining the estimated cost of construction, reconstruction, capital repairs, demolition of capital construction projects,
and works to preserve cultural heritage objects (historical and cultural monuments) of the peoples of the Russian Federation on the territory of the Russian Federation”. Furthermore, in the Russian Federation, there are constantly updated Guidelines, recommendations and official communications issued by government agencies on individual, more specific issues of pricing in construction, determining estimated prices for resources, developing and applying elementary estimated norms and unit prices, rationing overhead costs and estimated profits, etc.

F. Sweden

17. Trafikverket uses four different methods or approaches depending on the stage in the processes of inquiry, planning or production.

(a) In the early stages of the planning process a study of strategic choice of measures is conducted wherein rough cost estimations aimed at capturing the largest cost items are calculated. These items are quantified, and the corresponding costs are evaluated by analysing key figures from previously completed construction projects. For internal use, there are templates available with and without pre-filled values.

(b) In the next phase of the planning process (preliminary studies of a number of possible alternatives → railway/road study of one proposed alternative), two methods are used. First, a so-called supporting calculation is conducted. In general, these types of estimations are conducted by external consultants and are based on traditional methods for estimating construction costs (i.e. quantity * prices per item). The template used allows for triple estimations.

(c) In addition to the supporting calculation, a separate evaluation is made using the successive principle method. The evaluation is based on an analysis of uncertainty that is conducted by a balanced and competent analysis group. This group makes forecasts of the final investment cost. Moreover, they identify and evaluate uncertain items that are important with respect to cost. The method is used to evaluate the uncertainty of the investment cost.

(d) Based on the result from the two underlying evaluations mentioned above, the final evaluated expected total costs are documented in the template summary of total cost. The summary of total cost is conducted based on the supporting calculation and the result from the analysis of uncertainty to ensure a common layout and transparency for any given stage of the planning process. The documents are later used to follow up the actual final cost compared to the estimated costs.

18. When a project enters the detailed planning and construction phases, the calculation process goes on to ongoing forecasting work.
G. Türkiye

19. By means of:
   - Feasibility studies
   - Official unit prices and unit price analysis (updated annually for all kinds of construction works)
   - Similar infrastructure construction projects previously completed.

II. How do you compare transport infrastructure construction costs over time and normalize these costs by region/time?

A. Croatia

20. Ex-post evaluation of transport infrastructure construction costs is conducted a few years after the projects has been finalized.

21. Developments of the construction market are carefully monitored in order to obtain the best value for invested money, including changes depending on global financial market flows as well as crises.

22. The costs of inland waterways construction cannot be compared because each location is specific. In general, costs are defined through public procurement procedures/tenders, in accordance with operational construction plans. The planned costs of transport infrastructure construction are being monitored through the estimated prices on the market at the time of the call for tenders and through ex-post evaluation after the project is completed.
B. Cyprus

23. The prices collected in the database are re-evaluated over time taking into consideration major issues that can affect the prices like deviation on the cost of labour, petrol, inert materials, construction steel, VAT (Value added tax) etc. The prices collected in the database take into account the region/part of the country.

C. Latvia

24. To compare the construction costs the following indicator is used: changes of the average costs for the reconstruction of one km of 7.5 m wide asphalt pavement in several years. These costs include those works, the cost of which constitutes the major part of project cost. Unit prices for specific works are average prices offered by contractors in construction tenders in respective years. Costs are not determined for each region specifically; they are determined for the whole of Latvia.

D. Russian Federation

25. The initial maximum contract price is determined by official statistical information on price indices for products (costs, services) and for investment purposes (by types of economic activity, e.g. construction) as published by the Federal State Statistics Service. Maximum contract prices are determined for the corresponding period or actual inflation indices (if any) established by the authorized executive authorities of the subjects of the Russian Federation, in case of procurement at the expenses of the budget of the subject of the Russian Federation.

26. The initial maximum price of the contract (hereinafter – the MSPC) for procurement of services is determined in the following order:

(a) Recalculation with the use of indices of actual inflation in the corresponding period, of the estimated cost of work and services to be undertaken by the technical customer aimed at determining the price level at the date of approval of the project document as compared to the price level at the date of determination.

(b) Indicators of the estimated cost of works and services carried out by the technical customer at the current price level are multiplied by the index of projected inflation for the period of construction, reconstruction, or capital repairs.

(c) The index of forecasted inflation for the period of provision of services (performance of works) is calculated as the arithmetic mean between the indices of projected inflation on the start date and the end date of the provision of services (works), determined taking into account the period of provision of services (work) in accordance with the project documentation.

E. Sweden

27. After an infrastructure construction project is completed, the final costs are analysed in comparison to previously evaluated costs. Both evaluations and final costs are specified by a common structure.

<table>
<thead>
<tr>
<th>Block</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project administration</td>
</tr>
<tr>
<td>2</td>
<td>Inquiry and planning</td>
</tr>
<tr>
<td>3</td>
<td>Design</td>
</tr>
<tr>
<td>4</td>
<td>Acquisition of land and property</td>
</tr>
<tr>
<td>5</td>
<td>Environmental measures</td>
</tr>
<tr>
<td>Block</td>
<td>Name</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Contract works – Earth works</td>
</tr>
<tr>
<td>6.1</td>
<td>Earth works</td>
</tr>
<tr>
<td>6.2</td>
<td>Structures</td>
</tr>
<tr>
<td>6.3</td>
<td>Tunnels</td>
</tr>
<tr>
<td>7</td>
<td>Contract works - Railway</td>
</tr>
<tr>
<td>7.1</td>
<td>Track works</td>
</tr>
<tr>
<td>7.2</td>
<td>Electrical works</td>
</tr>
<tr>
<td>7.3</td>
<td>Environmental measures</td>
</tr>
<tr>
<td>7.4</td>
<td>Telecommunication works</td>
</tr>
<tr>
<td>8</td>
<td>Unique measures and archaeology</td>
</tr>
<tr>
<td>9</td>
<td>Delivery and end of project</td>
</tr>
<tr>
<td>10</td>
<td>Overall uncertainty (only budget)</td>
</tr>
</tbody>
</table>

28. All figures are converted to comparable price levels using indices.
29. This common structure makes it possible to aggregate several projects and do benchmarking between different project, regions etc.
30. The followed-up investment costs from major infrastructure construction projects are compiled and categorized in an Excel-sheet, thus allowing for usage in evaluation of future projects.

F. Türkiye

31. Official deflator coefficients are published for each sector (tourism, agriculture, mining, energy, transportation ...). This calculation is based on the monetary value of all goods and services produced in an economy. Thus, predictive approaches can be made as year-based and sector-based.
32. In addition; various parametric assumptions, depending on the terrain conditions for regional differences, provide useful results in practice.

III. How do you make sure that the mechanism you use to calculate and assess transport infrastructure costs also serves as a tool for costs control?

A. Croatia

33. The prepared feasibility studies and Cost Benefit Analysis are subject to ex-post controls a few years after project finalisation.
34. In the inland waterway sector, this is ensured in a way that aside from the construction of transport infrastructure, the supervision of the execution of works are subject to control by supervising engineers whom issue reports on the process.
B. Cyprus

35. Based on the information collected in the database, the Budget of the New Project is calculated through a detailed Bill of Quantities of all the works to be executed.

36. The correctness of the estimated budget is almost assured because a) it is based on the collected costs in the database of the recently constructed/completed projects (considering also the region of the project) and b) the relevant corrections are made to these costs based on the deviation regarding cost of labour, petrol, inert materials, VAT, etc.

C. Latvia

37. Cost control mechanism in road construction sector is not established.

D. Russian Federation

38. A cost control mechanism regulates restrictions and conditions according to the level of estimated costs considered when composing the final price of construction projects. The Federal Autonomous Institution “Main Directorate of State Expertise” carries out state expertise of estimated calculations. Mandatory verification of the reliability of the determined estimated cost is carried out on the basis of project documentation, within the framework of the state expertise in cases of attracting funds from the budgets of the budgetary system of the Russian Federation, funds of legal entities created by the Russian Federation, subjects of the Russian Federation, municipalities, legal entities whose share in the authorized (stock) capitals of the Russian Federation, subjects of the Russian Federation, municipalities is more than 50 percent.

E. Sweden

39. The common structure described above in paragraph 25-28, is used throughout the whole investment process.

F. Türkiye

40. Since transportation investments are affected by many parameters in practice, it is not easy to reach the precise results with preliminary evaluation and calculation mechanisms. Comparative data and analytical approaches are used to reach the nearest predictive approaches.

IV. Do you use different cost calculation and evaluation methodologies for construction in different modes? If yes, please explain.

A. Croatia

41. The methodology for calculating and evaluating the construction of transport infrastructure for certain modes is applied in compliance with the regulations relating to different sources of financing. During the preparation of project documentation, alternative solutions are presented, and cost estimates are given depending on the type of water structures. The final assessment of an eligible water structure is influenced by price, environmental impact and efficiency.
B. Cyprus

42. Generally, the same process is used for all modes; however, there are road transport infrastructure projects where Design, Build, Financing and Operating (DBFO) or Design and Build (DB) approaches are used. These methods are used for very special and expensive projects like the construction of the airports, desalination plants etc.

C. Latvia

43. This question does not fall under the responsibility of Latvian State Roads.

D. Russian Federation

44. Methods for calculating and estimating construction costs (of various types of transport infrastructure) are in place and are based on general construction principles and additional methodological documents that consider specific conditions. When drawing up estimates and industry methods, the following methods of determining the cost can be used:

   (a) Resource method - using estimated norms and estimated prices of construction resources placed in the federal state information system of pricing in construction, created in accordance with the regulations on the federal state information system of pricing in construction;

   (b) Basic index method - with application to the estimated cost determined using single quotations, including their individual components, information about which is included in the federal registry of estimated standards developed at the basic price level, corresponding indices of changes in the estimated cost;

   (c) Resource-index method - using estimated norms, estimated prices of construction resources at the basic price level and simultaneous application of information on estimated prices posted in the federal state information system of pricing in construction, as well as indices of changes in the estimated cost to the components of unit prices at the basic price level. The resource-index method provides for a combination of the resource method with a system of indexes for resources used in construction. When determining the estimated cost by basic index or resource index methods, indices of changes in the estimated cost are used, information about which is included in the Federal Registry of Estimated Standards.

E. Sweden

45. The analysis of uncertainty is generally not conducted for projects with an expected total cost below SEK 25 million. The level of ambition with respect to the scope of the analysis group and length – in terms of days – of the analysis is adapted to the size and complexity of the project. Projects with an expected total cost above SEK 500 million, require a larger analysis group, more experienced facilitators and a two-day analysis-workshop.

F. Türkiye

46. Different cost calculation and evaluation methodologies are used when technical risks are identified.

47. Risks may involve soil characteristics and properties of the project area (ground water level, weak soils, liquefaction risks, or areas in needs of rehabilitation etc.).

48. Risks may also be identified based on similar previously implemented projects carried out under similar terrain and climate conditions (flat terrain, sloping-steep terrain, hydrologic data etc.).
G. Czechia (case study)

Model, methodology and best practice for evaluating, calculating and analysing inland transport infrastructure construction costs in the Czech Republic

1. Key information on transport infrastructure in the Czech Republic

49. The total length of the network of roads and motorways in the Czech Republic is 55,792 km. Motorways and Class I roads are owned by the state whilst Class 2 and Class 3 roads are owned by the regions. The railway network in the Czech Republic is rather dense for historic reasons and its current total lengths is 9,539 km.

50. Figure III shows the organigramme of state transport infrastructure development.

51. Development directions and strategies for state infrastructure of national importance in the Czech Republic are defined by the Ministry of Transport. The Road and Motorway Directorate (RMD), Railway Infrastructure Administration (RIA) and Waterways Directorate (WWD) serve as the executive authorities for individual transport modes. These organisations are preparing the projects, are in charge of implementation and building of transport constructions and providing for operation and maintenance in their role of infrastructure managers.

52. The State Transport Infrastructure Fund (STIF) has been set up for the purpose of financing. This is an authority similar to a bank which provides national resources as well as European Union funds. STIF is an implementing agency of European Union funds in the Czech Republic. This means that STIF finances projects, prepares budgets and is responsible for an efficient financing. These are the main reasons why STIF needs a clear standard for how to calculate or estimate construction costs and why STIF prepares pricing databases for transport infrastructure constructions.

53. Financial resources in the total amount of USD 40.855 billion were provided via STIF for transport infrastructure in the Czech Republic in the period 2001–2017. Figure IV presents the overview of financing in years 2001–2017 for individual transport modes, including tolls, telematics and contributions provided in line with the Act on STIF.
2. Estimation and calculation of transport infrastructure construction costs

54. For understanding construction costs estimation and calculation, it is important to know the process and stages of construction preparation in the Czech Republic. Construction preparation has four stages, which answer the questions “Why? Where? What? Who?” The first stage, the Feasibility Study, is used for selection of the best project alternative or version and includes economic assessment of projects. After the approval of the Feasibility Study, project preparation can start. Then the project continues with Zoning Permit Design Documents. The appropriate project location is defined at this stage. Detailed Design for Building Permit represents the next stage. The Detailed Design for Contract and Construction is made before the contractor tender. These are the four stages of construction preparation. For each of these stages, a different pricing database is used, as shown in the table below.

<table>
<thead>
<tr>
<th>No</th>
<th>Stages of preparation</th>
<th>Answer to question</th>
<th>Pricing database</th>
<th>Level of Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Feasibility Study</td>
<td>Why?</td>
<td>Pricing Norms</td>
<td>Specific type of road or railway - number of kilometres</td>
</tr>
<tr>
<td>2.</td>
<td>Zoning Permit</td>
<td>Where?</td>
<td>Object Indicators</td>
<td>Construction objects</td>
</tr>
<tr>
<td></td>
<td>Design Documents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Building Permit</td>
<td>What?</td>
<td>Price Index of Crucial Components of Objects</td>
<td>Crucial components of the objects</td>
</tr>
<tr>
<td></td>
<td>Design Documents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Contract &amp;</td>
<td>Who?</td>
<td>Industrial Classification of Building Structures and Works</td>
<td>Aggregated items including wages, machines, material, supplementary construction</td>
</tr>
<tr>
<td></td>
<td>Construction Design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Documents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

55. This means that Pricing Norms are used for the Feasibility Study and construction costs are estimated based on the number of kilometres of a specific type of road or railway. Construction costs for Zoning Permit Design Documents are defined based on Object Indicators. Construction objects represent the level of detail used for Zoning Permit Design Documents. The structure of items for Pricing Index of Crucial Components of Objects, used for Building Permit Design Documents, is more detailed. The crucial components of a
motorway object for example are excavations, embankments, motorway surface, marking or ditches.

56. The pricing database for Contract and Construction Design Documents is the most detailed and the most important from the construction costs point of view. This is because contract conditions in motorway, road and railway constructions in Czechia are usually based on the International Federation of Consulting Engineers (FIDIC) Red Book (measuring contracts). The items structure in this pricing database is used for the contractor tender and for invoicing during construction. Items from this most detailed database have a high degree of aggregation, including costs of wages, machines, material, as well as supplementary construction. The price of individual items does not come out from the past statistic prices but from an expert calculation. Another reason why the pricing database for Contract and Construction Design is the most important from the price point of view is that this is essential for pricing calculation for all other databases. Each component is made out of several items, each object is made out of several components and finally the construction consists of several objects. The basic price of the item translates into the complete final price of the construction during the entire process of preparation. All the prices are linked to achieve price stability during preparation. Prices are created from bottom to top, while classification (objects, construction components and individual items) are created from the top to bottom.

57. Inclusion of the risk component of the price based on risk analysis represents another important factor for ensuring price stability within the process of design preparation and implementation of projects. At the stage of the Feasibility Study, there is a big difference between maximum and minimum price due to a lack of information regarding the project. However, by estimating the risk component of the price, price increases during the preparation phase are avoided. In the subsequent stages of the construction process the cost remains relatively stable and is not raised as was encountered in the past. Increasing accuracy of construction costs calculation during construction preparation with the inclusion of the risk component of the prices is displayed in Figure V.

Figure V
Increasing accuracy of construction costs during construction preparation with inclusion of the risk component of the prices

58. Pricing databases are regularly updated according to the needs, depending on technical development and practical experience from previous year. Ministry of Transport approves these databases updates and prescribes an obligation to use these databases for
estimation and calculation of transport infrastructure construction costs of the projects financed by STIF. At present, we are focusing on two topics within the area of transport infrastructure constructions pricing – calculation of construction lifecycle costs and introduction of the BIM method (Building Information Modelling or Building Information Management). We are testing software for defining of bridge lifecycle costs, working on standardising and drafting of methodologies, technical rules and instructions for 5D information models that will include not only spatial positions, but also time planning and calculation of construction costs. We are persuaded that introducing of the BIM method represents an opportunity for increasing productivity within the construction sector, rendering it more attractive for the younger generation and improving competitiveness and efficiency of preparation, implementation, and management of transport constructions.

3. **Analysis of construction costs of roads and motorways**

59. In addition to systematic updating of supporting documents for transport constructions pricing during project preparation, the winning bids from tenders for contractors for work organised by the Road and Motorway Directorate are being analysed over the long term. In total, 1,649 constructions have been analysed since 2004. A long-term statistic of real prices offered by construction contractors is thus available. As roads and motorways are funded from public resources, this bid prices development statistic has been transparently published online under the link www.merne-naklady-staveb.cz.

H. **Finland (case study)**

60. The Finnish Transport Infrastructure Agency (FTIA) is responsible for Finnish road, railway and maritime investments and maintenance. FTIA’s annual budget (2020) is about 2 billion €, of which 650 million € is investments. FTIAs budget is about 25 per cent of Finland's infrastructure markets volume. FTIAs personnel are about 600 people, of which about 10 per cent work in construction projects.

61. FTIA does not have any production capacities at all. All projects are outsourced. FTIA uses several contract models. Most common is the traditional Design Bid Build method. Design Build, where design and build phases are combined into the same agreement is also quite common. The advantage of the latter is that it encourages contractors to be innovative and more productive. This is possible, when the planning and design belongs to the contractor and the owner only defines the standards, functionality and quality of the project. Construction management provides the owner with a central focal point for managing and administering all phases of the project construction, including threats planning, design, construction as integrated tasks. Public-Private Partnerships (PPP) projects, where design, build, operate and maintain phases and private financing are combined into the same long-term agreement, are also used to a limited extent. Alliance or Integrated Project Team (IPT) projects is a new method of contracting. Owner and one or more service providers (designer, constructor, supplier etc.) are working as an integrated project team. The method has nowadays been heavily used in large, risky projects, mainly because of risk management and for creating innovation and productivity gains.
62. FTIA does not use unit price-based contracts at all. That is partly a strategic decision and partly, because FTIA wants to make civil engineering projects more productive. FTIA is a small organization and there are no resources for supervision.

63. In the tendering process and in contracts, FTIA has a bill of quantities, but that is for information purposes only, it does not provide a justification for payments. The normal way in all contract models is payment through a lump sum. Naturally, there are parts and elements, that are based on unit prices, but that is because of risk management. In cases where the quantity of some works is not at all known (for example rock blasting), it may be paid based on a unit price.

64. When contractors count their offers, they count, the amount of resources they need to get the work done. They know their own achievement of resources in different works and in different situations.

65. In construction cost estimation, FTIA is trying to simulate the contractor's method. FTIA uses average combination of resources and impending work achievements. The method is called standard cost estimation.

66. The cost estimation calculation is based on the Finnish Infra2015 construction element and project nomenclature. It consists of about 1,000 construction elements. These elements define the workload in a project. In the Finnish cost estimation system, the elements and their structures are all modelled in accordance with the amount of resources needed. Then the project is individualized by using data on the circumstances, environmental factors, subsoil and ground requirements etc. The idea is that the more detailed the information of the project the better the cost estimation.

Figure VI
Applicability of Procurement methods
FTIA tries to estimate, how much a given project will cost. It does not come up with an estimation by comparing a project to other projects. When FTIA has the whole cost estimation calculation in its data system, the calculations are made and risk factors are identified.

Afterwards estimation is compared to the contractor’s tender and finally to the final cost of the project. In the calculation they have estimations of all parts of the project, so focus is given to those parts which may be more problematic. When there are several projects in the calculation system, FTIA analyzes the data and produces statistics also used for further improvement of the calculation model.

FTIA wants the cost calculation to be a regular part of the planning or design process. That makes the effective cost management of the project possible. Project costs are known throughout the entire project cycle and can be compared with prices of alternative technical solutions.

The most laborious part in cost estimation is to handle the large quantity of data surrounding planning and design and have it reflected in the cost calculation system. In large projects, the amount of data is significant. FTIA wants to build an interface between infrastructure models and its own cost calculation system. In doing so it will be possible to automate various steps involved in the cost estimation process.

I. Türkiye (case study)

1. Calculating, forecasting and evaluating transport infrastructure construction costs

Highway infrastructure cost studies in Türkiye are being done across three categories: for road construction costs, for road maintenance costs and for superstructure costs such as the construction of bridges and tunnels. Infrastructure cost information is needed for the
separate phases of the projects. These phases consist of planning, implementation, and management phases. The purpose of road infrastructure cost studies is done:

- to improve productivity, to ensure common understanding of terminology;
- to ease cost-benefit analyses and financial feasibility studies;
- to use in tender procedures;
- to obtain the best competitive situation in order to offer the projects on best competitive tendering;
- to control cost overruns;
- to do better estimation of budget and budget allocations;
- to get data for privatization, etc.

The cost data and analysis is important especially for decision makers and planners for the road authorities, consultants, financial institutions, infrastructure markets, etc.

72. In Türkiye cost estimation studies are performed using three different methods such as: (1) Actual costs on realized and completed projects; (2) Cost estimates depending on preliminary works and design for real projects using unit prices for bidding; and (3) Cost estimates on virtual projects.

73. Cost estimating is an attempt to forecast the actual cost of a project. Cost estimates play an important role for determination of the bid amount as well as development of the project budget. Inaccurate cost estimates may lead to lost opportunities, lower than expected returns and unsuccessful projects. Estimating in general requires a detailed study of the bidding documents including construction drawings and specifications, a quantity takeoff, and determination of costs.

2. Cost estimates depending on preliminary works and design for real projects using unit prices for bidding

74. In general cost estimates could be classified into two groups: preliminary cost estimates and detailed cost estimates. Preliminary cost estimates are usually prepared before drawings and specifications are available and detailed cost estimates are prepared after construction drawings and specifications are available.

(a) Preliminary estimates

75. Preliminary cost estimates are usually performed at the early stages of the projects with limited information since drawing and specifications are not available. One of the main reasons for having preliminary estimates is to decide about feasibility of a project. If a project is determined as feasible based on the preliminary estimate than detailed design, bidding and construction stages could be initiated, therefore early estimates play a crucial role on committing resources for further development of a project. Preliminary estimates could also be used for the evaluation of different project alternatives and also for development of an initial project budget. Preliminary cost estimates are not expected to be fully accurate since detailed drawings are not available and there are several uncertainties present about project cost at the early stages. However, a quick and reasonably accurate estimate is needed based on the information available, especially when a feasibility decision is to be made. In general data of past projects are used to develop preliminary cost estimates. A very simple method to determine a preliminary cost estimate is to use average unit cost of similar projects.

(b) Detailed estimates

76. Detailed estimating requires determination of the quantities and all the costs to complete the project. The first step of detailed estimation is investigation of the bidding documents for preparation of quantity takeoff. A quantity takeoff is a detailed calculation of quantities for each work item that is going to be performed to complete the project. Quantity takeoff is an important step of estimating and bidding and a complete set of bid documents including drawings, specifications and conditions of contract are needed for preparation of quantity takeoff accurately.
(c) **Contract types**

77. Other than privatization there are two general classifications of contracts used in the construction industry based on the way in which a contractor is paid: fixed price contracts and cost-plus contracts. In fixed price contracts, contractors agree to construct the facility on a fixed price basis where either the overall price (lump sum contract) or unit prices (unit price contract) are fixed.

78. In lump-sum pricing, a contractor’s fee for services is established as a total contract amount. A price is agreed upon by the client (owner) and the contractor for the whole project. The risks due to market fluctuations belong to the contractor. So, it is a nice system for the client (owner) who knows exactly how much the job will cost (unless there is an unforeseen event) and will get his job completed in the minimum time. However, in this system, a complete control must be kept on the job since the contractor may use poor material and unqualified labor. The owner may be in an adversary position with the contractor especially if the scope of work is not clearly defined. For the contractor, the advantage of lump sum pricing is that it gives him a set target to shoot for. The disadvantage lies in the fact that a lump sum contract allows no flexibility for adjustments thus, a risk premium is required to financially cover the cost of unforeseen job conditions. Poor cost estimating may result in disastrous situations for the contractor.

79. The unit pricing method establishes payments based on the amount of production or quantity of works completed at a fixed price. In Türkiye, in unit price contracts, costs can be calculated by multiplying quantities with unit prices which are published every year by the Ministry of Environment and Urban Planning. However, sometimes, the unit prices offered by the contractor are used.

80. A combination of lump-sum and unit-price contracts is also possible. In mega projects where quantities associated with some part of work are determined, whereas some quantities cannot be clarified due to uncertainties (about geological conditions, poor scope definition etc.), a combination of lump-sum and unit-price can be used. Although a lumpsum price is determined, for the unclear part of work, contractor may be paid in unit-prices.

(d) **Overhead costs**

81. Overhead costs are expenses that cannot be related to any specific item of work. If the costs can be related to an item of work they should be included under the material, labor, or equipment costs. The overhead costs are usually estimated as a percentage of total project cost. In calculation of unit prices of Ministry of Environment and Urban Planning the overhead expenses and profit is taken as 25 percent of the cost.

(e) **Cost overruns**

82. If the actual cost exceeds the tender cost, an increase of up to 20 per cent of the tender price is made by the General Directorate of Highways, up to 40 per cent is made by the Presidency of the Republic, for more than 40 per cent the contract is cancelled, and a new tender is made to complete project. Due to budget constraint, benchmarking of transport infrastructure construction costs is significant for having realistic construction costs and a stable investment program with no cost explosions.

3. **Construction cost data collection depending on completed projects**

(a) **Construction cost of roads**

83. As mentioned above the purpose of road infrastructure construction is to calculate realized road unit costs and ranges, to find out which parameters are important to specify costs, to determine investment and current budget based on more realistic parameters, in order to perform benefit-cost analysis based on realistic construction, maintenance, and operation costs. The road infrastructure construction cost study is performed every 10 years. The results of these studies will lead to work rational, cost effective and will ensure data for planning, budgeting, productivity, strategic planning, privatization, determine performance criteria’s, etc. Road projects Infrastructure cost have been calculated regarding road standard as motorways, state and provincial roads.
84. For road construction cost calculation to ease benchmarking infrastructure construction cost, superstructures cost as bridges and tunnels separately are excluded and calculated separately. In addition, the investment projects under investment programs have been very different than each other, definition on road construction projects were deemed necessary and were done as resurfacing, resurfacing by strengthening, pavement replacement, road conditioning, reconstruction, new construction and capacity enlargement. These are:

(i) **Resurfacing**

85. Placing a new surface of an existing road in order to service in good condition, to increase skid resistance, to seal by aiming to preserve road from negative atmospheric conditions, to increase driver comfort, to extend pavement life, etc. The aim is not to increase the bearing capacity of pavement however to extend its lifetime by preserving the road from bad weather conditions.

(ii) **Resurfacing by strengthening**

86. Renewing of road surface with reinstalling bituminous layer either directly or by removing a determined depth of the pavement by milling to increase bearing capacity of road and to eliminate road defects.

(iii) **Pavement replacement**

87. Renewing of the pavement either by removing the total thickness of all paving layers, existing asphalt layers from an existing road way, and then providing a new paved surface without changing capacity or geometry of the road, i.e. without changing subgrade.

(iv) **Road conditioning**

88. Reconditioning includes improvement of grades, curves, intersections or sight distances in order to improve traffic safety or changing the subgrade to widen shoulders or to correct structural problems in addition to resurfacing or pavement replacement.

(v) **Reconstruction**

89. The total rebuilding of both pavement and subgrade of an existing highway. Work which either changes the location of the existing subgrade shoulder points or removes all the existing pavement and base course for at least 50 per cent of the length of the project. In other words, it is the rebuilding of an existing roads’ pavement and subgrade to correct road geometry, to increase road safety, to ease maintenance works and to increase preservation.

(vi) **Capacity enlargement**

90. Same as reconstruction and involves the construction of additional through travel lanes beyond the work associated with reconstruction.

(vii) **New construction**

91. There is not any existing road for this kind of project. This is the new building of a road with all parts; subgrade, pavement, structures, etc.

92. In addition to the road project types explained above, project sizes have also been regarded for construction cost studies of road projects in Türkiye. Projects sizes has been regarded as a parameter and taken into consideration as small size, medium size, large size and mega projects. The more complex and difficult projects are large size or mega projects, on the other hand easy projects in terms of terrain type and projects type are small or medium size projects. In addition, many parameters have been regarded when the costs studies based on size of projects. As an analysis method descriptive analysis has been also used.

93. Not only the type of project but also project standards, pavement type, project length, project size (including bridge length, tunnel, etc.), construction duration, degree of urbanization, bidding type, terrain type, etc. are regarded as parameters. Multiple regressions are applied to data sets. The effect of independent variables on dependent variables is
analyzed and stepwise regression is used. All cost is calculated regarding units as TL/Km and TL/LanexKm.

94. On the other hand, land acquisition cost, design cost, environmental mitigation, construction and project management costs are calculated and given as percentages. Construction cost work types such as earthworks, superstructures, pavement, bridges, and tunnels, miscellaneous have been also calculated and given as percentages.

95. Construction costs are also very different according to whether the projects are passing through urban areas or rural areas. The degree of urbanization is important and this parameter is also considered.

96. Cost overruns of road projects have also been analyzed and tried to be explained.

97. The following flowchart shows the processes of actual cost calculation from actual road projects starting from the step of data collection, storing of data to the step of statistical analysis to explain how the road infrastructure cost changes depending on which parameters, data overruns and so on.
Figure VIII
Flowchart which shows the processes of cost calculation and analysis on actual projects
(viii) The road’s superstructure such as bridges and tunnels costs

98. The road superstructure construction cost on the other hand is also performed every 10 years regarding completed projects. The superstructures as tunnel and bridges have been regarded and their unit cost as given as TL/m\(^2\) for bridges and TL/m for tunnels regarding a single tube tunnel and twin tube tunnel. For bridges costs are also subdivided as sub-structure costs and over structure costs.

99. The following flowchart shows the processes of actual cost calculation from actual road’ superstructure projects starting from the step of data collection, storing of data to the step of statistical analysis to explain how the road’s superstructures cost changes depending on which parameters, data overruns and so on.
Figure IX
Flowchart which shows the processes of cost calculation and analysis on actual road’s superstructure projects
Construction Cost Calculations on Virtual Projects:

In Türkiye in addition to construction cost calculation on real completed projects, cost is also calculated practicing unit costs on virtual projects every year. Different virtual projects are used to regard different parameters. These parameters are road class; terrain type; geometry of road as platform width, pavement width, shoulder width; average, horizontal and vertical curvature; roughness; and different road pavement type regarding traffic composition. Terrain type is regarded as flat, rolling and mountainous. Road class is also regarded as motorways, primary roads and secondary roads. On the other hand, carriageway is regarded as single carriageway and double carriageway roads, but the number of lanes is not taken into account. The cost is given as TL per km. The following table is an example for flat terrain type. These tables are produced annually for rolling and mountainous terrain type also. This table is produced with 2019 prices. These data is mostly used for benefit-cost analysis.
### Table 1
Sample table for road construction costs for virtual projects to be used in Benefit-Cost analysis

**YOL YAPIM MALİYETLERİ (VERGİLER HARIÇ)**

ARAZİ TIPI, AĞIR TAŞIT TRAFİĞİ VE PLATFORM GENİŞLİKLERINE GORE

(ROAD CONSTRUCTION COSTS (TAX EXCLUDED) ACCORDING TO TERRAIN TYPE, HEAVY VEHICLE TRAFFIC AND PLATFORM WIDTH)

(WITH 2019 UNIT PRICES)

<table>
<thead>
<tr>
<th>ARAZİ TIPI (Terrain Type)</th>
<th>Ağır Taşıt Trafığı (Heavy Vehicle Traffic)</th>
<th>Üstyapı Tipleri (Pavement Type)</th>
<th>Platform Genişliği (m) (Platform Width)</th>
<th>8.00</th>
<th>10.00</th>
<th>12.00</th>
<th>Bölünmüş Yol (Dual Carriageway)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tek Kat Sathi Kaplama</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 1)</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Cross Section Type 1)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>601.385</td>
<td>751.732</td>
<td>902.078</td>
<td>1.623.740</td>
<td></td>
</tr>
<tr>
<td>Toplam (Total)</td>
<td></td>
<td>Toplam (Total)</td>
<td>1.569.565</td>
<td>1.855.278</td>
<td>2.140.991</td>
<td>3.853.784</td>
<td></td>
</tr>
<tr>
<td>0-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Çift Kat Sathi Kaplama</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 2)</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Double Layer Surface Treatment) (Cross Section Type 2)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>637.840</td>
<td>797.300</td>
<td>956.760</td>
<td>1.722.167</td>
<td></td>
</tr>
<tr>
<td>Toplam (Total)</td>
<td></td>
<td>Toplam (Total)</td>
<td>1.606.020</td>
<td>1.900.846</td>
<td>2.195.673</td>
<td>3.952.211</td>
<td></td>
</tr>
<tr>
<td>50-250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250-500</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>Asfalt Betonu</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 3-1)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>1.190.919</td>
<td>1.488.648</td>
<td>1.786.378</td>
<td>3.215.480</td>
<td></td>
</tr>
<tr>
<td>(Asphaltic Concrete) (Cross Section Type 3-1)</td>
<td>Toplam (Total)</td>
<td>Toplam (Total)</td>
<td>2.159.099</td>
<td>2.592.195</td>
<td>3.025.291</td>
<td>5.445.524</td>
<td></td>
</tr>
<tr>
<td>DÜZ (Flat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-1000</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>Asfalt Betonu</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 3-2)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>1.235.635</td>
<td>1.544.544</td>
<td>1.853.452</td>
<td>3.336.214</td>
<td></td>
</tr>
<tr>
<td>(Asphaltic Concrete) (Cross Section Type 3-2)</td>
<td>Toplam (Total)</td>
<td>Toplam (Total)</td>
<td>2.203.815</td>
<td>2.648.090</td>
<td>3.092.366</td>
<td>5.566.258</td>
<td></td>
</tr>
<tr>
<td>1000-1500</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>Asfalt Betonu</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 4)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>1.307.018</td>
<td>1.633.773</td>
<td>1.960.528</td>
<td>3.528.950</td>
<td></td>
</tr>
<tr>
<td>(Asphaltic Concrete) (Cross Section Type 4)</td>
<td>Toplam (Total)</td>
<td>Toplam (Total)</td>
<td>2.275.199</td>
<td>2.737.320</td>
<td>3.199.441</td>
<td>5.758.994</td>
<td></td>
</tr>
<tr>
<td>1500-3000</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>Asfalt Betonu</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Tipo Enkesit 5-1)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>1.382.060</td>
<td>1.727.575</td>
<td>2.073.090</td>
<td>3.731.561</td>
<td></td>
</tr>
<tr>
<td>(Asphaltic Concrete) (Cross Section Type 5-1)</td>
<td>Toplam (Total)</td>
<td>Toplam (Total)</td>
<td>2.350.240</td>
<td>2.831.121</td>
<td>3.312.003</td>
<td>5.961.605</td>
<td></td>
</tr>
<tr>
<td>1500-3000</td>
<td>Toprak İşleri (Earthworks)</td>
<td>Toprak İşleri (Earthworks)</td>
<td>691.557</td>
<td>788.248</td>
<td>884.938</td>
<td>1.592.889</td>
<td></td>
</tr>
<tr>
<td>Beton (Tipo Enkesit 5-2)</td>
<td>Sanat Yapıları (Structures)</td>
<td>Sanat Yapıları (Structures)</td>
<td>276.623</td>
<td>315.299</td>
<td>353.975</td>
<td>637.155</td>
<td></td>
</tr>
<tr>
<td>(Concrete)</td>
<td>Üstasyapı (Pavement)</td>
<td>Üstasyapı (Pavement)</td>
<td>972.897</td>
<td>1.216.122</td>
<td>1.459.346</td>
<td>2.675.468</td>
<td></td>
</tr>
<tr>
<td>Toplam (Total)</td>
<td></td>
<td>Toplam (Total)</td>
<td>1.941.078</td>
<td>2.319.668</td>
<td>2.698.259</td>
<td>4.905.512</td>
<td></td>
</tr>
</tbody>
</table>
101. It is important that road infrastructure investments are made on time to avoid negative effects on the economy. The lifespan, maintenance and construction costs of infrastructure are approximate figures because of the various construction materials, different terrain type, the techniques used and operation conditions. Due to budget constraint, benchmarking of transport infrastructure construction costs is significant for having realistic construction costs and a stable investment program with no cost explosions. Identify suitable methodological approaches, models and tools for gathering and disseminating information about infrastructure construction costs as well as collaboration with potential partners in the public private sector and on the national, regional and international level are crucial from our point of view.

4. Additional questions

(a) Comparison of transport infrastructure construction costs over time and normalization of these costs by region/time

102. For benchmarking of infrastructure costs of different projects, costs should be converted to comparable price levels using indices. An infrastructure project's construction lasts more than one year even sometimes 5-6 or more years. Construction projects cost are given by bidding year prices. To bring projects cost to comparable levels different indices are being used. The used indices are Construction Costs Indices which were published annually by the Turkish Statistical Institute. In addition, official deflator coefficients which are produced and published annually by the Department of Strategy and Budget for each sector (tourism, agriculture, mining, energy, transportation, etc.) are also used especially for investment program. This calculation is based on the monetary value of all goods and services produced in an economy. It is calculated by using the evaluation coefficients of the construction report cards and work completion documents used in the tenders for construction, facility and repair works published annually in the official gazette by the Ministry of Environment and Urban Planning. In addition, in order to calculate the foreign exchange cost, the calculation is made according to the Tender Date Exchange Rate information obtained from the Central Bank and revised to present prices with deflator.

(b) How to make sure that the mechanism used to calculate and assess transport infrastructure costs also serves as a tool for costs control:

103. Prices or pro forma invoices are obtained from the producers material makers, main dealers, wholesalers and authorized dealers of the work, manufacturing and/or material. Appropriate comparisons are made in the price determination based on market research to be carried out based on the whole work, business group, work item and material market values. The issue of whether the hesitated prices are in line with the real market values is clarified by the written market values to be obtained from the Chambers of Commerce and/or Industry. In addition, the implementation is constantly updated in case of the detection of the directions that are misstated by constantly examining the mechanism we use to calculate and evaluate transportation infrastructure costs.

(c) Are different cost calculation and evaluation methodologies in use for construction in different modes?

104. The Turkish calculation and evaluation methods do not vary according to different transportation systems.

J. Sweden (case study)

1. Background

105. In 2008, based on experiences and development initiatives within the Swedish Transport Administration, the Government of Sweden decided that the successive principle should be applied when calculating road and railway investments with a project cost > €50 million. By then many large infrastructure projects had had serious cost overruns in recent years with the financial consequence that other urgent projects had to be postponed. The aim
with the government directive was to achieve a more realistic estimate of the most likely final cost and an identification of the biggest uncertainties in the actual project to increase the probability for project success as to cost and time. Besides introducing the successive principle for calculations, the government prescribed other measures like the introduction of advisory boards to the projects and systematic and compulsory monthly follow-up of project performance.

2. The Successive Principle in essence

Using the Successive Principle, you can handle the uncertainty or contingency in project budgets. It’s a top-down procedure you in successive steps clarify the many uncertain factors. In this manner it has documented an ability to eliminate unplanned budget overruns and delays. The Successive Principle is based upon an integration of modern statistical theory and psychology with well-known procedures of project management, engineering economy and general management. In fact, it allows human intelligence and intuition to play a more natural role as a supplement to the historical knowledge. Among others it applies research which bypasses the numerous and serious pitfalls, which so far has hindered accurate and neutral expert evaluations.

3. Established process for calculating investment costs within the Swedish Transport Administration

Figure X
Overall calculation process chart

Planning and preliminary design process

Detailed design  Construction (Civil works)

Supporting calculation  Supporting calculation  Supporting calculation  Uncertainty analysis  Uncertainty analysis  Uncertainty analysis

Fixed cost summary  Fixed cost summary  Fixed cost summary  Forecasts specified under the model of risk management

Forecasts  Forecasts  Forecasts  Forecasts

= Road- or railway plan with force of res judicata

21 Lichtenberg & Partners
Supporting calculation: This estimate is normally performed by external consultants and based on traditional bottom-up method for estimations. (Quantity x price per unit). The template allows for three estimations (minimum, most likely, maximum).

Uncertainty analysis using the ‘‘Successive principle’’: A balanced, cross-knowledge and experienced analysis group make forecasts of the final investment cost including identifying and evaluating uncertain items with importance on costs. This method is used to evaluate uncertainty of investment cost.

Fixed cost summary: The fixed estimated cost, from a specific stage in the planning process, based on the supporting calculation and the result from the uncertainty analysis shall be documented in a common way. This documentation is made in a template, which purpose is to secure a common layout and transparency. These documents are used later, when following up the actual final cost compared to planned cost.

107. The uncertainty analysis is performed during a two-day group-seminar and according to a standardized procedure with a work breakdown structure (WBS) based on 10 main blocks (see table 2 below). Every block is tipple-judged by each member of the analysis group as an interval with a minimum, a plausible and a maximal cost.

Table 2
Structure for planning, estimating, follow-up and analysing investment costs

<table>
<thead>
<tr>
<th>Block</th>
<th>Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project administration</td>
<td>All costs related to STA’s internal organisation and management of a project</td>
</tr>
<tr>
<td>2</td>
<td>Inquiry and planning</td>
<td>Preliminary studies (all possible alternatives); rail- and roadway studies (pros &amp; cons, risk)</td>
</tr>
<tr>
<td>3</td>
<td>Design</td>
<td>Detailed design</td>
</tr>
<tr>
<td>4</td>
<td>Acquisition of land and property</td>
<td>In order to get access to land for building of new constructions</td>
</tr>
<tr>
<td>5</td>
<td>Environmental measures</td>
<td>In order to reduce noise and vibrations, handle contaminated soil, etc.</td>
</tr>
<tr>
<td>6</td>
<td>Contract works – Earth works</td>
<td></td>
</tr>
<tr>
<td>6.1</td>
<td>Earth works - Railway</td>
<td>Excavation, fill, embankment, platforms, buildings</td>
</tr>
<tr>
<td>6.2</td>
<td>Structures</td>
<td>Bridges, underpasses (roads, pedestrians, bicyclists), retaining walls</td>
</tr>
<tr>
<td>6.3</td>
<td>Tunnels</td>
<td>Blasted, drilled or cut-and-cover inclusive entrances and working and rescue tunnels</td>
</tr>
<tr>
<td>6.4</td>
<td>Earth works - Roads</td>
<td>Excavation, fill, embankment, hard surface, guard rail</td>
</tr>
<tr>
<td>7</td>
<td>Contract works - Railway</td>
<td></td>
</tr>
<tr>
<td>7.1</td>
<td>Track works</td>
<td>Superstructure including ballast, rail, sleepers, point switches</td>
</tr>
<tr>
<td>7.2</td>
<td>Electrical works</td>
<td>Electric supply, overhead line, masts, electrical substations, transformers, converter substations</td>
</tr>
<tr>
<td>7.3</td>
<td>Signal works</td>
<td>Signalling equipment such as signals, interlocking systems, automatic block signal system</td>
</tr>
<tr>
<td>7.4</td>
<td>Telecommunication works</td>
<td>Transmission in copper wire and fibre optic cables, fixed information installations for passengers</td>
</tr>
<tr>
<td>8</td>
<td>Unique measures and archaeology</td>
<td>Extraordinary measures (for example moving a ski jumping arena); archaeological excavation</td>
</tr>
<tr>
<td>9</td>
<td>Delivery and end of project</td>
<td>Delivery for operation, as-built documents/factual drawings, inspections both regarding internal delivery and contract work</td>
</tr>
<tr>
<td>10</td>
<td>Financial reserve for uncertainties</td>
<td>Only used in calculation and budgeting of total costs in early stages. Not used for economic outcomes.</td>
</tr>
</tbody>
</table>

108. Some general uncertainties like the organisation stability (Swedish Transport Administration), market/business cycle, politics, new laws, regulations and decrees, weather conditions will be evaluated separately but included in the overall assessment.

109. The follow-up of actual cost and project performance is part of the established process and data is collected based on the structure in table 2.

4. Interpretation of the results

110. The results from the analysis are presented in a number of reports showing various focus or improvement areas to be addressed further depending on uncertainty or risk spread. Below in Figure XI the s-curve for each estimate is plotted. It is expected that the standard deviation should decrease during the planning phase since risks and uncertainties should decrease as well. Swedish Transport Administration normally uses the last cost estimate applying the 50 per cent probability value as the budget for the project.
5. Conclusion

111. The improvement during the last 10 years is substantial. Most large infrastructure projects in Sweden have been finalized within budget and on time. In addition, the quality of the input from Swedish Transport Administration to the Government’s rolling four-year financial infrastructure investment plan has improved noticeably.

V. Conclusion

112. The methods and techniques for assessing the cost of construction are extensive.

113. Through a comparative analysis based on the methods and techniques for determining the cost of construction of future periods - the “planned” cost of construction, we can distinguish the “common components” used by most countries to assess this cost:

- calculation of cost estimates (costs), which in most of the countries discussed above are based on market research and experience working with similar projects;
- determination and calculation of the costs of the planned construction project by type of work, by analyzing key indicators of previously completed construction projects;
- determination of the scope of work included in the estimate in accordance with the construction technology existing in the country in accordance with applicable norms and standards for the performance of work;
- the existence and development of directives (normative legal acts, methodologies, and methodologies) for assessing the costs of road projects;
- tender for the performance of work - competitive selection of proposals for a road construction project, carried out on a competitive procurement basis.

114. The difference is in the methods of approach to the selection of optimal parameters and acceptable calculations for determining the price of a road construction project. The following individual features of determining the cost of a construction project can be distinguished.

115. In Germany, a special place in the methodology is determined by the analysis of costs and benefits, considering an additional assessment of environmental and nature protection,
spatial planning, and urban development. The costs of the above work was included in the German federal infrastructure plan, envisaged for development until 2030 (FTIP). The purpose of the environmental assessment is to incorporate in the early stages the costs and benefits of environmental aspects (carbon dioxide emissions, air pollutants and noise) in relation to the impact on areas with special environmental properties.

116. In Germany, the value is determined by the selection of the structure and production methods with the possibility of comparison by numerous indicators (parameters). The impact of the parameters is determined by the set of planning periods, directly the construction time, as well as the average service life of the facility. When planning subcontracting work in a project, the calculation is differentiated for maximum costs.

117. In Sweden, the “triple grading template” is used:

- In order to study the investment expenditures in the early stages, calculations are carried out for the largest cost items;
- Next, in the planning process, an auxiliary calculation is carried out, based on traditional methods for assessing the cost of construction (the number of products per unit price);
- An assessment of the uncertainty of investment value is a forecast of the final cost of investments (through this calculation, uncertain elements are identified and evaluated - factors that are important in terms of costs).

118. The final expected total costs are generated and documented as a generalization of the total cost based on an auxiliary calculation and the result of an uncertainty analysis.

119. Upon completion of the project, the expected total costs are used to compare with actual final costs.

120. In Cyprus, to determine the “planned” cost of a project, a data bank is created based on the available costs of past construction periods (years) generated by the type of work. The total price of the tender is formed based on the provisions of the law governing the procurement (tender) procedure. If there is a significant deviation from the total price of the tender, the bidding process is cancelled. The factors and reasons that influenced the deviation are investigated, and the tender is repeated.

121. In Croatia, a cost estimate for infrastructure projects is being prepared based on market research and experience working with similar projects. The construction of transport infrastructure is the subject of open international procurement / tender procedures.

122. In Poland, the index method is used to determine the cost of a construction project. In the absence of a single suitable price index, costs are calculated according to an individual estimate. Sources of information for individual estimates are:

- contracts or agreements concluded in past periods (years);
- prices valid in the current period (year) and published in current publications, reference books, catalogs and offers;
- forecast data in the field of pricing.

123. In Türkiye, there are official unit prices that are updated annually for all types of construction work through unit price analysis.

124. In Latvia, the planned construction costs are determined based on the prices of similar works defined in other previously concluded construction contracts, forecasts of macroeconomic development indicators, changes in the construction market of the transport infrastructure and forecasts for the development of this market. When planning costs, the conditions of the construction contract are preliminarily agreed upon by the parties (customer-contractor).
Annex V

Chapter 3
Consolidated list of terminologies on benchmarking of road, rail, inland waterway, and intermodal terminals construction costs

I. Background

1. The Inland Transport Committee (ITC) at its eighty-third session in February 2021 has agreed to extend the mandate of the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4) for one more year until 2022. The purpose of the extension as defined by ITC will be to continue and revamp the data collection efforts of the Group across all modes resulting in a more data rich final report as well as to prepare an additional benchmarking analysis of transport infrastructure maintenance and operation costs. At its eleventh session (April 2021) the Group reviewed ECE/TRANS/WP.5/GE.4/2019/1/Rev.2 and decided that some revisions would be required in view of its decision to perform an additional benchmarking analysis of transport infrastructure maintenance and operation costs whereby different terminologies are in use. The Group then decided that the following lead countries will work on revising and expanding these terminology lists and adding new terms related to maintenance and operation costs: Croatia (for inland waterways); Türkiye (for road) and Poland (for rail).

2. The present document consists of a revised and expanded terminology list for road, rail and inland waterways only.

3. This document contains:

   (a) in Appendix I: general terminology relevant for benchmarking of all inland transport infrastructure costs, based on ECE/TRANS/WP.5/GE.4/2017/1/Rev.2,

   (b) in Appendix II: revised terminology on benchmarking road transport infrastructure construction costs based on document ECE/TRANS/WP.5/GE.4/2019/1,

   (c) in Appendix III: terminology on benchmarking rail transport infrastructure construction costs based on ECE/TRANS/WP.5/GE.4/2018/5,

   (d) in Appendix IV: terminology used for benchmarking of construction costs of inland waterway infrastructure based on ECE/TRANS/SC.3/2018/15-ECE/TRANS/WP.5/2018/5, and


4. The Group of Experts will be expected to review this document and, on its basis, agree on how it would want to include the terminology chapter in its final report.
Appendix I

General terminology relevant for benchmarking of all inland transport infrastructure costs

I. Terminology

1. Acquisition: The process of obtaining right of way by negotiation and/or eminent domain proceedings. Negotiation would involve getting the owner to convey, dedicate, or possibly option the property to the public agency. Compensation must be paid in all acquisitions or takings (6).

2. Acquisition cost: All costs included in acquiring an asset by purchase/lease or construction procurement route, excluding costs during the occupation and use or end-of-life phases of the life cycle of the constructed asset (1).

3. Administrative costs: The costs incurred in contract management and administration overhead expenses (4).

4. Annual budget:
   (a) The total budget for the financial year as approved by the legislative body.
   (b) The annual budget is a group of appropriations which a department has the authority to disburse or encumber in a fiscal year.

5. Assets: Something that has a potential or actual value to an organization, can be physical or intellectual or financial.

6. Asset management:
   (a) A systematic process of operating, maintaining, and upgrading transportation assets cost effectively by combining engineering practices and analysis with sound business practice and economic theory.
   (b) The management of the physical infrastructure such as pavements, bridges, and airports, as well as human resources (personnel and knowledge), equipment and materials, and other items of value such as financial capabilities, right-of-way, data, computer systems, methods, technologies, and partners (10).

7. Budget: is a financial plan, actual or estimated, showing the items on which the expenditure of contract funds are authorized (6).

8. Capital Cost: The initial construction costs and costs of initial adaptation where these are treated as capital expenditure. Note 1 to entry: The capital cost may be identical to the acquisition cost if initial adaptation costs are not included (1).

9. Construction contingency: The additional mark-up applied to cover the cost of undefined and yet unknown construction requirements that are expected to be zero at completion of construction. Construction contingency is a risk cost (3).

10. Construction phase: The project development phase that includes advertising the project, awarding the contract, and performing the actual construction (3).

11. Construction Product: The item manufactured or processed for incorporation in construction works. Note 1 to entry: Construction products are items supplied by a single responsible body. Note 2 to entry: Adapted from the definition in ISO 6707-1 according to the recommendation of ISO/TC59/AHG Terminology (2).


13. Construction Works: Everything that is constructed or results from construction operations. Note 1 to entry: This covers both building and civil engineering works, and both
structural and non-structural elements. Note 2 to entry: Adapted from the definition in ISO 6707-1 (2).

14. Construction Administration Cost: The normal cost of administration, management, reporting, design services in construction, and community outreach required in the construction phase of a project (3).

15. Construction Allowance: The amount of additional resources included in an estimate to cover the cost of known but undefined requirements for a construction activity or work item. A construction allowance is a normal cost (3).

16. Contract:

(a) The procurement document between two or more parties which creates an obligation to provide goods or services or perform tasks and which includes offer, acceptance, exchange of consideration, legal sufficiency, a defined contract period, a maximum amount payable, and terms and conditions as appropriate.

(b) The legally binding document that provides determination of responsibilities and liabilities (6).

17. Contractor: The private entity that provides design, construction, and/or maintenance services to a highway or railway agency. May refer to the design-builder or a concessionaire (4).

18. Cost-based estimating: The method to estimate the bid cost of a work item by estimating the cost of resources (time, equipment, labour, and materials) for each component task necessary to complete the work item, and then adding a reasonable amount for contractor’s overhead and profit (4).

19. Cost: The monetary value or price of a project activity or component that includes the monetary value of the resources required to perform and complete the activity or component, or to produce the component. A specific cost can be composed of a combination of cost components, including direct labour hours, other direct costs, indirect labour hours, other indirect costs, and purchased price (However, in the earned value management methodology, in some instances, the term cost can represent only labour hours without conversion to monetary worth) (6).

20. Design life of infrastructure asset: The length of time for which an infrastructure asset is being designed.

21. Discounted cost: The resulting cost when the real cost is discounted by the real discount rate or when the nominal cost is discounted by the nominal discount rate (1).

22. Discount rate: The time value of money used as the means of comparing the alternative uses for funds by reducing the future expected costs or benefits to present-day terms. Discount rates are used to reduce various costs or benefits to their present value or to uniform annual costs so that the economics of the various alternatives can be compared (approximately equal to interest minus inflation) (4).

23. Disposal cost: Costs associated with disposal of the asset at the end of its life cycle, including taking account of any asset transfer obligations. Note 1 to entry: Asset transfer obligations could include bringing the assets up to a predefined condition. Note 2 to entry: Income from selling the asset is part of WLC22, where the residual value of the road infrastructure components, materials and appliances can be included (1).

24. Drainage structure: Any device or land form constructed to intercept and/or aid surface water drainage (7).

25. Earthwork: The operations connected with excavating and placing embankments with soil, earth or rock (6). Earthwork for rail: work conducted in order to prepare land for construction work; land grading, soil exchange etc. (8).

---

22 Whole-Life Cost
26. Embankment: The raised structure of soil, soil aggregate, rock or combination of the three. Materials used for fill section (6).

27. Emulsion: The fluid system in which liquid droplets and/or liquid crystals are dispersed in a liquid. Note 1 to entry: Dispersion is thermodynamically metastable (5).

28. End-of-life cost: The net cost or fee for disposing of an asset at the end of its service life or interest period, including costs resulting from, deconstruction and demolition of the asset infrastructure; recycling, making environmentally safe recovery and disposal of components and materials and transport and regulatory costs (1).

29. Environmental Impact Assessment – the ongoing identification of environmental factors to determine the past, current and potential impact (positive or negative) of an organisation’s activities on the environment. This process includes the identification of the potential regulatory, legal and business exposure, as well as health and safety impacts and environmental risk assessment (9).

30. Estimate: The approximate quantity and cost of materials, construction items, and labour required for a specific construction project (6).

31. Excavation: The act of cutting, digging, or scooping to remove material (6).

32. External costs: The costs associated with an asset that are not necessarily reflected in the transaction costs between provider and consumer and that, collectively, are referred to as externalities. Note 1 to entry: These costs may include business staffing, productivity and user costs; these can be taken into account in a LCC analysis but should be explicitly identified (1).

33. Feasibility study - a structured process that identifies the engineering options and their implications including environmental issues. It culminates in a feasibility report and a design development (and, sometimes, implementation) proposal (9).

34. Foundation: That portion of a structure (usually below the surface of the ground) which distributes the pressure to the soil or to artificial supports. Footing has similar meaning (6).

35. Implementation year: The year that a project is anticipated to be complete and open to traffic (6).

36. Infrastructure: Basic facilities, services, and installations needed for the functioning of a community or society, including water and sewage systems, lighting, drainage, parks, public buildings, roads, railways, waterways and transportation facilities, and utilities (7).

37. Life Cycle: The consecutive and interlinked stages in the life of the object under consideration (2).

38. Life Cycle Cost - LCC: Cost of a civil engineering works or part of works throughout its life cycle, while fulfilling technical requirements and functional requirements (2).

39. Life-cycle cost analysis: An economic assessment of an item, area, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in equivalent dollars (4).

40. Net present value: The net value of all present and future costs and benefits converted to a single point in time using a discount rate factor (4).

41. Nominal cost: The expected price that will be paid when a cost is due to be paid, including estimated changes in price due to, for example, forecast change in efficiency, inflation or deflation and technology (1).

42. Normal Cost: The most probable cost for a unit or element of the project. The normal cost represents the cost that can most reasonably be expected if no significant problems occur. The normal cost typically has small uncertainty or variance (3).
43. **Operation Cost**: The cost incurred in running and managing the facility or built environment, including administration support services. Note 1 to entry: Operation costs could include rent, rates, insurances, energy and other environmental/regulatory inspection costs, local taxes and charges (1).

44. **Project**: The undertaking to develop, implement, or construct a particular transportation enhancement at a specific location or locations (3).

45. **Project classification**: The official classification of the type of project provided for in construction (6).

46. **Real Cost**: Cost expressed as a value at the base date, including estimated changes in price due to forecast changes in efficiency and technology, but excluding general price inflation or deflation (1).

47. **Risk**: The potential impact of an uncertain condition or action on project objectives and outcomes (4).

48. **Risk allocation**: The process of allocating contractual obligations and risks between parties (4).

49. **Terrain**: The physical features of a tract of land (7).

50. **Topography**: The details of a surface, including natural and man-made structures, on a map or chart (6).

51. **Whole-Life Cost**: All significant and relevant initial and future costs and benefits of an asset, throughout its life cycle, while fulfilling the performance requirements (1).

52. **Whole-Life Costing**: The methodology for systematic economic consideration of all whole-life costs and benefits over a period of analysis, as defined in the agreed scope. Note 1 to entry: The projected costs or benefits may include external costs (including, for example, finance, business costs, income from land sale, user costs). Note 2 to entry: Whole-life costing can address a period of analysis that covers the entire life cycle or (a) selected stage(s) or periods of interest thereof. Note 3 to entry: This definition should be contrasted with that for life-cycle costing (1).

---

**II. References**


(5) Bitumen and bituminous binders - Terminology, EN 12597, May 2014.

(6) TxDOT Glossary, Texas Department of Transportation, 2013.


(8) Definitions compiled by experts of PKP Polish Railway Lines;

(9) University of Birmingham and Network Rail Railway Lexicon Mk 24, February 2011.

Appendix II

Revised terminology on Benchmarking Road Transport Infrastructure Construction Costs

I. Terminology

1. Abutment: The part of a bridge consisting of the cap, backwall, and wingwalls at the ends of a bridge which supports the superstructure, contains the earth in the approach fills, and directly receives the impact loads produced by traffic passing from the roadway onto the bridge. An abutment is a wall supporting the end of a bridge or span and sustaining the pressure of the abutting earth (11).

2. Access: The driveway by which vehicles and/or pedestrians enter and/or leave property adjacent to a road (14).

3. Access control: The condition whereby the road agency either partially or fully controls the right of abutting landowners to direct access to and from a public highway or road (12).

4. Aggregate: The granular material of natural, manufactured or recycled origin used in construction (9).

5. Alignments: The geometric design elements that define the horizontal and vertical configuration of the roadways.

6. Analysis period: The time period used for comparing pavement-type alternatives. An analysis period may include several maintenance and rehabilitation activities during the life cycle of the pavement being evaluated. The analysis period should not be confused with the pavement design or service life (5).

7. Arterial: The highway designed to move relatively large volumes of traffic at high speeds over long distances. Typically, arterials offer little or no access to abutting properties (12).

8. Asphalt: The homogenous mixture typically of coarse and fine aggregates, filler aggregate and bituminous binder which is used in the construction of a pavement. Note 1 to entry: Asphalt can include one or more additives to enhance the laying characteristics, performance or appearance of the mixture (10).

9. Asphalt binder: Asphalt cement or modified asphalt cement, which acts as a binding agent to glue aggregate particles into a cohesive mass (11).

10. Asphalt cement: The asphalt specifically prepared or refined to standards of quality and consistency. It is prepared for direct use in the manufacture of asphalt pavements (11).

11. Asphalt Concrete (AC): The asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure (10).

12. Asphaltic Concrete Pavement (ACP): The compacted mixture of mineral aggregate and asphaltic materials. An ACP overlay is a supplemental base-pavement or wearing surface placed on an existing base-pavement or wearing surface where major repairs to a pavement structure are required to restore a satisfactory riding surface or upgrade the strength of the pavement structure (11).

13. Asphalt Concrete for very thin layers (AC-TL): The asphalt for surface courses with a thickness of 20 mm to 30 mm, in which the aggregate particles are generally gap-graded to form a stone to stone contact and to provide an open surface texture (10).

14. Asphalt for Ultra-Thin Layers (AUTL): The hot mix asphalt road surface course laid on a bonding layer, at a nominal thickness between 10 mm and 20 mm with properties suitable for the intended use. The method of bonding is an essential part of the process and the final product is a combination of the bonding system and the bituminous mixture (10).
15. At-grade: The combination of horizontal alignments and vertical grade lines which intersect (11).

16. Backfill:
   (a) The material used to replace other material removed during construction.
   (b) The material placed adjacent to structures (11).

17. Base: The layer used in a pavement system to reinforce and protect the subgrade or subbase (17).

18. Balanced cantilever bridge: The type of bridge that constructed using balanced cantilever technique to attach the segments in an alternate manner at opposite ends of cantilevers supported by piers. (7)

19. Benefit /Cost Ratio (B/C): the method used to compare the benefit versus the cost of proposed alternatives. For highway projects, benefits may include reduced fuel consumption, travel time, and air pollution; costs may include construction, right of way, and maintenance (11).

20. Binder: The material used to adhere to aggregate and ensure cohesion of the mixture. Note 1 to entry: Any solid support may be adhered with the binder (8).

21. Binder Course: The structural part of the pavement between the surface course and the base (10).

22. Bio-Fluxed Bitumen: The bitumen whose viscosity has been reduced by the addition of a flux oil derived from vegetal or animal oils (8).

23. Bitumen: The virtually not volatile, adhesive and waterproofing material derived from crude petroleum, or present in natural asphalt, which is completely or nearly completely soluble in toluene, and very viscous or nearly solid at ambient temperatures (8).

24. Bituminous Base: The main structural element of a pavement. Note 1 to entry: The base can be laid in one or more courses, described as “upper” base, “lower” base. (10)

25. Bituminous Binder: The adhesive material containing bitumen. Note 1 to entry: A bituminous binder may be in any of the following forms: unmodified, modified, oxidized, cut-back, fluxed, emulsified. Note 2 to entry: To avoid uncertainty, whenever possible the term describing the actual binder in question should be used (8).

26. Bituminous Emulsion: The emulsion in which the dispersed phase is bituminous. Note 1 to entry: Unless otherwise stated, continuous phase is assumed to be aqueous solution (8).

27. Borrow: The material used for embankments. Borrow is excavating, removing and properly using materials obtained from approved sources of the right of way. Delivered borrow is borrow obtained by the contractor from sources other than the right of way (11).

28. Box culvert: The culvert with a square or rectangular cross-sectional profile having four sides, including a bottom (13).

29. Bridge:
   (a) The structure, including supports, erected over a depression or an obstruction, such as water, a highway, or a railway; having a roadway or track for carrying traffic or other moving loads; and having an opening measured along the centre of the roadway of more than 20 feet between faces of abutments, spring lines of arches, or extreme ends of the openings for multiple box culverts or multiple pipes that are 60 inches or more in diameter and that have a clear distance between openings of less than half of the smallest pipe diameter.
   (b) The product that connects a local area network (LAN) to another local area network that uses the same protocol (for example, Ethernet or Token Ring network) (11).

30. Bridge Maintenance: Work performed to keep a facility in its current condition, including all activity in a facility’s life that does not require a redesign and development project (21).
31. Bridge reconstruction: The process whereby an existing bridge is replaced by a new bridge construction (7).

32. Bridge rehabilitation: The process whereby rehabilitation and repairing of an existing bridge with recovering. This definition is not valid for suspension bridges and similar ones bearing special construction techniques (7).

33. Cable stayed bridge: A bridge in which the superstructure is directly supported by cables or stays, passing over or attached to towers located at the main piers (21).

34. Capacity: The ability to accommodate a moving stream of people or vehicles in a given time period (13).

35. Carriageway: The part of a road used by vehicular traffic:
   (a) Single carriageway: The road with only one line in each direction.
   (b) Dual (double) carriageway: The road on which travelling in opposite direction is separated (see divided highway) (7).

36. Centreline C/L, C.L., CL or C-Line: The line dividing the roadway in two parts, each of which is reserved for traffic moving in one of the opposite directions. It is a survey line with continuous stationing for the length of the project. Construction plans and right of way maps refer to this line. Horizontal alignment is the centre of the roadbed (11).

37. Concrete: The composite material consisting of a binding medium within which are embedded particles or fragments of aggregate; in hydraulic cement concrete, the binder is formed from a mixture of hydraulic cement and water (11).

38. Controlled access highway: The state highway in accordance with applicable state law on which owners or occupants of abutting lands and other persons are denied access to or from the highway except at such points only and in such manner as may be determined by the department. Maintenance Collection (11).

39. Controlled highways: Those highways officially designated as a part of the Interstate or Primary system of highways (11).

40. Control of Access (COA):
   (a) Refers to conditions on certain sections of highways where the right to access the highway by abutting property owners or occupants is fully or partially controlled by a public authority. Control of access is a purchased property interest.
   (b) Full control of access means that the authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting crossings at-grade or direct private driveway connections.
   (c) Partial control of access means that the authority to control access is exercised to give preference to through traffic to a degree that, in addition to access connections with selected public roads, there may be some crossings at grade and some private driveway connections (11).

41. Corrective Maintenance: The activity performed to correct deficiencies that negatively impact the safe, efficient operations of the facility, and future integrity of the pavement section. Corrective maintenance generally is reactive to unforeseen conditions to restore a pavement to an acceptable level of service (5).

42. Corridor:
   (a) A strip of land between two termini within which traffic, topography, environment, and other characteristics are evaluated for transportation purposes. Also, for transmission of a utility.
   (b) A broad geographical band that identifies a general directional flow of traffic. It may encompass streets, highways, and transit alignments (21).

43. Corridor study:
A planning project that defines the relationships between a roadway and its adjacent land. Corridor studies are used to:

- Define acceptable levels of access and mobility,
- Determine transportation system needs to support surrounding land uses,
- Consolidate and control access points,
- Identify operational deficiencies and promote operational efficiency, and
- Promote redevelopment of an underperforming corridor (20).

44. Cost per lane Km: The average expenditure per lane km (11).

45. Cost per Km: The average expenditure per km for single carriage highways.

46. Course: The element of a pavement constructed with a single asphalt mixture. Note 1 to entry: A course can be laid in one or more layers (10).

47. Crack seal: The application of sealing material directly in the cracks of the pavement surface to prevent moisture damage (11).

48. Cross-section: The vertical section, generally at right-angles to the centreline showing the ground. On drawings it commonly shows the road to be constructed, or as constructed (14).

49. Culvert: The structure, usually for conveying water under a roadway but can also be used as a pedestrian or stock crossing, with a clear span of less than six meters (12).

50. Curb: The vertical or sloping element along the edge of a pavement or shoulder forming part of a gutter, strengthening or protecting the edge and clearly defining the edge to vehicle drivers. The surface of the curb facing the general direction of the pavement is called the “face” (11).

51. Curvature: The sharpness of a curve (13).

52. Cut: The section of highway or road below natural ground level. Also referred to as a cutting or excavation (12).

53. Design life of pavement (or Design period of pavement): The length of time for which a pavement structure is being designed based on structural distresses and traffic loadings (5).

54. Divided highway: The highway with separate carriageways for traffic moving in opposite directions (12).

55. Double layered Porous Asphalt (2L-PA): The asphalt where with a top layer of a grain size 4/8 mm of about 25 mm thick and the second/bottom layer of porous asphalt with a course aggregate (11/16 mm). The total thickness is about 70 mm. It gives a better noise reduction than a single layer porous asphalt due to the finer texture at the top (that gives less tyre vibrations), (10).

56. Drainage: The removal of water from the highway right-of-way area by use of culverts, ditches, outsell channels and other drainage structures (14).

57. Edge line: The line used to differentiate the outer edge of the traffic lanes from the shoulder (14).

58. Expansion (Capacity Improvement): The reconstruction which also involves the construction of additional through travel lanes beyond the work associated with reconstruction (7).

59. Expressway: The divided arterial highway for through traffic. It has a full or partial control of access and generally has grade separations at major intersections (11).

60. Fill: The embankment material placed above natural ground line (11).

61. Flexible pavement: The pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction, and cohesion for stability (11).
62. Freeway: The highest level of arterial characterized by full control of access and high design speeds (12).

63. Geometric design: A geometric design refers to the dimensions and elements of a highway or road (11).

64. Geometric improvement: The improvements which focus on increasing intersection capacity and enhancing safety; often involves widening to provide auxiliary turn lanes and the installation or modification of traffic signals (13).

65. Girder: The horizontal main structural element of a bridge which supports vertical loads (11).

66. Grade:
   (a) The slope of a roadway, channel, or natural ground.
   (b) Any surface prepared for the support of construction such as that for paving or laying a conduit (11).

67. Grade controls: The automatic controls on an asphalt pavement which compensate for grade variations. A grade control sensor transmits an electronic signal to either thicken or thin out the depth of the asphalt mat. The signals are based upon the grade control sensor resting on the pavement surface or on a string line (11).

68. Grade line: The slope in the longitudinal direction of the roadbed, usually expressed in percent, which is the number of units of change in elevation per 100 units' horizontal distance (11).

69. Grade separation: The crossing of two roadways, a roadway and railroad, or a roadway and a pedestrian/bicycle facility at different levels (13).

70. Grading for earthworks:
   (a) The preparation of a subgrade, in line and elevation, for application of pavement materials including base and surfacing materials.
   (b) Any striping, cutting, filling, stockpiling, or combination thereof which modifies the land surface (11).

71. Guardrail: The traffic barrier used to shield potentially hazardous areas (11).

72. Highway: The entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel (11).

73. Highway class: The rural/urban description of the lane characteristics (11).

74. Highway maintenance and service equipment: It includes both on-road and off-road equipment. (11)

75. Horizontal curve: The bend from a straight line along a roadway (13).

76. Grading: The particle size distribution expressed as the percentages by mass passing a specified set of sieves (9).

77. HCR-Motorways-Expressway: The high Capacity Roads such as Motorways and Expressways. These roads are full access or half access controlled (at least) double carriageway highways. Both physical and geometric capacity of this type of roads are high. The applied design speed on these roads are also higher than on other roads. They may be toll roads.

78. Hot Rolled Asphalt (HRA): The dense, gap graded bituminous mixture in which the mortar of fine aggregate, filler and high viscosity binder are major contributors to the performance of the laid material”. Coated chippings (nominally single size aggregate particles with a high resistance to polishing, which are lightly coated with high viscosity binder) are always rolled into and form part of a Hot Rolled Asphalt surface course. This durable surface layer was often used as a surface layer in the United Kingdom of Great Britain and Northern Ireland (10).
79. **Interchange**: The grade separation of two or more roads with one or more interconnecting carriageways (14).

80. **Intersection**: The place at which two or more roads cross at grade or with grade separation (14).

81. **Lane line**: The broken line separating lanes for traffic moving in the same direction or a solid line for delineating traffic lanes and shoulder edge (11).

82. **Lane-Km.**: The measure of the total length of travelled pavement surface. Lane-km. is the centreline length (in km.) multiplied by the number of lanes (11).

83. **Layer**: The element of a pavement laid in a single operation (10).

84. **Limited access roadway**: The roadway especially designed for through traffic and over, from, or to which owners or occupants of abutting land or other persons have no right or easement of access by reason of the fact that their property abuts such limited access facility or for any other reason. Interstate highways, parkways, and freeways are usually developed as limited-access facilities (11).

85. **Line**: The baseline of roadway (11).

86. **Local road**: The road that primarily provides access to adjacent land and provides service to motorists over relatively short distances (11).

87. **Longitudinal slope**: Either the fore slope, which occurs when the roadway is located on a fill and the clear zone slopes down from the roadway, or the backslope, which occurs when the roadway is located on a cut and the clear zone slopes up from the roadway (13).

88. **Low-volume road**: The roadway generally subjected to low levels of traffic (11).

89. **Medium Capacity Roads (MCR)-Primary Roads**: The roads of which the geometric and physical capacity is medium. They are not access controlled. They are usually toll-free roads. They may be double or single carriageway highways. They are also main arterials and principal roads of national highways system of countries. The applied speed limits on these roads are lower than on HCR.

90. **Medium Capacity Roads (MCR)-Secondary Roads**: The roads whose geometric and physical capacity is medium but relatively lower than MCR-Primary Roads. They are not access controlled. They are toll-free roads. They may be double or single carriageway highways. They are important connectors of the national highways system to towns. The applied speed limits on these roads are lower than on HCR.

91. **Maintenance of roadway infrastructure**: The preservation through treatment activities of the entire roadway, including surface, shoulders, roadsides, structures, and such traffic control devices which are necessary for the road way to perform its function (5).

92. **Maintenance activities**: The combination of all technical and associated administrative actions during the service life to retain a civil engineering works or an assembled system (part of works) in a state in which it can perform its required functions. Note 1 to entry: Maintenance includes cleaning, servicing, repainting, repairing, replacing parts of the construction works where needed, or according to approved levels of service. (Construction Products Directive Guidance Paper F). Note 2 to entry: Adapted from the definition in ISO 15686-1, ISO 6707-1 and in Construction Products Directive Guidance Paper F (2).

93. **Maintenance cost for road**: The total of labour, material and other related costs incurred to retain a road or its parts in a state in which it can perform its required functions. Note 1 to entry: Maintenance includes conducting corrective, responsive and preventative maintenance on constructed assets, or their parts, and includes all associated management, cleaning, servicing, repainting, repairing and replacing of parts where needed to allow the constructed asset to be used for its intended purposes (1).

94. **Maintenance Management System**: A formal procedure that is used to plan, organize, direct, control, and evaluate maintenance programs and maintenance management units (21).

95. **Maintenance Standard**: A formally established criterion for a specific operation that encompasses elements usually found in quality, quantity, and performance standards (21).
96. Major arterial: The roadway that services state-wide travel as well as major traffic movements within urbanized areas or between suburban centres (high mobility, limited access) (13).

97. Mastic Asphalt (MA): The voidless asphalt mixtures with bitumen as a binder in which the volume of filler and binder exceeds the volume of the remaining voids in the mixed”. This mixture is very durable and was often used as surface layer in certain countries (10).

98. Median: The portion of a divided highway separating the opposing traffic flows. A median may be traversable or non-traversable.

99. Modified Bitumen: The bituminous binder whose rheological properties have been modified during manufacture by the use of one or more chemical agents. Note 1 to entry: In this context, “chemical agent” includes natural rubber, synthetic polymers, waxes, sulfur and certain organo-metallic compounds, but not oxygen or oxidation “catalysts” such as ferric chloride, phosphoric acid and phosphorus pentoxide. Fibres and inorganic powders (“fillers”) are not considered to be bitumen modifiers. Modified bitumens may be employed “directly” or in the form of cut-backs or emulsions or blended with (for example) natural asphalt (8).

100. Motorway: The defined class of road for which certain activities or uses are restricted of prohibited by legislative provision (14) (insert definition from glossary?).

101. Multilane highway: The multilane highway is a highway with three or more lanes (11).

102. Natural Asphalt: The naturally occurring mixture of bitumen and finely divided mineral matter which is found in well-defined surface deposits and which is processed to remove unwanted components such as water and vegetable matter (10).

103. New Bridge Construction: The process involving construction of a bridge with approaching roads on an existing road alignment or on new road corridor (7).

104. New road construction: The construction of all parts of a road: structures, subgrade, pavement where no road existed before (7).

105. New Tunnel Construction: The process involving construction of a tunnel with approaching roads an existing road alignment or on new road corridor (7).

106. Operating Costs: The sum of all fixed and variable costs that can be associated with the operation and maintenance of the system during the period under consideration, generally including depreciation on plant and equipment, interest paid for loans on capital equipment, and property taxes on capital items (21).

107. Overlay: The layer or layers of paving materials placed on an existing surface where repairs to a pavement structure are required to restore a satisfactory riding surface and/or improve the strength of the pavement structure (11).

108. Overpass for roads: The grade separation where a minor highway passes over the major highway (12).

109. Pavement: That part of a roadway having a constructed surface for the facilitation of vehicular traffic (11).

110. Pavement Condition: The quantitative representation of pavement distress at a given point in time (5).

111. Pavement crack: The fissure or open seam in pavement which does not necessarily extend through the body of the pavement material. Pavement cracking includes alligator, longitudinal, and transverse cracking (11).

112. Pavement design: Design for (1) mixture or materials and (2) structure or thickness. These two designs cannot be clearly separated at the design stage; there must be interaction between them. Specifications are the link between mixtures and thickness design (11).

113. Pavement distress: The cracking, rutting, distortion or other types of surface deterioration which indicates a decline in the pavement’s surface condition or structural load-carrying capacity (11).
114. Pavement management: The method of finding cost-effective strategies for providing, evaluating and maintaining pavements in a serviceable condition (11).

115. Pavement Management System (PMS): The set of tools or methods that can assist decision makers in finding cost-effective strategies for providing, evaluating and maintaining pavements in a serviceable condition (11).

116. Pavement preservation: The program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations (6).

117. Pavement structure: The combination of sub-base, base, paving geotextiles, and surface courses placed on a subgrade to support and distribute the traffic load to the roadbed (3).

118. Pavement reconstruction: The replacement of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure. Reconstruction may utilize either new or recycled materials incorporated into the materials used for the reconstruction of the complete pavement section. Reconstruction is required when a pavement has either failed or has become functionally obsolete (6).

119. Pavement rehabilitation: The act of restoring a pavement to a former condition. It consists of structural enhancements that extend the service life of an existing pavement and/or improve its load carrying capacity. Rehabilitation techniques include restoration treatments and structural overlays:

- Major rehabilitation consists of structural enhancements that both extend the service life of an existing pavement and/or improve its load-carrying capability.
- Minor rehabilitation is non-structural enhancement made to the existing pavement sections to eliminate age-related, top-down surface cracking that develops in flexible pavements as a result of environmental exposure (5, 6).

120. Pavement replacement: The renewal of the pavement by providing a new paved surface without changing capacity or geometry of the road, i.e. without changing the subgrade or by removing the total thickness of all layers of pavement, existing asphalt layers from an existing pavement and providing a new paved surface without changing the subgrade (7).

121. Paving Bitumen: The bitumen used to coat aggregate and/or reclaimed asphalt, mainly used in the construction and maintenance of paved surfaces and hydraulic works. Note 1 to entry: In Europe, the most-used grades of paving bitumen are defined by their needle penetration at 25°C, up to a maximum value of 900 x 0,1 mm (8).

122. Pedestrian bridge: The bridge designed for, and intended to carry, primarily pedestrians, bicyclists, equestrian riders and light maintenance vehicles, but not designed and intended to carry typical highway traffic (18).

123. Percent of grade: The grade of centerline or profile grade road between vertical points of intersection +0.10% = Increase in elevation by 0.10 feet for each 100 feet station (11).

124. Percent slope (% Slope): The change in elevation divided by the horizontal distance over which the change occurs for a vertical line. (11).

125. Periodic Maintenance: The periodic activities on a section of road at regular and relatively long intervals aiming to preserve the structural integrity of the road. These operations tend to be large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and often even design. Activities can be classified as preventive, resurfacing, overlay and pavement reconstruction (19).

126. Portland cement: The finely powdered substance, usually grey or brownish grey, composed largely of artificial crystalline minerals, the most important of which are calcium and aluminium silicates. The calcium silicate compounds, upon reaction with water, produce the new compounds capable of imparting the stone like quality to the mixture (11).
127. Portland cement concrete pavement: the hardened mixture of Portland cement, aggregate, and water used to pave streets or highways. This mixture may or may not contain steel reinforcing (11).

128. Pre-cast: The concrete that is formed, placed, and cured before being placed in its final position. An example is a pre-case concrete beam for a bridge (11).

129. Prestressed concrete: The precast concrete subject to pretensioning, post-tensioning, or a combination of both (11).

130. Preventive Maintenance: The planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity) (5).

131. Pre-stressed simple beam bridge: The type of bridge, simply supported prestressed concrete beams (7).

132. Porous Asphalt (PA): The bituminous material with bitumen as a binder prepared so as to have a very high content of interconnected voids which allow passage of water and air in order to provide the compacted mixture with drain and noise reducing characteristics (10).

133. Radius: The line segment extending from the centre of a circle to the curve (11).

134. Reconditioning: The process including improvement of grades, curves, intersections or sight distances in order to improve traffic safety or changing the subgrade to widen shoulders or to correct structural problems in addition to resurfacing or pavement replacement. (7).

135. Recycled Aggregate: The aggregate resulting from the processing of inorganic or mineral material previously used in construction. Note 1 to Entry: Recycled aggregates can also be obtained from production residues or nonconforming products, e.g. crushed unused concrete (9).

136. Regulating Course: The course of variable thickness applied to an existing course or surface to provide the necessary profile for a further course of consistent thickness (10).

137. Remaining Service Life: The structural life remaining in the pavement at the end of analysis period (5).

138. Reinforced concrete pavement: The Portland concrete pavement in which steel is used to control the width of shrinkage and thermal cracking of the concrete. The steel adds strength to the concrete in tension (11).

139. Residual Value of pavement: Value of the in-place pavement materials less the cost to remove and process the materials for reuse (5).

140. Restoration:
   (a) The act or process of accurately recovering the form and details of a property and its setting as it appeared at a particular period of time by means of the removal of later work or by the replacement of missing earlier work (4).
   (b) The repair and/or replacement of specific lost functions within a natural system, such as habitat, water buffers, and soil function (13).

141. Resurfacing: Placing a new surface on an existing road to increase skid resistance, to seal by aiming to preserve road from negative atmospheric conditions, to increase driver comfort, to extend pavement life, to reduce noise etc, etc. The aim is not to increase the bearing capacity of pavement. (7).

142. Resurfacing by strengthening: Renewing of road surface with reinstalling bituminous layer by removing determined depth of pavement by milling in order to increase bearing capacity of road and to eliminate road defects. (7).

143. Right of Way (ROW):
   (a) The general term denoting land, property or interest therein, usually in a strip, acquired for or devoted to transportation purposes.
(b) The general term denoting land, property or interest therein, usually in a strip, acquired for or devoted to a highway for the construction of the roadway. Right of way is the entire width of land between the public boundaries or property lines of a highway. This may include purchase for drainage (14).

144. Rigid pavement: the pavement structure which distributes loads to the subgrade, having as one course a Portland cement concrete slab of relatively high-bending resistance (11).

145. Road: A route trafficable by motor vehicles. In law, the public right-of-way between boundaries of adjoining property and is owned or administrated by a road authority (14). Or Definition from 1968 Convention on Road Traffic: The entire surface of any way or street open to public traffic.

146. Roadbed: The graded portion of a highway prepared as a foundation for the pavement structure and shoulders (3).

147. Roadside: The general term denoting the area beyond the shoulder breakpoints (12).

148. Road infrastructure: The infrastructure which forms part of a roadway, pathway or shoulder, including:
   - structures forming part of the roadway, pathway or shoulder,
   - materials from which a roadway, pathway or shoulder is made (7).

149. Road tunnel: The tunnel constructed for the purpose of building an underground road (7).

150. Roadway:
   (a) The portion of the highway within the limits of construction.
   (b) That portion of a highway improved, designed, or ordinarily used for vehicular travel, exclusive of the berm or shoulder. In the event a highway includes two or more separate roadways, the term “roadway” as used in the Equipment Manual shall refer to such roadway separately, but not to all such roadway collectively (11).

151. Roadway alignment: The vertical and horizontal location of a road (13).

152. Roadway improvement: The construction or reconstruction made to the roadway cross-section (11).

153. Rolling terrain: The natural slopes consistently rise above and fall below the highway grade with, occasionally, steep slopes presenting some restrictions on highway alignment. In general, rolling terrain generates steeper gradients, causing truck speeds to be lower than those of passenger cars (12).

154. Routine Maintenance for highway systems: The work that is planned and performed on a routine basis to maintain and preserve the condition of the highway system or to respond to specific conditions and events that restore the highway system to an adequate level of service (6).

155. Rural: The areas with large expanses of undeveloped or agricultural land, dotted by small towns, villages, or any other small activity clusters (13).

156. Rural road: The road, street, way, highway, thoroughfare, or bridge that is located in an unincorporated area and that is not privately owned or controlled, any part of which is open to the public for vehicular traffic, and over which the state or any of its political subdivisions have jurisdiction (11). It is characterized by low volume high-speed flows over extended distances. Usually without significant daily peaking but could display heavy seasonal peak flows (12).

157. Salvage Value: The value (positive if a residual economic value is realized and negative if demolition costs are accrued) of competing alternatives at the end of the life cycle or analysis period. [It] typically consists of remaining service life and residual value (5).

158. Seal coat: The asphaltic coating, with aggregate, applied to the surface of a pavement structure for the purpose of waterproofing and preserving the surface, reconditioning a
previous asphaltic surface treatment, improving the surface texture of the wearing surface, changing the surface colour or providing resistance to traffic abrasion (11).

159. Service life: The period of time from completion of construction until the structural integrity of the pavement is determined to be unacceptable and rehabilitation/replacement is required (Hallin et al. 2011) (5).

160. Shoulder: The portion of the roadway adjacent to the travelled way (on either side) for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface (11).

161. Shoulder breakpoint: The hypothetical point at which the slope of the shoulder intersects the line of the fill slope. Sometimes referred to as the hinge point (12).

162. Soft Asphalt (SA): The mixture of aggregate and soft bitumen grades. This flexible mixture is used in the Nordic countries for secondary roads (10).

163. Shoulder drains: The drains usually used to drain runoff from bridge embankment areas (11).

164. Shoulder hinge point: The point in the cross-section of a road, at which the side slope would intersect with the unsealed shoulder, or in the absence of an unsealed shoulder, the sealed shoulder (14).

165. Sidewalk: The portion of the cross-section reserved for the use of pedestrians (12).

166. Sight distance: The distance measured along the carriageway over which objects of defined height are visible to a driver (14).

167. Single tube road tunnel: The tunnel through which the traffic normally flows in two directions (bi-directional flow) (7).

168. Skid resistance of a road surface: The capacity to convey friction in the contact area between tyre and road surface. Skid resistance is necessary to offset the horizontal forces that occur in the contact area between tyre and road surface during vehicle movements (accelerating, braking and steering). In order to be able to drive safely on a road it is important for a road surface to have adequate skid resistance in both wet and dry conditions (15).

169. Stone Mastic Asphalt (SMA): The gap-graded asphalt mixture with bitumen as a binder, composed of a coarse crushed aggregate skeleton bound with a mastic mortar. This mixture is often used as a surface layer in cases where high stability is needed. The surface structure also has good noise reducing properties (10).

170. Subbase: The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course (or in the case of rigid pavements, the Portland cement concrete slab). The layer used in the pavement system between the subgrade and the base course (11).

171. Subgrade: The top surface of a roadbed upon which the pavement structure, shoulders, and curbs are constructed and extending to such depth as will affect the structural design (3, 17).

172. Substructure: That part of a bridge structure covered on bent details, or below the bridge seats including back walls and wing walls at abutments (11).

173. Sunk costs: Costs of goods and services already incurred and/or irrevocably committed. Note 1 to entry: These are ignored in an appraisal. The opportunity costs of obtaining or continuing to tie up capital are, however, included in WLC analysis and the opportunity costs of using assets can be dealt with as costs in LCC analysis (1).

174. Superelevation: The method of banking the roadway by attaining a vertical difference between the inner and outer edges of pavement (11).

175. Superelevation rate: The rate of rise in cross section of the finished surface or a roadway on a curve, measured from the lowest edge to the highest edge (11).

176. Superstructure: That part of a bridge structure covered on the span details, or above the bridge seats (11).
177. Surface Course: The top layer or layers of a pavement structure designed to accommodate the traffic load and resist skidding, traffic abrasion, and weathering (3).

178. Surface treatment: The application of bituminous material followed by a layer of mineral aggregate. Multiple applications of bituminous material and mineral aggregate may be used (16).

179. Suspension bridge: The type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders (7).

180. Technical Performance: The performance related to the capability of construction works or an assembled system (part of works), which are required or are a consequence of the requirements made either by the client, users and/or by regulations (2).

181. Technical Requirement: The type and level of technical characteristics of a construction works or an assembled system (part of works), which are required or are a consequence of the requirements made by the client, users and/or by regulations (2).

182. Toll road: The highway open to traffic only upon payment of a direct fee (11).

183. Traffic: The movement of vehicles, pedestrians, ships, or planes through an area or along a defined route (21).

184. Traffic lane: The strip of roadway intended to accommodate the forward movement of a single line of vehicles (11).

185. Traffic Control Device: A sign, signal, marking, or other device placed on or adjacent to a street or highway by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic (21).

186. Traffic Signal: Any power-operated traffic control device, other than a barricade warning light or steady burning electric lamp, by which traffic is warned or directed to take some specific action. Also referred to as Highway Traffic Signal or Traffic Control Signal (1).

187. Traffic Sign: A device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating, warning, or guiding traffic (21).

188. Traffic Volume: The number of persons or vehicles passing a point on a lane, roadway, or other travelway during some time interval, often one hour, expressed in vehicles, bicycles, or persons per hour (21).

189. Travel lane: The portion of a roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes (13).

190. Two-tube tunnel (twin tube tunnel): The tunnel through which traffic flows in one direction through each tube that is uni-directional flow (7).

191. Underpass: The grade separation where the subject highway passes under an intersecting highway (12).

192. Underwater tunnel: A tunnel which is partly or wholly constructed under a body of water. They are often used where building a bridge or operating a ferry link is impossible, or to provide competition or relief for existing bridges or ferry links (7).

193. Urban: The central business districts, residential districts and open space parks typical of larger cities (13).

194. Urgent maintenance: It is undertaken for repairs that cannot be foreseen but require immediate attention, such as collapsed culverts or landslides that block a road (23).

195. Vertical curve: The parabolic curve drawn tangent to two intersecting grade lines to provide a smooth transition from one grade to another (11).

196. Viaduct: The elevated roadway span over a valley, floodplain, wetland, or gorge which provides unrestricted wildlife movements or passage of other activity (13).
II. References


(3) Standard specifications for construction of roads and bridges on federal highway projects FP - 14, United States Department of Transportation, Federal Highway Administration (Section 101), 2014.


(7) General directorate of Turkish highways definition.

(8) Bitumen and bituminous binders - Terminology, EN 12597, May 2014.

(9) Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas, EN 13043, 2016.


(11) TxDOT Glossary, Texas Department of Transportation, 2013.


(18) NCHRP 20-07, TASK 244 LRFD Guide Specifications for The Design of Pedestrian Bridges.


(20) FDOT, “What is a Corridor Study?” Available at (https://www.fdotd7studies.com/altus19studies/what-is-a-corridor-study/), 2020

(21) AASHTO Transportation Glossary, 4th edition, 2009


(23) WB, Transport Note No. TRN-4, 2005
Appendix III

Terminology on Benchmarking Rail Transport Infrastructure Construction Costs

I. Terminology

1. Active level crossing - automatic with user-side protection: The level crossing where user-side protection is activated by the approaching train. This shall include a level crossing with both user-side protection and warning (1).

2. Active level crossing - automatic with user-side warning: The level crossing where user-side warning is activated by the approaching train (1).

3. Active level crossing – manual: The level crossing where user-side protection or warning is manually activated by a railway employee (1).

4. Active level crossing - rail-side protected: The level crossing where a signal or other train protection system permits a train to proceed once the level crossing is fully user-side protected and is free from incursion (1).

5. Ballast: The selected material placed on the subgrade to support and hold the track with respect to its alignment within the bounds of specified top (vertical) and line (horizontal). Ballast preferably consists of accurately graded hard particles, normally stone, easily handled in tamping, which distribute the load, provide elasticity, drain well and resist plant growth. Generally, ballast must consist of broken stones. Granite is a very suitable material thanks to its toughness (2).

6. Branch line: The line carrying trains from the mainline to destinations on lower priority routes than the mainline (2).

7. Bridge: The structure that is built over a river, road, or other railway line to allow trains to cross from one side to the other (3).

8. Broad-gauge: The track wider than the standard gauge of 1435 mm (2).

9. Catenary system: The generalised term used to describe the whole overhead line equipment (2).

10. Connected facility: The facility connected to the main railway network, such as a terminal or port. Such facilities are connected to rail transport but lie outside the main railway network (4).


12. Contact wire: The overhead wire touched by an electric train’s pantograph in order to draw power (2).

13. Conventional lines: All railway lines that are not classified as ‘dedicated high speed lines’ or ‘upgraded high speed lines’ (4).


15. Culvert: The small bridge or pipe carrying a stream under a railway (3).

16. Dedicated high speed line: The line specially built to allow traffic at speeds generally equal to or greater than 250 km/h for the main segments. High speed line may include connecting lines, in particular connecting segments into town centre stations located on them, on which speeds may take account of local conditions (4).

17. Dedicated line: The rail link used exclusively by one type of traffic (freight or passengers) (4).
18. Development of the railway infrastructure: The network planning, financial and investment planning as well as the constructing and upgrading of the infrastructure (5).

19. Diamond crossing turnout: The turnout where two tracks cross (3).

20. Double-track line: The line in which one track is provided for each direction of travel (4).

21. Ecopassage for railway: The structure which allows animals to cross the railway line safely (3).

22. Electrified line: The line equipped with a power cable providing electric traction power to the trains (6).

23. Elevator: The installation which transports people or goods vertically between specific levels of a railway station (3).

24. Escalator: The installation in the form of moving stairs which transports people or goods vertically between specific levels of a railway station (3).

25. European Railway Traffic Management System (ERTMS): The major industrial project being implemented by the European Union, which will serve to make rail transport safer and more competitive. It is made up of all the train-borne, trackside and lineside equipment necessary for supervising and controlling, in real-time, train operation (4).

26. European Train Control System (ETCS): The component of ERTMS to guarantee a common standard that enables trains to cross national borders and enhances safety. It is a signalling and control system designed to replace the several incompatible safety systems currently used by European railways. As a subset of ERTMS, it provides a level of protection against over speed and overrun depending upon the capability of the line side infrastructure (4).

27. Fastenings: The elements such as bolts and springs that fasten rails to a sleeper (3).

28. Footbridge for railways: The engineering structure designed for pedestrians, constructed over the railway line (3).

29. High speed line: The specially built high-speed line equipped for speeds generally equal to or greater than 250 km/h or specially upgraded high-speed lines equipped for speeds of at least 200 km/h (7).

30. Infrastructure manager for railway (railway infrastructure manager): The body or firm responsible for the operation, maintenance and renewal of railway infrastructure on a network, as well as responsible for participating in its development within the framework of its general policy on development and financing of infrastructure (5).

31. Interoperability: The ability of a rail system to allow the safe and uninterrupted movement of trains which accomplish the required levels of performance (5).

32. Land grading: The work conducted in order to ensure a level base for further construction work (3).

33. Level crossing: Any level intersection between a road or passage and a railway, as recognised by the infrastructure manager and open to public or private users. Passages between platforms within stations are excluded, as well as passages over tracks for the sole use of employees (1).

34. Lighting installation: The non-traction installation including lighting of passenger passages, platforms, level crossings, marshalling yards, signal boxes etc. (3).

35. Main line: The main inter-city and other main passenger or freight route available for rail services. Main railway lines comprise the high-speed railway lines and important major conventional railway lines (4).

36. Maintenance: activities performed in order to optimise asset lifetimes and to sustain the condition and capability of existing infrastructure (10)/ The works intended to maintain the condition and capability of existing infrastructure (5).
37. Marshalling yard: The railway facility equipped with tracks with special layout and technical facilities, where sorting, formation and splitting-up of trains takes place; wagons are sorted for a variety of destinations, using a number of rail tracks (8).

38. Narrow gauge: The gauge track narrower than the standard gauge of 1435 mm (2).

39. Network: The lines, stations, terminals, and all kinds of fixed equipment needed to ensure safe and continuous operation of the rail system (6).

40. Non-electrified line: The line not equipped with a power cable providing electric traction power to the trains; usually trains on such line are driven by diesel engine (3).

41. One-sided turnout: The turnout where from one main track (of a main line), one or two diverted tracks (of a branch line) diverge (3).

42. Operation and traffic management: the procedures and related equipment permitting coherent operation of the various structural subsystems, during both normal and degraded operation, including in particular train composition and train driving, traffic planning and management (7).

43. Overhead power line: The electric power transmission line suspended to towers or poles. Overhead line equipment includes the wires and associated equipment, suspended over or adjacent to the railway line, for supplying electricity to trains (4).

44. Passenger information system: The system presenting all key elements of a railway timetable for passengers at stations (3).

45. Passive level crossing: The level crossing without any form of warning system or protection activated when it is unsafe for the user to traverse the crossing (1).

46. Pedestrian passage: The structure that allows pedestrians to pass the railway without any threat of collision with a train; there are different types of pedestrian passages e.g. footbridges or tunnels (3).

47. Platform: The structure constructed alongside the tracks at a passenger station that allows passengers wait, board and disembark from a train (3).

48. Preparatory work: The work conducted in order to prepare land for earthwork; removal of trees and bushes, demolition, etc. (3).

49. Rail: The rolled steel shape designed to be laid end-to-end in two parallel lines on sleepers, to form a track for railway rolling stock (2).

50. Railway infrastructure: The railway lines and engineering structures, buildings, and equipment, including grounds on which they are situated, dedicated to management passenger and freight services as well as maintenance of the property of the railway manager (3).

51. Railway infrastructure in ports and terminals: The line infrastructure in the administrative area of ports and terminals (3).

52. Railway line: One or more adjacent running tracks forming a route between two points (4).

53. Railway station: A building or a building complex designed to provide services for passengers and accompanying persons, i.e. ticket offices, waiting rooms, shops, bars; facilities for train operations are excluded from this definition (3).

54. Ramp: The structure constructed alongside the tracks at a freight station which allows goods to be loaded and unloaded from a train (3).

55. Removal of wired infrastructure collision: The removal of any type of cables or wires which were originally installed at the place of construction, upgrade or renewal work, in order to avoid collision with new wired infrastructure to be installed at this place (3).

56. Renewal of the railway infrastructure: The major substitution works on the existing infrastructure which do not change its overall performance (5).
57. Retaining structure: The engineering structure used for soil stabilisation, especially at slopes (3).

58. Secondary line (or branch line): The line of less importance than a main line (or trunk line) (4).

59. Section: The railway track between two locations (e.g. between two stations) (6).

60. Siding: The section which is directly or indirectly connected with a railway line, used to perform loading, maintenance, or parking operations of railway vehicles or movement and entering of railway vehicles into operation on a railway network (3).

61. Signal box: The small building near a railway, which contains the switches used to control the signals (9).

62. Signalling system: The system used to control railway traffic safely, essentially to prevent trains from colliding. The main purpose of signalling is to maintain a safe distance at all times between all trains on the running lines (4).

63. Single-track line: The line where traffic in both directions shares the same track (4).

64. Slab track: The form of railway track comprising a concrete base to which the base plates carrying the rails are secured. It eliminates the need for individual sleepers (2).

65. Sleeper: The wood, concrete or steel object that holds the rails apart and supports the track on the ballast (2).

66. Soil exchange: The excavation work conducted in order to remove the original soil and refilling this area with the soil meeting the requirements of the construction work (3).

67. Standard-gauge: The track at the width of 1435 mm (3).

68. Subgrade: The prepared surface of the natural ground or upper surface of fill material (2).

69. Superstructure - The group of track elements that are found above the formation layer, i.e. rails, sleepers, fastenings, ballast (3).

70. Switches and crossings: The specially designed rail components allowing trains to change tracks; any track elements which are not plain line (2).

71. Tamping: The compacting ballast under the sleepers to maintain the correct geometry of the track (2).

72. Technical specification for interoperability (TSI): The specification by which each subsystem or part of a subsystem is covered in order to meet the essential requirements and ensure the interoperability of the European Union rail system (1).

73. Telecommunications and IT: The installation for wireless communications in railway traffic management (3).

74. Terminal: The station where handling of goods takes place (goods are loaded on, or unloaded from, transport vehicles). May also include shunting of wagons between trains, without any loading or unloading (4).

75. Track: The assembly of rail, fastenings and sleepers over which railway carriages, wagons, locomotives and trains are moved (2).

76. Track bed: The foundation of the track, adjusted for laying the superstructure (3).

77. Traction current: The electric current supplied for the purpose of electric traction, collected by pantograph from the overhead supply (4).

78. Traction electric power engineering: The construction of overhead power lines, cable lines, substations, lightning protection, earthing systems etc. (3).

79. Trunk line: The line that is the main route on a railway (4).

80. Tunnel: The structure provided to allow a railway line to pass under higher ground, and which has excavated without disturbing the surface of that ground (2).
81. Turnout: The trackwork element where a track divides into two (2).

82. Turnout sleeper: The special kind of a sleeper laid under a turnout; it is longer than a regular sleeper (3).

83. Upgrade of the railway infrastructure: The major modification works to the infrastructure which improve its overall performance (5).

84. Upgraded high speed line: The conventional line specially upgraded to allow traffic at speeds of at least 200 km/h for the main segments (4).

85. Viaduct: The multi-span bridge structure for non-collision traffic across the railway line (3).

II. References


(2) University of Birmingham and Network Rail Railway Lexicon Mk 24, February 2011;

(3) Definitions compiled by experts of of the Polish national rail infrastructure manager (PKP PLK S.A.);

(4) RailNetEurope (RNE);


(8) Eurostat/ITF/UNECE, RNE;

(9) Collins Dictionary;

(10) International Union of Railways.
Appendix IV

Terminology used for benchmarking of construction costs of inland waterway infrastructure

I. Terminology

A. Hydrological and hydrotechnical terms

1. Alluvial: something made of gravel/mud/silt/sand deposited and formed by rivers or floods (3).
2. Alluvium: a fine-grained deposit, composed mainly of mud and silt, deposited by a river (3).
3. Apron: layer of stone, concrete or other material to protect a structure’s toe against scouring (3).
4. Aquatic dredged material placement: dredged material placement options under which the dredged material is submerged and remains under water (3).
5. Bar: an elevated region of sediment (sand or gravel) that has been deposited by the flow (3).
6. Barrage: hydraulic structure designed to retain head water on secondary branches of a river in order to regulate the delivery rate in the main channel (4).
7. Bathymetry: the study of underwater depth of water bodies, topography of a water body (3).
8. Bed profile: a curve indicating the elevation and shape of a river bed; may be a longitudinal curve or a transverse curve at a cross-section (3).
9. Bottom water outlet: hydraulic structure for draining reservoir or channel (4).
10. Canal: artificially created watercourse in an earthen cutting or embankment (4).
11. Canalization of rivers: means of increasing depth of waterways by creating pools using dams and connecting them with locks (4).
12. Chevron: U-shaped river engineering structure with blunt nose and open end facing downstream; the current is diverted along both sides of the structure (3).
13. Cross-section, profile: a plane, generally perpendicular to the centreline of the river or the fairway (3).
14. Dam: water retaining structure partitioning off the waterway and its valley to raise the water level (4).
15. Design level: water level at the stream flow measuring station established with multi-year probability (4).
16. Differentiated parameters: planned dimensions of inland waterways depending on water levels (4).
17. Discharge (Q): the volume rate of water flow, including any suspended solids (e.g. sediment), dissolved chemicals and/or biological material which is transported through a given cross-sectional area (Q=A x V, where A is cross sectional area (m²) and V is the mean velocity of water (m/s)) (3).
18. Drawdown: the difference between the working and the design water level (4).
19. Dredged material: material excavated from the river bed (3).
20. Dyke (or dike): hydraulic structure in the form of an embankment designed to protect against flooding, to restrict artificial water bodies and watercourses or to guide diverted water flows (4).

21. Fairway: area on an inland waterway for the movement of craft and marked locally and (or) on a map. It also allows for safe passage on the water, indicated by aids to navigation (4).

22. Fairway axis: centreline of the fairway (3).

23. Fairway parameters: depth, width, vertical clearance and bend radius of the fairway (4).

24. Flood control: regulation of flood waters to prevent or minimize inundation of valuable property or land (3).

25. Floodplain (flood plain): an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge events (3).

26. Ford: a shallow sector of the river that stretches across the whole width of the river (3).

27. Free flowing river: sections of natural rivers which are not impounded due to barrages such as hydropower plants or lock facilities and where water levels can be subject to considerable fluctuations (3).

28. Gauge zero: elevation of the gauging station with respect to the mean sea level (3).

29. Gauging station: equipment for measuring the water level of surface water bodies (3).

30. Geodetic survey: a survey that takes the configuration and size of the earth’s surface into account and is used to precisely define horizontal and vertical positions suitable for conducting other surveys (3).

31. Granulometric river bed improvement: the use of coarse gravel to cover lower zones of the river bed in order to halt river bed degradation (3).

32. Granulometry (of the sediment): size of particles of sediment forming the river bed (3).

33. Gravel: unconsolidated rock fragments that have a general particle size range and include size classes from granule- to boulder-sized fragments (3).

34. Guaranteed parameters: dimensions of inland waterways as set in the technical specifications for the design levels (4).

35. Guide bund: a transverse river training structure aiming to narrow the river bed and to divert flow into the fairway in order to maintain sufficient depth by increasing the natural sediment transport capacity (3).

36. Head water: raised water level caused by the obstruction or hindrance of the watercourse or a change in the flow of groundwaters.

37. High navigable water level (HNWL) corresponds to a level existing for not less than 1% of the navigation period, established on the basis of observations over a substantial number of years (30 to 40 years), excluding periods when there was ice (5).

38. Hydraulic complex: a set of hydraulic structures all at the same location and used for the same purpose (4).

39. Hydraulic structure: engineering structure designed to make use of water resources and to control the harmful effects of the water (4).

40. Hydroelectric power plant: a set of hydraulic structures and equipment used to convert the energy potential of a watercourse into electrical power (4).

41. Hydromorphology: physical characteristics of a river, including the river bed, banks, connections with the landscape, including longitudinal continuity and habitat continuity (3).
42. Inland waterway network: all inland waterways open for public navigation in a given area (1).

43. Inland waterways: natural or artificially created water bodies and watercourses indicated by navigation signs or other means and used for navigation (4).

Note: inland waterways include rivers, lakes, reservoirs, canals and other water bodies. The length of rivers and canals is measured in mid-channel. The length of lakes and lagoons is measured along the shortest navigable route between the most distant points to and from which transport operations are performed. A waterway forming a common frontier between two countries is reported by both.

44. Lock (navigation lock): hydraulic system to overcome differences in height along a waterway, in which vessels may be raised or lowered by filling up or emptying out one or more lock chambers (3).

45. Lock chamber: an enclosure consisting of a section of canal that can be closed to control the water level. It is used to raise or lower vessels that pass through it (4).

46. Longitudinal dike (training wall): a rock structure parallel to the river centre line to confine the flow in the fairway (3).

47. Low navigable water level (LNWL) corresponds to a long-term mean water level reached or exceeded on all but 20 ice-free days per year (approximately between 5% and 6% of the ice-free period) (5).

48. Maintenance of navigable hydraulic structures: operation and repair of hydraulic structures designed to allow navigation.

49. Mean discharge: average quantity of water that flows through a certain cross-section of the river per unit of time over a certain period of time (m³/s) (3).

50. Mean high water (MHW): mean of multi-year maximum water levels; the average water level is measured at a water gauge over a specific period of time (3).

51. Mean low water (MLW): mean of multi-year minimum water levels (3).

52. Mean water level (MWL): mean water level over a multi-year period (3).

53. Morphological modelling: application of specialized software packages in order to determine and predict morphological changes of the river bed (3).

54. Morphology (of the river bed): describes the shapes of river channels and how they change over time (3).

55. Multibeam: specialized equipment for hydrographic surveys used for precise 3D imaging of the river bed (3).

56. Navigable canal: waterway built primarily for navigation (1).

57. Navigable hydraulic structure: hydraulic structure on a waterway allowing navigation (including bank protection structures, breakwaters, dykes, moles, dams, approach channels, underwater structures created by dredging, pumping stations, navigable locks, boat lifts, hydroelectric power plant buildings, spillways, bottom water outlets and outlet works, tunnels and other facilities) designed to comply with set fairway parameters and allow the passage of vessels.


59. Navigable river: natural waterway open for navigation, irrespective of whether it has been improved for that purpose (1).

60. Radius of curvature of the fairway: measured on a plan or a map, the radius of an arc on the axis of the fairway (4).

61. Reservoir: an artificial water body formed of a water retaining structure on a watercourse for water storage and flow regulation (4).
62. Riprap: rock armour, rubble or other material used to armour shorelines, streambeds, bridge abutments, etc. against scour and water or ice erosion (3).

63. River basin: the land area that is drained by a river and its tributaries (3).

64. River bed (riverbed): bed formed by the flow of the river, along which run-off is carried without flooding the flood plain (4).

65. Shoal: shallow section of river bed difficult for navigation (4).

66. Spillway: hydraulic structure for passage of water discharged from upstream pool to avoid overfilling (4).

67. Stream flow measuring station: hydrological station for monitoring water levels and flows (4).

68. Towpath: bank that the fairway runs along (4)

69. Water conduit: hydraulic structure for water supply and drainage in the appropriate direction (4).

70. Water outlet: hydraulic structure for release from the upstream pool of the channel or waterway (4).

71. Water retaining structure: hydraulic structure designed to retain head water (4).

72. Waterways: stretches of water bodies and watercourses used for navigation and logging (4).

73. Weir: device in hydraulic structure in which water is discharged through an opening from a free surface of the flow (4).

B. Inland waterway infrastructure and inland water transport

74. Aids to navigation (AtoN): devices, systems or services, external to a vessel, designed and operated to enhance safe and efficient navigation of all vessels and/or vessel traffic (6).

75. Beach area: part of the coastal protection belt on the water line, along the sea, around marine bays and estuaries subject to restrictions on economic activity (4).

76. Categories of navigable inland waterways in line with the UNECE/ECMT Classification of European Inland Waterways; canals, navigable rivers and lakes are shown in the annex (7).

NB.: In some cases, the “carrying capacity of vessels” may be used to classify navigable inland waterways.

77. Coastal protection belt: part of a water protection zone of a given width along a river, the sea or around reservoirs which is subject to stricter controls on economic activity than the rest of the water protection zone (4).

78. Combined transport: waterway suitability for combined transport is classified as follows:

   (a) Waterways suitable for combined transport: inland navigation vessels with a width of 11.40 or 11.45 m and a length of approximately 110.0 m are able to operate on such waterways carrying three or more layers of containers, 50% of the containers being empty. Otherwise a permissible length of pushed convoys of 185.0 m should be possible, in which case they could operate with two layers of containers, 50% of containers being empty.

   (b) Waterways suitable for combined transport with restrictions: this is mainly interpreted by Governments as inland waterways allowing the transport of at least two layers of containers, 50% or less of them being empty, sometimes with the use of ballasting.

   (c) Waterways not suitable for combined transport: waterways where the transport of even two layers of containers is impossible (5).
79. Connections to other modes of transport: availability and distance from ports to connections to other modes of transport in km:
   (a) Maritime shipping;
   (b) Passenger rail connection;
   (c) Freight rail connection;
   (d) Motorway access;
   (e) Airport (1).
80. Deepening dredging: dredging to maintain specified parameters in approach channels (in a port) (4).
81. Draught: vertical distance from the lower part of the hull to the water level mark corresponding to the current load of the vessel.
In which:
   (a) Declared draught: maximum draught of vessels arriving in a port within one year or season;
   (b) Navigable draught: maximum draught with which a vessel can move through an approach channel (in a port) in actual hydrometeorological conditions at the time of the vessel’s passage (4).
82. Dredging: work to deepen, expand or align existing and create new navigation channels (4).
83. Dry dock: structure for the inspection, repair and construction of vessels in a dry basin in which the vessel stands below the level of the water in the port (4).
84. Engineering works: dredging, remedial work, sweeping, maintenance dredging, hydrographic surveys and maintenance of inland navigation equipment (4).
85. Hydrographic conditions of navigation: a range of measures to ensure conditions for inland navigation, including equipping inland waterways with navigation and communications systems, aids to navigation, visible and audible alarms, and providing information to vessels on navigation and hydrometeorological conditions (4).
86. Hydrographic survey: geodetic and hydrological work performed for the purposes of engineering works and maintenance of hydraulic structures with the necessary technical documentation (4).
87. Inland waterway infrastructure: all facilities for inland navigation, including hydraulic structures on the waterway, beacons, roadstead, winter harbours, places of refuge, aids to navigation, power generation facilities, communications networks and facilities, alarm systems, information systems and vessel traffic management systems, and other facilities for the operation of inland waterways (4).
88. Internavigational period: the period during which inland waterways are closed to navigation (4).
89. Maintenance dredging: work to remove obstacles to navigation (4).
90. Maintenance of navigation equipment: preparation, installation, rearrangement and cleaning of navigation signs, work to ensure their visibility, soundings, provision of informing to skippers about current and changing conditions (4).
91. Navigational equipment: a system of special alarms for safe navigation (4).
92. Navigational period: the period during which the inland waterways are open for navigation (4).
93. Pilot chart: schematic map of inland waterways with navigation equipment indicated (4).
94. Public mooring place: an arranged and equipped place on the waterway, along the shore or next to a floating object that enables vessels to stay outside the fairway to meet the
required compliance with resting times of crew members; in case of emergencies and accidents; for the execution of small-scale repairs; for crew changes.

95. Remedial work: installation in riverbed of structures to create and support differentiated guaranteed depths or to protect bank from scouring (4).

96. Roadstead: part of inland waterways intended for berthing, formation and uncoupling of vessel convoys, integrated fleet service operations and for trans-shipment operations (4).

97. Slipway: structure for the construction or repair and launch of a vessel (4).

98. Sweeping: work to locate underwater obstructions to navigation (4).

99. Turnaround time: total of operating time of vessel or survey team, time required for servicing and time towing vessel (4).

100. Vertical clearance: height in the middle of the bridge with due regard of the fairway and the shape of the bridge; it takes into account the security clearance of about 30 cm between the uppermost point of the vessel’s structure or its load and the bridge (5).


102. Winter harbour/shelter: part of a surface water body and (or) set of structures set up and equipped for the repair, winter mooring, berthing or technical inspection of vessels and floating objects (4).

C. Ports and port infrastructure

103. Bollard: mooring post for the purpose of berthing of ships and other vessels to a port structure (8).

104. Breakwater: hydraulic structure providing protection to port or coastal waters from waves, deposits and ice. Depending on the facilities protected, breakwaters can be subdivided into:

(a) Port (external), separating port basin from the water body;
(b) Internal (groynes), dividing a basin into smaller areas (8).

105. Fender: shock absorption system for dissipating the force of impact of vessels, reducing load on the wharf structure and the side of the vessel, and protecting them from mechanical damage (4).

106. Groyne: breakwater with neither end connected to the shore (4).

107. Harbour aquatorium: defined section of the water body, except the fairway, designed for the safe approach, manoeuvring, berthing and departure of vessels (4).

108. Infrastructure providing access to ports: fairways and facilities, devices and installations associated with their functioning, leading to each seaport and located within the area of a seaport. These include port entrance channels, fairways, anchorages, turning basins and vessel traffic services (VTS) and vessel traffic management systems (VMTS) (8).

109. Inner approach channel: hydraulic structure, a natural or artificial waterway located within a port, designed to allow vessels to approach or depart from quays and to manoeuvre within seaport waters. Some ports have loading/unloading and parking quays along channels (4).

110. Landing stage: a place solely for vessels to embark or disembark passengers, not part of an inland port (1).

111. Mole: breakwater with one end adjacent to the shore (4).

112. Outer harbour: area of water within the port adjacent to roadstead and the entrance to the port, separated from the port by breakwaters. Used for performing manoeuvres by entering and exiting vessels, it is also the area where waves act differently and their height and influence becomes much less severe (8).
113. Port basin: area of water adjacent to the shoreline surrounded by quays or other port structures, maintained at the required depth level, by which ships are berthed and their cargo is exchanged (8).

114. Port infrastructure: harbour and freely accessible facilities, devices and structures within the land area or waters of the port, associated with the functioning of the port and intended for performing tasks assigned to the port by the port management body.

115. Port or quay operator: transport organization operating the port or quay, goods operations (including trans-shipment), servicing of vessels or other vehicles and (or) services for passengers and their luggage (4).

116. Public port infrastructure: harbour aquatorium, rail and road access routes (up to the first intersection outside the port area), telecommunications, heating, gas, water and electricity installations, utilities systems, other objects for the use of two or more economic actors at the seaport (4).

117. Quay wall: constructed vertical or almost vertical wall to hold waterside cranes (3).

118. River port: all the facilities located on the land and in the waters of inland waterways, set up and equipped to provide services for passengers and vessels, loading, unloading, receiving, storage and dispatching of goods, in combination with other modes of transport (4).

119. Ro-Ro berth: a location at which a Ro-Ro ship can berth and load and unload motor vehicles and other mobile Ro-Ro units via ramps from ship to shore and vice versa (1).

120. Seaport hydraulic structures: engineering structures (harbour aquatorium, quays, jetties, other types of wharf facilities, moles, dams, groynes, other shore protection structures, artificial or natural underwater structures, including channels, operational aquatorium of a wharf, anchorage) located within the land area or waters of a seaport and designed to ensure the safety of vessels during navigation, manoeuvring and when moored (4).

121. Seaport infrastructure: mobile and fixed objects that allow the seaport to function, including harbour aquatorium, hydraulic structures, docks, tugs, icebreakers and other ships of the port fleet, aids to navigation and other navigation and hydrographic equipment for maritime routes, vessel traffic management systems, information systems, trans-shipment equipment, rail and road access ways, telecommunications, heating, gas, water and electricity installations, other installations, equipment and utilities systems located within the land area or waters of a seaport and designed to ensure the safety of maritime navigation, the provision of services and State monitoring in the seaport (4).

122. Statistical port: a statistical port consists of one or more ports, normally controlled by a single port authority, able to record ship and cargo movements (1).

123. Turning basin: a basin located between docks and port channels or fairways, with special provisions for the safe performance of rotating manoeuvres of ships to allow them to enter port channels, change course, or align in port with the use of their own thrusters or with the help of tugboats. The diameter of a turning basin should correspond to 150% of the length of the largest vessel to use its area (8).

124. Wave absorber: a structure preventing from forming rebound waves in a dock; may be a separate unit or a part of a quay or a breakwater (8).

125. Wharf (wharf structure): hydraulic structure with devices for the safe approach of vessels and used for the safe berthing, loading, unloading and servicing of vessels and the embarkation and disembarkation of passengers (4).

Note: types of quay according to design feature:

(i) massive reinforced concrete box caisson;
(ii) massive caisson foundation;
(iii) on a cellular cofferdam;
(iv) L-shaped wall;
(v) with capping beams and anchor slab;
(vi) with capping beams and raking trestle;
(vii) with capping beams;
(viii) slab quays (8).

Types of wharf:

(a) **Quay**: wharf structure adjacent to the shore and located along the water’s edge (4).

(b) **Pier**: wharf structure set on the slope of the shore such that there is practically no side pressure on the construction (4).

(c) **Jetty**: wharf structure standing proud from the shore in the port waters and allowing ships to berth on at least two sides (4).

(d) **Dolphin**: wharf structure consisting of a separate standing structure for positioning of the vessel during docking or for guiding vessels and other craft along the wharf (8).

(e) **Floating jetty**: berthed vessel fixed to the shore or in the roadway of an inland waterway, designed for mooring and berthing of vessels and manufacturing operations (4).

126. Wharf length: total length of wharf structures in metres (1).

### References

2. American Society of Civil Engineers (ASCE) www.infrastructurereportcard.org/making-the-grade/glossary/.
Appendix V

**Terminology on Benchmarking Intermodal Terminals**

**Infrastructure Construction Costs**

1. **Slope**: The incline angle of a roof surface, given as a ratio of the rise to the run. Should be above 2 per cent.

2. **Internal Road**: Roads that are completely inside the Logistic / Intermodal Platform. Should support mega trucks operations (two lines in each direction, wide enough) and mega trucks weight (about 5 Tn/sq m).

3. **Plot**: any measured piece or parcel of land, prepared for the installation of logistic activities. The entrance should be free of obstacles, to allow truck operations.

4. **Installations**: any construction needed to guarantee the supplying to the plot.

5. **Telecommunication installation**: a kind of telecom technology to guarantee the voice and wide band connection to any plot. Should be done by optical fibre. In addition, it should include an installation to guarantee the supply to all the designed area by connecting to an external network.

6. **Energy installation**: electrical installation to guarantee the energy consumption of the plot. Should be designed at least with 50 W/sq m. In addition, it should include an installation to guarantee the supply to all the designed area. It can be done by a new electrical substation or by connecting to an external network.

7. **Water Installation**: installation to guarantee the water consumption of the plot. In addition, it should include an installation to guarantee the supply to all the designed area. It can be done by a depot or by connecting to an external network.

8. **Water treatment installation**: installation to guarantee the evacuation of sewage water of the plot. In addition, it should include an installation to guarantee the treatment to all the designed area. It can be done by a own treatment plant or by connecting to an external network.

9. **Green areas**: free areas inside the logistic/intermodal platform dedicate to gardens. It is mandatory in most of designing regulations.

10. **Traffic signalization system**: all the installation needed to regulate and control the circulation of vehicles into the designed area.

11. **Security system**: all the installation needed to guarantee the security into the logistic/intermodal platform. It includes gate control, monitoring, and perimeter security. It should select the best technology in any case.

12. **Railway connections**: connections between railways and logistic platforms, airports, ports or inland waterways.

13. **Renewable energy**: any kind of energy generation that has zero carbon emissions: solar, wind, etc. At least a 30 per cent of the power consumption of a logistic / intermodal platform should be generated by own systems of renewable energy.

14. **Acquisition costs**: All costs needed to obtain the terrain needed to develop the logistic platform. Can be obtained by expropriation, buying or leasing.

15. **Logistic Platform**: Centre in a defined area within which all activities relating to the transport, logistics and distribution of goods, both for national and international transit, are carried out by various operators on a commercial basis.

16. **Intermodal terminal**: Area prepared for the interchange of goods between two different transport means, mainly trucks and train.

17. **Administrative Costs**: Costs incurred in contract management administration overhead expenses.
18. Project: Document that reflect the construction plan and costs of developing or modifying a logistic area.

19. Line: Each part of a road wide enough for one vehicle, often marked off by painted lines.

20. Earthmoving: The needed movement to obtain a terrain with less of 2 per cent of scope.

21. Conduits: A pipe, tube or similar prepared to be used in water circulation or by electrical or telecommunications installations.

22. Carrying capacity: The capacity of the land to support weight without deformation.

23. Pavements: The upper part of a road.

24. Electricity supply: The installation needed to guarantee the power to be used by any area of the logistic platform.

25. Dark water treatment plant: The installation needed to treat residual water to be adapted for the waste.

26. IT: Installation of telecommunications.


28. Fire Prevention: Installation needed to combat or avoid the fire risk.

29. Access Control: All installation needed to check the access of people or vehicles to an area. Usually informed by control cams, barriers, plate readers, etc.

30. CCTV: System of control by images used to security. Usually is formed by fixed cams, domos, recorders and control room).

31. Tasks preceding project development: all tasks to be implemented before the start of the project for a logistic platform (costs by unit)
   (a) Demand study ($/Unit): Analysis of demand to determine if the logistic platform is needed.
   (b) Modification of urban plan ($/Unit): tasks related to modification of the local town planning to allow the development of the logistic platform.
   (c) Environmental impact assessment ($/Unit): Assessment needed to receive the administrative environmental approval.
   (d) Archaeological requirements ($/Unit): Tasks related to receiving the administrative approval related to archaeological requirements.
   (e) Other administrative approvals ($/Unit): Tasks related to receiving other administrative approvals.

32. Land acquisition: Expropriation, purchase or renting the land needed to develop the logistic platform:
   (a) Land Purchase ($/m²): Cost (by m²) of land acquisition by purchasing the land. It includes the needed document management.
   (b) Expropriation ($/m²): Cost (by m²) of land acquisition by expropriating the land. It includes the needed document management.
   (c) Renting ($/m²/year): Cost (by m² and by year) of land acquisition by renting the land. Include the needed documents management.

33. Engineering tasks: Tasks related to preparation for construction:
   (a) Project ($/Unit): Elaboration of the engineering project.
   (b) Construction Permit ($/Unit): Cost of licences (all taxes paid to start the construction jobs).
(c) Works Management ($/Unit): Cost of engineering works during the construction.

34. Land adaptation: Tasks needed to adapt the available land to the technical requirements of a logistic platform:

(a) Land clearing ($/m2): Tasks required to take out the topsoil. Price by m2.

(b) Earth movement ($/m3): Soil movements needed to adapt the land to the requirements. Price by m3 of soil moved.

(c) Gravel Column ($/m3): Technique to increase the carrying capacity of the land. This technique consists of inserting gravel columns into the underground. Price of m3 of gravel inserted.

(d) Concrete Column ($/m3): Technique to increase the carrying capacity of the land. This technique consists of inserting into the underground concrete columns. Price of m3 of concrete inserted.

(e) Drain wick ($/m2): Technique to increase the carrying capacity of the land. This technique consists of inserting into the underground drain geotextile. Price of m2 of geotextile inserted.

(f) Preload ($/m3): Technique to increase the carrying capacity of the land. This technique consists of inserting additional soil into the underground to produce the desired effect. Price of m3 of soil placed.

(g) Perimeter fence ($/m): Perimeter fence used to guarantee that the logistic area is a closed area. Price of lineal meter of fence.

35. Internal roads: Internal roads in the logistic area:

(a) Asphalt Road ($/m2): m2 of asphalt road, including all the sub-layers needed.

(b) Concrete Road ($/m2): m2 of concrete road, including all the sub-layers needed.

36. Pavements: Internal pavements in the logistic area:

(a) Pedestrian pavement ($/m2): m2 of pavement adapted to pedestrian. Such pavement cannot support truck circulation. Price by m2 of pavement.

(b) Plot access pavement ($/m2): m2 of pavement constructed to access the plot. This pavement should support truck circulation. Price by m2 of pavement.

37. Conduits: A pipe, tube or similar prepared to be used in water circulation or for electrical or telecommunications installations:

(a) Rain water drainage conduit ($/m): Conduits to guarantee the drainage of rain water. Price by lineal m of conduit.

(b) Dark water conduit ($/m): Conduits for dark water. Price by lineal m of conduit.

(c) Potable water conduit ($/m): Conduits for potable water. Price by lineal m of conduit.

(d) Low-tension line conduit (480 v) ($/m): Conduits for low-tension electrical line. It does not include the cables. Price by lineal m of conduit.

(e) Medium-voltage line conduit (480 v - 20 kv) ($/m): Conduits for medium-tension electrical line. It does not include the cables. Price by lineal m of conduit.

(f) High-tension line conduit (>20 kv) ($/m): Conduits for high-tension electrical line. It does not include the cables. Price by lineal m of conduit.

(g) Telecommunication conduit ($/m): Conduits for telecommunication lines. It does not include the cables. Price by lineal m of conduit.

(h) Telephony conduit ($/m): Conduits for telephone lines. It does not include the cables. Price by lineal m of conduit.
(i) CCTV conduit ($/m): Conduits for CCTV installation. It does not include the cables. Price by lineal m of conduit.

(j) Optical fibre conduit ($/m): Conduits for Optical Fibre installation. It does not include the cables. Price by lineal m of conduit.

(k) Fire prevention conduit ($/m): Conduits for Fire Prevention installation. It typically uses water from tanks. Price by lineal m of conduit.

38. Cables: Cables installed in the logistic area urbanization:

(a) Low-tension electrical cable ($/m): Low-tension electrical cable installed in the logistic area. Usually a line requires more than 1 cable. Price by lineal m of cable.

(b) Medium-voltage electrical cable ($/m): Medium-tension electrical cable installed in the logistic area. Usually a line requires more than 1 cable. Price by lineal m of cable.

(c) High-tension electrical cable ($/m): High-tension electrical cable installed in the logistic area. Usually a line requires more than 1 cable. Price by lineal m of cable.

(d) Multimode optical fibre ($/m): Multimode fibre optics cable installed in the logistic area. Usually each cable has more than 1 fibre (typically, 16 or 32). Price by lineal m of cable.

(e) Monomodal optical fibre ($/m): Monomodal fibre optics cable installed in the logistic area. Usually each cable has more than 1 fibre (typically, 16 or 32). Price by lineal m of cable.

(f) Telephone cable of pairs ($/m): Telephone cable of pairs installed in the logistic area. Usually each cable has more than 1 pair (typically, 32). Price by lineal m of cable.

39. Roads installation: Internal roads additional installation:

(a) Road Paint ($/m2): All signalling painting on the roads. Price by m2 of paint.

(b) Pedestrian cross-roads ($/m2): Pedestrian cross-roads. Usually are elevated from roads, in order to help the accessibility and the speed control of trucks. Price by m2 of pedestrian cross-road.

(c) Sign Posts ($/unit): All the sign-posts needed in the logistic area to control the internal circulation. Price by sign posts installed.

(d) Streetlights ($/unit): All the streetlights installed in the logistic area. Price by streetlights.

40. Potable water supply: Entire installation needed to guarantee the supply of potable water:

(a) Deposit ($/m3): If needed, deposit of potable water to supply to the area. Prize of m3 of deposit.

(b) External conduit ($/m): Connection from the logistic area to external point of connection (given by local water company supplier). Price by lineal m of conduit.

(c) Connection valve ($/Unit): Connection valves installed in the logistic area. Price by valve installed.

(d) Check valve ($/Unit): Check valves installed in the logistic platform. Price by valve installed.

(e) Pumping ($/Unit): If needed, pump system of potable water. Price by system installed.

41. Power supply: Entire installation needed to guarantee the supply of electricity:

(a) Power station transformer ($/Unit): Power station transformer installed in the logistic area. Price by unit installed.
(b) Low-tension electrical panel ($/Unit): Electrical panel installed in the logistic area. Price by unit installed.

(c) Power sub-station ($/MW needed): Construction (or payment) of sub-station needed to guarantee the power supply. Prize by MW needed in the logistic area and used in the sub-station.

42. Rain drainage: Entire installation needed to guarantee the rain drainage, excluding conduits:

(a) Pumping ($/Unit): If needed, pumping system to guarantee the rain drainage. Price by unity installed.

(b) Oil separators ($/Unit): Installation of fat separators to avoid that engine oils enter the rainwater drainage system. Price by unity.

(c) Storm tank ($/Unit): Storm tank is a tank that can collect rainwater to avoid flooding. Price by unity installed.

(d) Canalization of existing courses ($/m2): Canalising existing courses in the land selected for developing the logistic platforms. Price by m2 of canalization.

43. Dark water treatment: All the installation needed to guarantee the circulation and treatment of dark water:

(a) Treatment system ($/eq people): Installation of treatment system to adapt the dark water to the applicable regulations. Price by equivalent people served by the treatment system.

(b) Pumping ($/Unit): If needed, a pumping system to guarantee the circulation of dark water should be installed. Price by unity installed.

44. Technical and social facilities complex:

(a) Hotels and Restaurants and other Social facilities ($/Unit): including hotels, restaurants, resting area, training centre, hairdresser, sewer etc.

(b) Technical support and trade area ($/m2): including facilities to provide technical support, incl. changing of the wheels/ tires, wires, mechanics, painting, maintenance, etc.

(c) Administration and commercial offices ($/Unit): Customs, standards and permission issues; freight forwarding, transportation offices; insurance, banks and other commercial offices etc.

(d) Other facilities ($/m2): support services for the companies at the logistic platform.

45. Garbage treatment plant:

Garbage Treatment Plant ($/m3): solid and liquid waste management facility

46. Telecom supply: Entire installation needed to guarantee telecom services:

(a) Outdoor telephone panel ($/Unit): Outdoor telephone panel installed (where any customer is connected to the telecom company). Price by unit installed.

(b) Monomodal optical fibre interconnection panel ($/Unit): Interconnection panel for monomodal optical fibre. Price by unit installed.

(c) Optical fibre repeater ($/Unit): Signal repeater of monomodal optical fibre. Price by unit installed.

(d) Multimodal optical fibre interconnection panel ($/Unit): Interconnection panel for multimodal optical fibre. Price by unit installed.

(e) Multimodal optical fibre interconnection panel ($/Unit): Signal repeater for multimodal optical fibre. Price by unit installed.

47. Fire prevention: The entire range of installations required by fire protection systems
(a) Fire tank ($/m³): Water tank used to supply water to fire protection systems. Price by m³ of tank.

(b) Check valve ($/Unit): Valves installed to prevent contamination and flooding from water sources used in fire protection systems. Price by valve installed.

(c) Fire prevention pumping ($/Unit): Pump system to guarantee the pressure of water in the fire protection system. Price by pump system installed.

(d) Fire truck ($/Unit): response time shall be less than 5 minutes.

48. Green areas: All tasks required for design and maintenance of the internal green areas:

   (a) Transplantation ($/Unit): Any transplantation that may be required from the original land into the logistic area. Price by transplant done.

   (b) Topsoil movement ($/m³): Topsoil moved to the green areas. Price by m³ of topsoil moved.

   (c) Gardening ($/m²): Gardening tasks required to finalize the green areas. Price by m² of green area adapted.

   (d) Irrigation network ($/m): Network of pipes needed to guarantee the irrigation in the green areas. Price by lineal meter of pipe installed.

   (e) Irrigation tank ($/m³): Tanks designed to collect rainwater and other kinds of water for irrigation purposes. Price by m² of tank installed.

   (f) Irrigation pumping ($/Unit): Pump system to guarantee the pressure needed in the irrigation water network.

49. CCTV: Close Control TV system:

   (a) Fixed digital cams ($/Unit): Fixed digital cameras installed in the logistic area. Price by unit.

   (b) Domo cam ($/Unit): Standalone camera which captures 360-degree panoramic videos and images installed in the logistic area. Price by unit.

   (c) Digital recorders ($/Unit): Digital recorders with more than 14 days of autonomy. Price by digital recorder installed.

   (d) Control room ($/Unit): Control room equipped with monitors, and other technical equipment, tables, chairs, etc. Price by control room installed.

50. Access control: Access Control system:

   (a) Access control barrier ($/Unit): Automated barrier for the access control system. Price by Access control barrier installed.

   (b) Plate recognition ($/Unit): Plate reader system in order to control the access of vehicles in the logistic area. Price by plate reader installed.

   (c) Logical access control ($/Unit): Tools and protocols used for identification, authentication, authorization, and accountability in computer information systems Price by system installed.

51. Intermodal terminal: An intermodal terminal is a big area, usually constructed in reinforced concrete to allow the interchange between trucks and train. (construction requirements may include: see items 34, a-g)

52. Truck park: A truck park is a big area, usually done in reinforce concrete to allow the trucks to park (construction requirements may include: see items 34, a-g)

53. Container freight station (CFS): Area prepared for handling of incoming/outgoing the containers (consolidation and deconsolidation of cargo):

   (a) General CFS area ($/m³): Goods are prepared for another transport mode or destination.
(b) CFS area for Dangerous Goods ($/m³): special segregation, separation and handling in accordance with a specific stowage plan.

54. Warehouse: a building for the storage of goods:
   (a) General cargo Goods ($/m²): Long, middle and short-term storage area.
   (b) Heat Controlled Goods ($/m²): Long, middle and short-term storage area for special products requiring temperature-controlled storage.
   (c) Separated Goods ($/m²): Long, middle and short-term storage area for products requiring specific treatment.
   (d) Dangerous Goods ($/m²): Long, middle and short-term storage area for dangerous goods in accordance with ADN or other relevant agreements.
   (e) Goods in Pressurized Equipment ($/m²): Long, middle and short-term products requiring pressurized storage.
   (g) Cold Chain storage($/m²): Long, middle and short-term storage area for products requiring a temperature-controlled environment.
   (h) Handling area ($/m²): area designed for loading and unloading of cargo.
   (i) Loading and Unloading area ($/m²): the services of loading or unloading cargo between any place or point of rest on a wharf or terminal, and railcars, trucks, or any other means of land transportation and barges.
Annex VI

Chapter 4/ section A
Benchmarking analysis of road transport infrastructure construction costs in the ECE region

I. Introduction

1. An important part of the mandate of the Group of Experts on Transport Infrastructure Construction Costs (GE.4) was to collect and analyse data to prepare a benchmarking analysis of transport infrastructure construction costs in the United Nations Economic Commission for Europe (ECE) region for each inland transport mode – road, rail, inland waterways – including intermodal terminals, freight/logistics centres and ports. The current report provides an overview of the analysis of road infrastructure construction costs received from a group of twelve ECE member States. The Government of Türkiye has taken the lead on the road sector data analysis. Annex VI will be issued as Chapter 4/ section A of the final report of the Group.

II. Approach for Data Analysis

2. The results of the questionnaire turned out to be useful for gaining insights into the difference observed in construction costs per km. Since the focus of the study was on the construction costs of the projects, the data was verified, organized, transformed, and extracted in an appropriate output form for subsequent use.

A. Data Reverification

3. After ensuring the integrity of the data, a comprehensive data verification strategy was applied to ensure that the data is free from any human or logical errors. The project details shared in the questionnaires were reverified using desk research to remove any errors or any misrepresentations.

B. Removing the Blanks

4. As mentioned earlier, the data received was sparse and scattered. The first challenge was to bring the data to a readable format which could later be analysed. For that purpose, all the projects with missing construction costs and project lengths were removed from the final dataset, as they did not serve any purpose to the study.

C. Standardizing the Cost Unit

5. Different countries gave their costs in their National Currencies. Since all values were to be handled in USD, all construction costs were then converted to USD. This was carried out using the ECE “Market price exchange rate” tool. For countries which were not reflected in the tool, foreign exchange rate at the end of fiscal year of 2016 was adopted.

D. Data Normalization

6. Once the errors were removed and the costs were standardized to 2016—all construction cost data was turned into 2016 USD prices using the GDP Deflators. The GDP

---

24 w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT 20- ME 6-MEER/30_en_MECCExchPPPsNEWY_r.px/
25 unstats.un.org/unsd/amaapi/api/file/15
price deflator was used as it presents a more accurate portrait of an economy where currency values may be in flux.

\[ \text{GDP Price Deflator} = \frac{\text{Nominal GDP}}{\text{Real GDP}} \times 100 \]

7. Using the United Nations GDP Deflators, changes in prices over several periods were measured. The implicit price deflator value was divided by 100 and then to bring the prices to reflect those of the year 2016, the costs of the concerned projects with the result was divided. However, for the data reflecting 2019 and 2020 prices an average value from the previous two years were used for GDP Deflator.

E. Compilation of Data

8. Once the data was normalized to 2016 — it was combined into a single spreadsheet and analysis was carried out to determine differences between the construction costs per km across countries.

F. Delving into the Data

9. In order to better appreciate the meaning of the results obtained in the course of this study, data for the construction projects were compared with the different factors influencing the construction costs including the direct input costs of the construction in order to (a) Determine why some countries report more costs of constructions and (b) determining the factors that affect the construction costs to varying degrees.

G. Data Limitations

10. The data sample received from the countries was sparse and carried limitations that impacted or influenced the interpretation of the research in the following capacities:

1. Data Sparsity

11. The data received from most countries was not enough for an in-depth analysis — which was a major setback. Most questionnaires were left unanswered — like the ones for ports, intermodal terminals and inland waterways while the questionnaires that were submitted were partially filled. For example, most road questionnaires were partially filled and breakdown project costs like the costs of bridges and viaducts, tunnels, pedestrian crossings etc. were left out. Such cases left no room to analyse the data in any way.

2. Missing Links and Data Access

12. Interpretation of the received findings led to the discovery that there were few missing details in the questionnaires that inhibited the potential of a thorough analysis of the results like lane width, international standards etc. This served as a challenge because there is limited data available on open sources for such aspects and even fewer research studies on construction costs’ benchmarking that could help a thorough analysis.

III. Benchmarking socio-economic indicators

A. Socio-economic indicators

13. In the following tables, Table A-1 to Table A-5 socioeconomic indicators by countries are given. The following graphs have been produced based on data received from countries.

Table III.1
Socio-Economic Indicators by Countries
<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Bulgaria</th>
<th>Croatia</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP (US $) (End of 2016)</td>
<td>395 197 917 596.40</td>
<td>53 102 474 547.50</td>
<td>50 063 797 663.80</td>
</tr>
<tr>
<td>Population (End of 2016)</td>
<td>8 736 668.00</td>
<td>7 127 822.00</td>
<td>4 172 441.00</td>
</tr>
<tr>
<td>GNP Per Capita (US $) (End of 2016)</td>
<td>46 220.00</td>
<td>7 580.00</td>
<td>12 390.00</td>
</tr>
<tr>
<td>Surface Area (Km²)</td>
<td>83 858.00</td>
<td>110 993.00</td>
<td>56 542.00</td>
</tr>
<tr>
<td>Density (End of 2016) Person/Km²</td>
<td>104.00</td>
<td>64.00</td>
<td>74.00</td>
</tr>
<tr>
<td></td>
<td>High Classified Roads (HCR)_Motorways</td>
<td>2 208.19</td>
<td>322.69</td>
</tr>
<tr>
<td></td>
<td>Medium Classified Roads (MCR)_Primary Single Carriageway</td>
<td>10 006.86</td>
<td>757.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double Carriageway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium Classified Roads (MCR)_Secondary Roads Single Carriageway</td>
<td>23 636.81</td>
<td>1 333.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double Carriageway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other Roads</td>
<td>97 745.21</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Single Carriageway</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Double Carriageway</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of Roads (End Of 2016) (Km)</td>
<td>73.60</td>
<td>19 330.06</td>
<td>104 290.00</td>
</tr>
<tr>
<td>Length of Tunnels (End of 2016) (M)</td>
<td>164 839.00</td>
<td>4 380.00</td>
<td>70 970.00</td>
</tr>
<tr>
<td>HCR_Motorways Per 1000 Km² (End of 2016)</td>
<td>26.32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MCR_Primary Roads Per 1000 Km² (End of 2016)</td>
<td>119.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MCR_Secondary Roads Per 1000 Km² (End of 2016)</td>
<td>281.73</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual Investment Budget of Roads (US $) (2016 Fiscal Year)</td>
<td>907 025 233.98</td>
<td>-</td>
<td>145 023 750.00</td>
</tr>
<tr>
<td>Annual Road Investment by PPP (US $) (Average of the Last Five Years 2012-2016)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual Investment Budget of Roads as Percentage of GNP (%) (Including Yearly PPP Investment)</td>
<td>2.57</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Roads in Length (Km) (End of 2016)</td>
<td>73.60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Double Carriageway Roads in Length (Km) (Average of the Last Five Years 2012–2016)</td>
<td>4.66</td>
<td>-</td>
<td>5.00</td>
</tr>
<tr>
<td>Annual Constructed Single Carriageway Roads in Length (Km) (Average of the Last Five Years 2012–2016)</td>
<td>68.95</td>
<td>-</td>
<td>0.50</td>
</tr>
<tr>
<td>Annual Constructed Tunnels in length (M) (Average of the Last Five Years 2012–2016)</td>
<td>7.90</td>
<td>-</td>
<td>1 300.00</td>
</tr>
<tr>
<td>Annual Constructed Bridges in Length (M) (Average of the Last Five Years 2012–2016)</td>
<td>-</td>
<td>-</td>
<td>500.00</td>
</tr>
<tr>
<td>Design Cost as Percentage of Construction Cost (%) (End of 2016)</td>
<td>10.00</td>
<td>-</td>
<td>2.50</td>
</tr>
</tbody>
</table>
### Table III.2
**Socio-Economic Indicators by Countries**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Cyprus</th>
<th>Estonia</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP (US $) (End of 2016)</td>
<td>20 055 640 912.10</td>
<td>22 239 718 030.00</td>
<td>236 800 000 000.00</td>
</tr>
<tr>
<td>Population (End of 2016)</td>
<td>851 560.00</td>
<td>1 315 635.00</td>
<td>5 495 000.00</td>
</tr>
<tr>
<td>GNP Per Capita (US $) (End of 2016)</td>
<td>24 700.00</td>
<td>16 904.00</td>
<td>43 400.00</td>
</tr>
<tr>
<td>Surface Area (Km²)</td>
<td>9 251.00</td>
<td>43 432.00</td>
<td>338 434.00</td>
</tr>
<tr>
<td>Density (End of 2016) Person/Km²</td>
<td>92.00</td>
<td>30.00</td>
<td>17.40</td>
</tr>
<tr>
<td>Length of Roads (End of 2016) (Km)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Classified Roads Single Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Classified Roads (MCR)-Secondary Roads Single Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Roads Single Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of Bridges (End of 2016) (M)</td>
<td>25 875</td>
<td>24 505.00</td>
<td>384 703.00</td>
</tr>
<tr>
<td>Length of Tunnels (End of 2016) (M)</td>
<td>2 000</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>HCR_Motorways Per 1000 Km² (End of 2016)</td>
<td>70</td>
<td>0.00</td>
<td>2.93</td>
</tr>
<tr>
<td>MCR_Primary Roads Per 1000 Km² (End of 2016)</td>
<td>52</td>
<td>37.05</td>
<td>37.11</td>
</tr>
<tr>
<td>MCR_Secondary Roads Per 1000 Km² (End of 2016)</td>
<td>248</td>
<td>55.37</td>
<td>111.17</td>
</tr>
<tr>
<td>Annual Investment Budget of Roads (US $) (2016 Fiscal Year)</td>
<td>-</td>
<td>168 576 942.50</td>
<td>373 200 000.00</td>
</tr>
<tr>
<td>Annual Road Investment by PPP (US $) (Average of the Last Five Years 2012-2016)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Investment Budget of Roads as Percentage of GNP (%) (Including Yearly PPP Investment)</td>
<td>-</td>
<td>0.758</td>
<td>0.16</td>
</tr>
<tr>
<td>Annual Constructed Roads in Length (Km) (End of 2016)</td>
<td>8</td>
<td>2 485.00</td>
<td>42.46</td>
</tr>
<tr>
<td>Annual Constructed Double Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016)</td>
<td>6</td>
<td>84.00</td>
<td>28.86</td>
</tr>
<tr>
<td>Annual Constructed Single Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016)</td>
<td>2</td>
<td>2 401.00</td>
<td>13.60</td>
</tr>
<tr>
<td>Annual Constructed Tunnels in Length (M) (Average of the Last Five Years 2012-2016)</td>
<td>-</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Bridges in Length (M) (Average of the Last Five Years 2012-2016)</td>
<td>-</td>
<td>6 102.00</td>
<td>-</td>
</tr>
<tr>
<td>Design Cost as Percentage of Construction Cost (%) (End of 2016)</td>
<td>1.5</td>
<td>3.00</td>
<td>3.50</td>
</tr>
</tbody>
</table>

### Table III.3
**Socio-Economic Indicators by Countries**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Germany</th>
<th>Iceland</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP (US $) (End of 2016)</td>
<td>3 853 184 000 000.00</td>
<td>20 055 640 912.10</td>
<td>1 863 000 000 000.00</td>
</tr>
<tr>
<td>Population (End of 2016)</td>
<td>82 180 000.00</td>
<td>338 349.00</td>
<td>60 600 000.00</td>
</tr>
<tr>
<td>GNP Per Capita (US $) (End of 2016)</td>
<td>57 671.00</td>
<td>59 423.85</td>
<td>30 742.50</td>
</tr>
<tr>
<td>Surface Area (Km²)</td>
<td>357 376.00</td>
<td>102 775.00</td>
<td>338 434.00</td>
</tr>
<tr>
<td>Density (End of 2016) Person/Km²</td>
<td>230.00</td>
<td>3.29</td>
<td>200.80</td>
</tr>
</tbody>
</table>
### Length of Roads (End Of 2016) (Km)

<table>
<thead>
<tr>
<th>Category</th>
<th>Germany</th>
<th>Iceland</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Classified Roads (HCR) Motorways</td>
<td>12 996.00</td>
<td>-</td>
<td>7 000.00</td>
</tr>
<tr>
<td>Medium Classified Roads (MCR) Primary Roads</td>
<td>34 465.00</td>
<td>3 111.00</td>
<td>20 000.00</td>
</tr>
<tr>
<td>Medium Classified Roads (MCR) Secondary Roads</td>
<td>3 602.00</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>Other Roads</td>
<td>600 000.00</td>
<td>5 108.00</td>
<td>500 000.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Germany</th>
<th>Iceland</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Bridges (End of 2016) (M)</td>
<td>2 131 877.00</td>
<td>31 111</td>
<td>-</td>
</tr>
<tr>
<td>Length of Tunnels (End of 2016) (M)</td>
<td>269 000.00</td>
<td>50 712</td>
<td>-</td>
</tr>
<tr>
<td>HCR_Motorways Per 1000 Km² (End of 2016)</td>
<td>36.37</td>
<td>-</td>
<td>23.00</td>
</tr>
<tr>
<td>MCR_Primary Roads Per 1000 Km² (End of 2016)</td>
<td>106.52</td>
<td>31</td>
<td>60.40</td>
</tr>
<tr>
<td>MCR_Secondary Roads Per 1000 Km² (End of 2016)</td>
<td>500.62</td>
<td>43</td>
<td>498.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Germany</th>
<th>Iceland</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Investment Budget of Roads (US $) (2016 Fiscal Year)</td>
<td>7 421 820 000.00</td>
<td>218 000 000.00</td>
<td>6 000 000 000.00</td>
</tr>
<tr>
<td>Annual Road Investment by PPP (US $) (Average of the Last Five Years 2012-2016)</td>
<td>362 850 000.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Annual Investment Budget of Roads as Percentage of GNP (%) (Including Yearly PPP Investment)</td>
<td>0.20</td>
<td>1.09</td>
<td>0.30</td>
</tr>
<tr>
<td>Annual Constructed Roads in Length (Km) (End of 2016)</td>
<td>113.00</td>
<td>102</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Double Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016)</td>
<td>47.00</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Single Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016)</td>
<td>66.00</td>
<td>88</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Tunnels in length (M) (Average of the Last Five Years 2012-2016)</td>
<td>5 500.00</td>
<td>1 508</td>
<td>-</td>
</tr>
<tr>
<td>Annual Constructed Bridges in Length (M) (Average of the Last Five Years 2012-2016)</td>
<td>13 239.00</td>
<td>155</td>
<td>-</td>
</tr>
<tr>
<td>Design Cost as Percentage of Construction Cost (%) (End of 2016)</td>
<td>18.00</td>
<td>0.1</td>
<td>5.0–10.0</td>
</tr>
</tbody>
</table>

---

**Table III.4**

**Socio-Economic Indicators by Countries**

<table>
<thead>
<tr>
<th>Category</th>
<th>Latvia</th>
<th>Republic of Moldova</th>
<th>Russian Federation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP (US $) (End of 2016)</td>
<td>27 663 388 541.90</td>
<td>8 526 490 539.00</td>
<td>1 247 227 421 134.20</td>
</tr>
<tr>
<td>Population (End of 2016)</td>
<td>1 959 536.00</td>
<td>3 551 954.00</td>
<td>144 342 396.00</td>
</tr>
<tr>
<td>GNP Per Capita (US $) (End of 2016)</td>
<td>14 600.00</td>
<td>3 180.00</td>
<td>9 750.00</td>
</tr>
<tr>
<td>Surface Area (Km²)</td>
<td>64 589.00</td>
<td>33 845.00</td>
<td>17 098 250.00</td>
</tr>
<tr>
<td>Density (End of 2016) Person/Km²</td>
<td>30.00</td>
<td>105.00</td>
<td>8.80</td>
</tr>
<tr>
<td>Length of Roads (End Of 2016) (Km)</td>
<td>High Classified Roads (HCR) Motorways</td>
<td>-</td>
<td>5 298.55</td>
</tr>
<tr>
<td></td>
<td>Medium Classified Roads</td>
<td>Single Carriageway</td>
<td>1 565.00</td>
</tr>
</tbody>
</table>
### Table III.5  
**Socio-Economic Indicators by Countries**

<table>
<thead>
<tr>
<th></th>
<th>Latvia (US $)</th>
<th>Republic of Moldova (US $)</th>
<th>Russian Federation (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(MCR)_Primary Roads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>107.00</td>
<td>59.00</td>
<td>4 149.08</td>
</tr>
<tr>
<td>Medium Classified Roads (MCR)-Secondary Roads</td>
<td>5 466.00</td>
<td>2 525.80</td>
<td>400 415.72</td>
</tr>
<tr>
<td>Single Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>-</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Other Roads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Carriageway</td>
<td>12 984.00</td>
<td>6 017.90</td>
<td>1 049 230.06</td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>-</td>
<td>0.00</td>
<td>-</td>
</tr>
</tbody>
</table>

| Length of Bridges (End of 2016) (M) | 315.21 | 26 856.00 | 2 361 196.67 |
| Length of Tunnels (End of 2016) (M) | -      | 0.00      | 58 752.36    |
| HCR_Motorways Per 1000 Km² (End of 2016) | -     | 0.00      | -            |
| MCR_Primary Roads Per 1000 Km² (End of 2016) | 25.89  | 24.90     | -            |
| MCR_Secondary Roads Per 1000 Km² (End of 2016) | 84.65  | 74.60     | -            |
| Annual Investment Budget of Roads (US $) (2016 Fiscal Year) | 316 609 200.00 | 81 236 913.00 | 4 794 254 077.51 |
| Annual Road Investment by PPP (US $) (Average of the Last Five Years 2012-2016) | - | 0.00 | 1 692 353 733.35 |
| Annual Investment Budget of Roads as Percentage of GNP (%) (Including Yearly PPP Investment) | 1.03 | 1.20 | 0.38 |
| Annual Constructed Roads in Length (Km) (End of 2016) | 440.00 | 9.80 | 2 736.62 |
| Annual Constructed Double Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016) | - | 0.00 | - |
| Annual Constructed Single Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016) | 440.00 | 9.80 | - |
| Annual Constructed Tunnels in length (M) (Average of the Last Five Years 2012-2016) | - | 0.00 | 2.74 |
| Annual Constructed Bridges in Length (M) (Average of the Last Five Years 2012-2016) | 242.00 | 0.00 | 50.49 |
| Design Cost as Percentage of Construction Cost (%) (End of 2016) | - | 1.07 | 12.00 |

<table>
<thead>
<tr>
<th></th>
<th>Sweden (US $)</th>
<th>Türkiye (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP (US $) (End of 2016)</td>
<td>520 418 000 000.00</td>
<td>856 791 000 000.00</td>
</tr>
<tr>
<td>Population (End 0f 2016)</td>
<td>9 995 153.00</td>
<td>79 814 871.00</td>
</tr>
<tr>
<td>GNP Per Capita (US $) (End of 2016)</td>
<td>52 067.00</td>
<td>10 807.00</td>
</tr>
<tr>
<td>Surface Area (Km²)</td>
<td>447 400.00</td>
<td>769 604.00</td>
</tr>
<tr>
<td>Density (End of 2016) Person/Km²</td>
<td>22.30</td>
<td>104.00</td>
</tr>
<tr>
<td>High Classified Roads (HCR)_Motorways</td>
<td>2 078.00</td>
<td>2 542.00</td>
</tr>
<tr>
<td>Medium Classified Roads (MCR)_Primary Roads</td>
<td>5 911.00</td>
<td>11 316.00</td>
</tr>
<tr>
<td>Single Carriageway</td>
<td>5 911.00</td>
<td>11 316.00</td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Length of Roads (End of 2016) (Km)</td>
<td>454.00</td>
<td>19 790.00</td>
</tr>
<tr>
<td>Medium Classified Roads (MCR)-Secondary Roads</td>
<td>17 826.00</td>
<td>32 015.00</td>
</tr>
<tr>
<td>Single Carriageway</td>
<td>17 826.00</td>
<td>32 015.00</td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>115.00</td>
<td>1 498.00</td>
</tr>
<tr>
<td>Other Roads</td>
<td>1 498.00</td>
<td>-</td>
</tr>
<tr>
<td>Single Carriageway</td>
<td>72 141.00</td>
<td>175 429.00</td>
</tr>
<tr>
<td>Double Carriageway</td>
<td>15.00</td>
<td>-</td>
</tr>
</tbody>
</table>
Length of Bridges (End of 2016) (M) 418.00 520 934.00
Length of Tunnels (End of 2016) (M) 6.60 345 851.00
HCR_Motorways Per 1000 Km² (End of 2016) 4.60 3.30
MCR_Primary Roads Per 1000 Km (End of 2016) 14.20 40.40
MCR_Secondary Roads Per 1000 Km² (End of 2016) 40.10 43.50
Annual Investment Budget of Roads (US $) (2016 Fiscal Year) 923 224 277.00 6 080 901 283.00
Annual Road Investment by PPP (US $) (Average of the Last Five Years 2012-2016) 0.00 1 657 913 741.00
Annual Investment Budget of Roads as Percentage of GNP (%) (Including Yearly PPP Investment) 0.20 0.90
Annual Constructed Roads in Length (Km) (End of 2016) 30.00 1 761.00
Annual Constructed Double Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016) 15.00 794.00
Annual Constructed Single Carriageway Roads in Length (Km) (Average of the Last Five Years 2012-2016) 15.00 967.00
Annual Constructed Tunnels in length (M) (Average of the Last Five Years 2012-2016) 5 900.00 39 339.00
Annual Constructed Bridges in Length (M) (Average of the Last Five Years 2012-2016) 5 000.00 26 395.00
Design Cost as Percentage of Construction Cost (%) (End of 2016) 3-5

14. In the following bubble graph density versus GNP per capita of countries which answered the questionnaire are plotted. Dimensions of bubbles represent density. From the following graph it is seen that there is no relation between density and GNP per capita of the countries. On the other hand, for the countries Austria, Germany, Iceland, Finland and Sweden GNP per capita is pretty high compared with other countries.

Figure III.1
GNP Per Capita Versus Density (End of 2016)

15. In addition to bubble graph the following bar chart is also plotted to illustrate density and GNP per capita indicators. Germany, Iceland and Sweden GNP per capita is almost higher than US $ 50,000. For Austria GNP per capita is also high but comparatively lower than these three countries. On the other hand, Germany, and Italy are more densely populated countries. Regarding all countries the size of the countries in terms of density and economy are not similar.

Figure III.3
Density and GNP Per Capita (End of 2016)
16. In the following bar charts road densities by their class are also given. Countries like Germany and Italy, secondary roads are very dense. On the other hand, there are not any motorways for countries namely Estonia, Iceland, Latvia and Republic of Moldova.

Figure III.7
HCR_Motorways, MCR_Primary Roads, MCR_Secondary Roads Per 1000 Km$^2$ by Countries (End of 2016)

17. The following bar chart also shows for the countries Austria, Germany and Italy MCR_Primary Road are also dense.
18. In the following bar chart, it is seen that annual investment budget of roads as percentage of GNP is high in Austria as 2.57 per cent.

Figure III.10
Indicators on Annual Investment Budget of Roads by Countries (2016 Fiscal Year)

19. The following, bar chart shows design cost as percentage of construction cost. Germany’s value is pretty high at 18 per cent, comparing with other countries. Additionally, the Russian Federation’s, Austria’s and Italy’s values are also relatively high.
20. The following bar chart also shows annual investment budget of roads per population. Iceland’s value is fairly high as 644 US $ per person compared with other countries.

IV. Benchmarking double carriageway asphalt roads construction costs analysis for all work types

21. The following three graphs present a summary of double carriageway asphalt road unit costs analysis of all countries provided data. These graphs show unit cost of double carriageway asphalt roads as maximum, minimum and averages by work types as resurfacing, resurfacing by strengthening, pavement replacement, reconditioning, expansion and new construction.
22. The above graph shows average unit cost of motorways by road works types are between 135,282 US $ per lanexkm and 2,157,667 US $ per lanexkm. Average unit cost of motorways by work types gradually increases from resurfacing to new construction in order. The biggest gap is for reconditioning, the maximum value is 27,934,255 US $ per lanexkm on the other hand, minimum one is 37,289 US $ per lanexkm. The ratio between them is 749.

23. Comparing costs by work types the highest value is obtained for reconditioning road works and the lowest value for resurfacing.

Figure IV.2
Benchmarking of Double Carriageway-Primary Roads Construction Costs for All Member Countries Which Sent Data (US $/Lane x Km) (2016 prices)
24. The above graph shows average unit cost of double carriageway primary asphalt roads by road works types are between 11,807 US $ per lanexkm and 2,193,160 US $ per lanexkm. Average unit cost of primary roads by work types gradually increases from resurfacing to new construction but not in order. Reconditioning and expansion unit costs are not fit well. The biggest gap is for expansion, the maximum value is 6,755,612 US $ per lanexkm, on the other hand minimum one is 150,879 US $ per lanexkm. The ratio between them is 44.78.

25. Comparing by work types the highest value is obtained for expansion road work type on the other hand the lowest one is for resurfacing as it is expected.

Figure IV.3
Benchmarking of Double Carriageway-Secondary Roads Construction Costs for All Member Countries Which Sent Data (US $/Lane x Km) (2016 prices)

26. The above graph shows average unit cost of double carriageway asphalt secondary roads by road works types are between 10,442 US $ per lanexkm and 1,405,245 US $ per lanexkm. Average unit cost of secondary roads by work types gradually increases from resurfacing to new construction but not in order. Resurfacing by strengthening unit cost is pretty much higher. Reconditioning unit cost is also high but lower than resurfacing by strengthening cost. The biggest gap is for resurfacing by strengthening, the maximum value is 6,975,743 US $ per lanexkm, on the other hand minimum one is 43,358 US $ per lanexkm. The ratio between them is 160.89.

27. Comparing by work types the highest value is obtained for resurfacing by strengthening road work type not as expected on the other hand, the lowest one is for resurfacing as it is expected.
V. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway medium and high classified roads resurfacing costs

Table V.1
Double Carriageway Medium and High Classified Roads Resurfacing Costs (US $/LanexKm) (2016 prices)

<table>
<thead>
<tr>
<th></th>
<th>HCR_Motorways-Expressways</th>
<th>NCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
<td>Minimum</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>245,000</td>
<td>215,000</td>
<td>180,000</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>500,000</td>
<td>500,000</td>
<td>300,000</td>
</tr>
<tr>
<td>TURKEY</td>
<td>32,500</td>
<td>21,750</td>
<td>16,500</td>
</tr>
</tbody>
</table>

28. In the above table double carriageway medium and high classified asphalt roads which are motorways, primary roads and secondary roads resurfacing cost by countries are given. Only Cyprus, Italy, Sweden and Türkiye provide data for motorways and only Türkiye provided data for primary and secondary roads resurfacing cost.

29. The following map shows motorways resurfacing cost by colour.

Figure V.3
Double Carriageway High Classified Roads-Motorways Average Resurfacing Costs Map (US $/LanexKm) (2016 prices)
30. In the above graph double carriageway high classified roads which are motorways average resurfacing costs are plotted. The highest one is observed in Sweden and the lowest one is observed in Italy. The ratio between them is 40.54.

31. In the above map resurfacing cost of medium classified primary double carriageway roads are shown. Only Türkiye provided resurfacing cost data of primary roads as seen in the following bar charts.
32. In the following map resurfacing cost of medium classified secondary double carriageway roads are shown. Only Türkiye provided resurfacing cost of secondary roads data as seen in the following bar charts.

Figure V.7
Double Carriageway Medium Classified Primary Roads Average Resurfacing Costs by Countries (US $/LanexKm) (2016 prices)

Figure V.9
Double Carriageway Medium Classified Secondary Roads Average Resurfacing Costs Map (US $/LanexKm) (2016 prices)
VI. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway medium and high classified roads resurfacing by strengthening costs

Table VI.1
Double Carriageway Medium and High Classified Roads Resurfacing by Strengthening Costs (US $/LanexKm) 2016 prices

<table>
<thead>
<tr>
<th></th>
<th>MCR_Motorways-Expressways</th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
<td>Minimum</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>1,971.93</td>
<td>814.93</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ISRAEL</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>46,000</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>1,971.93</td>
<td>814.93</td>
<td>814.93</td>
</tr>
<tr>
<td>TURKEY</td>
<td>514.13</td>
<td>-</td>
<td>922.21</td>
</tr>
</tbody>
</table>

33. In the above table double carriageway medium and high classified roads which are motorways, primary roads and secondary roads resurfacing by strengthening costs by countries are given. As it is seen only Austria, Italy, Sweden and Türkiye provide data for motorways and only Türkiye provide data for primary and secondary roads resurfacing work type.

34. The following map shows motorways resurfacing by strengthening costs as colored.
35. In the above graph double carriageway high classified asphalt roads which are motorways average resurfacing by strengthening costs are plotted. The highest one is observed in Sweden and the lowest one is observed in Italy. The ratio between them is 13. The average cost of Sweden is pretty much higher than other countries.
36. The above map shows primary double carriageway roads resurfacing by strengthening costs. Only Türkiye provided resurfacing by strengthening cost of primary roads, data is seen in the following bar charts.

37. In the following map double carriageway secondary roads resurfacing by strengthening costs is colored. Only Türkiye and Bulgaria provided resurfacing by strengthening costs data. Average cost data is plotted on the following bar charts. The ratio between them is 42.
VII. Analysis about double carriageway asphalt roads 
construction costs by work types

Benchmarking double carriageway high and medium classified roads 
pavement replacement costs

Table VII.1
Double Carriageway High and Medium Classified Roads Pavement Replacement Costs 
(US $/LanexKm) (2016 prices)
38. The above table provides country by country overview of double carriageway medium and high classified roads which are motorways, primary roads and secondary roads pavement replacement costs. Only Austria, Bulgaria, Croatia, Italy, the Russian Federation, Sweden and Türkiye provided data for motorways and Bulgaria, Iceland, the Russian Federation and Türkiye provided data for primary roads and Bulgaria and Türkiye provided data for secondary roads.

39. The following map shows motorways pavement replacement costs of data provided countries by coloured.

Figure VII.1
Double Carriageway High Classified Roads-Motorways Average Pavement Replacement Costs Map (US $/LanexKm) (2016 prices)

![Map of Motorways Replacement Costs](image)

Figure VII.2
Double Carriageway High Classified Roads-Motorways Average Pavement Replacement Costs by Countries (US $/LanexKm) (2016 prices)

![Chart of Motorways Replacement Costs by Country](image)

40. In the above graph, costs for double carriageway high classified roads which are motorways average pavement replacement costs are plotted. The highest average is observed in Bulgaria and the lowest average is observed in the Russian Federation. The ratio between them is 24.42.
41. The above map shows double carriageway primary roads pavement replacement costs of data provided countries by colour ed. Bulgaria, Iceland, the Russian Federation and Türkiye provided pavement replacement construction cost data. Average pavement replacement costs of countries are plotted on the following bar charts. Highest average cost is obtained in Iceland and lowest average one is in the Russian Federation.

42. From the above bar chart, it is seen that the highest average Pavement Replacement costs of Primary Roads are observed in Iceland. The lowest one however in the Russian Federation. In the following map secondary roads pavement replacement costs are coloured. Only Türkiye and Bulgaria provided pavement replacement costs data. Data is also plotted on the following bar charts.
Figure VII.7
Double Carriageway Medium Classified Secondary Roads Average Pavement Replacement Costs Map (US $/LanexKm) (2016 prices)

Figure VII.8
Double Carriageway Medium Classified Secondary Roads Average Pavement Replacement Costs by Countries (US $/LanexKm) (2016 prices)
VIII. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway high and medium classified roads reconditioning costs

Table VIII.1
Double Carriageway High and Medium Classified Roads Reconditioning Costs (US $/LanexKm) (2016 prices)

<table>
<thead>
<tr>
<th>Country</th>
<th>HCR Motorways</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Number of Projects</th>
<th>Length of Repaired Projects (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUSTRIA</td>
<td>1,182,281</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>3,405,148</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>1,755,483</td>
<td>1,443,168</td>
<td>1,495,874</td>
<td>11</td>
<td>3</td>
<td>1,495,874</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>1,772,983</td>
<td>1,030,308</td>
<td>106,052</td>
<td>508</td>
<td>86</td>
<td>1,030,308</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TURKEY</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

43. In the above table double carriageway medium and high classified roads which are motorways, primary roads and secondary roads reconditioning costs by countries are given. As it is seen only Austria, Bulgaria and the Russian Federation provided data for motorways and Finland, the Russian Federation and Türkiye provide data for primary roads and Finland, the Russian Federation and Türkiye provided data for secondary roads.

44. The following map shows motorways reconditioning costs of data provided countries by coloured.

Figure VIII.1
Double Carriageway High Classified Roads-Motorways Average Reconditioning Costs Map (US $/LanexKm) (2016 prices)
45. In the above graph double carriageway high classified roads which are motorways average reconditioning cost are plotted. The highest average is observed in Austria and the lowest one is observed in the Russian Federation. The ratio between them is 11.

46. The above map shows double carriageway primary roads pavement reconditioning costs of data provided countries by colour. Finland, the Russian Federation and Türkiye provided reconditioning cost. Average costs of reconditioning cost of countries data are plotted on the following bar charts. Highest average cost is observed in Finland and lowest average is observed in the Russian Federation. The ratio between them is 23.26.
47. In the following map secondary roads reconditioning costs are shown by colour. Only Finland, the Russian Federation and Türkiye provided reconditioning costs data. Data is plotted on the following bar chart. The average reconditioning cost of secondary roads for Finland is higher than the other two countries, Russian Federation and Türkiye.

Figure VIII.5
**Double Carriageway Medium Classified Primary Roads Average Reconditioning Costs by Countries (US $/LanexKm) (2016 prices)**

![Bar Chart for DC, Reconditioning, MCR Primary Roads (US $/LanexKm)](image)

![Map for DC, Reconditioning, MCR Secondary Roads (US $/LanexKm)](image)
IX. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway medium classified roads reconstruction costs

Table IX.1
Double Carriageway Medium Classified Roads Reconstruction Costs (US $/LaneKm) (2016 prices)

<table>
<thead>
<tr>
<th></th>
<th>MCR, Primary Roads</th>
<th>MCR, Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>241,000</td>
<td>111,313</td>
</tr>
<tr>
<td>CROATIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>591,412</td>
<td>300,455</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TURKEY</td>
<td>277,571</td>
<td>225,638</td>
</tr>
</tbody>
</table>

48. In the above table double carriageway medium classified roads which are primary and secondary roads reconstruction costs by countries are given. As it is seen only Bulgaria, the Russian Federation and Türkeiye provided data for primary and secondary roads. The following map shows primary roads reconstruction costs of data by colour.
49. Average double carriageway primary roads reconstruction costs by countries are plotted on the above bar chart. Highest average cost is observed in the Russian Federation and lowest average is observed in Bulgaria. The ratio between them is 2.70.
50. In the above map double carriageway secondary roads reconstruction costs are coloured. Only Bulgaria, the Russian Federation, Finland and Türkiye provided reconstruction costs data for secondary roads reconstruction. Data is plotted on the following bar chart. Costs are fairly close to each other and the ratio between upper average cost and lower average cost is 1.62.

Figure IX.5
Double Carriageway Medium Classified Secondary Roads Average Reconstruction Costs by Countries (US $/LanexKm) (2016 prices)

X. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway medium and high classified roads expansion (capacity improvement) costs

Table X.1
Double Carriageway High and Medium Classified Roads Expansion (Capacity Improvement) Costs (US $/LanexKm) (2016 prices)

51. In the above table double carriageway medium and high classified roads which are motorways, primary roads and secondary roads expansion (Capacity improvement) costs by countries are given. As it is seen Austria, Finland, Italy, the Russian Federation and Sweden provided data for motorways and Estonia, Finland, and Türkiye provided data for primary roads and only Türkiye provided data for secondary roads.
52. The following map shows motorways expansion costs by colour.

Figure X.1
Double Carriageway High Classified Motorways Roads Average Expansion (Capacity Improvement) Costs Map (US $/LanexKm) (2016 prices)

Figure X.2
Double Carriageway High Classified Roads-Motorways Average Expansion (Capacity Improvement) Costs by Countries (US $/LanexKm) (2016 prices)

53. In the above graph double carriageway high classified roads which are motorways average expansion costs are plotted. The highest average is observed in Finland and the lowest one is observed in Italy. The ratio between them is 11.79.

Figure X.4
Double Carriageway Medium Classified Primary Roads Average Expansion (Capacity Improvement) Costs Map (US $/LanexKm) (2016 prices)
54. The above map shows double carriageway primary roads expansion costs of data provided countries are colored. Estonia, Finland and Türkiye provided expansion costs.

Figure X.5
Double Carriageway Medium Classified Primary Roads Average Expansion (Capacity Improvement) Costs by Countries (US $/LanexKm) (2016 prices)

55. In the following map secondary roads expansion costs are shown by colour. Only Türkiye provided expansion costs of double carriageway secondary roads data. Data is plotted on the following bar charts. The upper expansion cost of double carriageway primary roads is observed in Finland and the lowest one is in Türkiye. The ratio between them is 15.45.

Figure X.7
Double Carriageway Medium Classified Secondary Roads Average Expansion (Capacity Improvement) Costs Map (US $/LanexKm) (2016 prices)
XI. Analysis about double carriageway asphalt roads construction costs by work types

Benchmarking double carriageway medium and high classified roads new construction costs

Table XI.1
Double Carriageway High and Medium Classified Roads New Construction Costs (US $/LanexKm) (2016 prices)

<table>
<thead>
<tr>
<th>New Construction</th>
<th>HCR_Motorways-Expressways</th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Average</td>
<td>Maximum</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>7,984.51</td>
<td>2,689.24</td>
<td>13.33</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>2,771.12</td>
<td>1,689.70</td>
<td>1,094.12</td>
</tr>
<tr>
<td>CROATIA</td>
<td>2,764.72</td>
<td>2,668.00</td>
<td>1,734.36</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>379.00</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>3,467.59</td>
<td>1,729.62</td>
<td>408.20</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>462.00</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>2,013.46</td>
<td>1,412.14</td>
<td>762.44</td>
</tr>
<tr>
<td>SWITZERLAND</td>
<td>5,550.00</td>
<td>4,395.00</td>
<td>2,500.00</td>
</tr>
<tr>
<td>TURKEY</td>
<td>1,000.50</td>
<td>961.97</td>
<td>791.62</td>
</tr>
</tbody>
</table>

56. In the above table double carriageway medium and high classified roads which are motorways, primary roads and secondary roads new construction costs by countries are given. As is seen Austria, Bulgaria, Croatia, Cyprus, Finland, Italy, the Russian Federation, Sweden and Türkiye provided data for motorways and Croatia, Finland, the Russian Federation and Türkiye provided data for primary roads and Bulgaria, the Russian Federation and Türkiye provided data for secondary roads.

57. The following map shows motorways new construction costs of data provided countries are shown with colour.
58. In the above graph double carriageway high classified roads which are motorways average new construction costs are plotted. The highest average is observed in Sweden and the lowest average is observed in Italy. The ratio between them is 6.15.
59. The above map shows double carriageway primary roads new construction costs of data provided countries by colour. Croatia, Finland, the Russian Federation and Türkiye provided double carriageway primary roads new construction cost data. Average costs of new construction cost of countries are plotted on the following bar charts. Highest average cost is obtained in Croatia and lowest average one is in the Russian Federation.

Figure XI.5
Double Carriageway Medium Classified Primary Roads Average New Construction Costs by Countries (US $/LaneKm) (2016 prices)

60. In the following map double carriageway secondary roads new construction costs are colored. Only Bulgaria, the Russian Federation and Türkiye provided cost data. Data is plotted on the following bar charts. The ratio between them is 5.24.

Figure XI.7
Double Carriageway Medium Classified Secondary Roads Average New Construction Costs Map (US $/LaneKm) (2016 prices)
61. The average new construction costs of double carriageway secondary roads for data provided countries are given in above bar chart. Upper average new construction cost of double carriageway secondary roads is observed in Bulgaria and the lowest one is in Türkiye. The ratio between them is 6.68.

XII. Benchmarking Single Carriageway asphalt roads construction costs analysis for all work types

62. The above graph shows unit cost of single carriageway secondary roads by road works types are between 40 US $ per km and 2,000,000 US $ per km. Average unit cost of secondary roads by work types gradually increases from resurfacing to new construction but not in order. Reconditioning does not fit in order. Comparing by work types the highest value is
obtained for the reconstruction and the new construction road work types as while the lowest one is for pavement replacement.

Figure XII.2
Benchmarking of Single Carriageway Roads – Secondary Roads Construction Costs for All Member Countries Which Sent Data (US $/LanexKm)(2016 prices)

63. The above graph shows unit cost of single carriageway primary roads by road works types are between 323 US $ per km and 4,507,840 US $ per km. Average unit cost of primary roads by work types gradually increases from resurfacing to new construction but not in order. Comparing by work types the highest value is obtained for new construction road work type as it is expected on the other hand the lowest one is for reconditioning not as it is expected.

XIII. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads resurfacing costs

Table XIII.1
Single Carriageway Medium Classified Roads Resurfacing Costs (US $/Km) 2016 prices

<table>
<thead>
<tr>
<th></th>
<th>MCR_Primary Roads</th>
<th></th>
<th>MCR_Secondary Roads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
<td>Minimum</td>
<td>Length of Resurfaced Projects (Km)</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>123,615</td>
<td>97,035</td>
<td>55,417</td>
<td>20</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>130,000</td>
<td>120,000</td>
<td>110,000</td>
<td>140</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>184,486</td>
<td>95,426</td>
<td>83,246</td>
<td>232</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>191,667</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>18,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>119,153</td>
<td>111,523</td>
<td>107,896</td>
<td>19</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>220,000</td>
<td>150,000</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>TURKEY</td>
<td>38,764</td>
<td>23,625</td>
<td>8,461</td>
<td>3,476</td>
</tr>
</tbody>
</table>
64. The above table gives single carriageway medium classified roads which are primary roads and secondary roads resurfacing cost by countries. As it is seen only Croatia, Estonia, Finland, Latvia, Sweden and Türkiye provided data for primary roads and Estonia, Iceland, Italy, Latvia, Sweden and Türkiye provided data for secondary roads resurfacing cost.

65. The following map shows primary roads resurfacing costs by coloured.

Figure XIII.1
Single Carriageway Medium Classified Primary Roads Average Resurfacing Costs Map (US $/Km) (2016 prices)

66. It is seen from the following bar charts the highest average unit cost of resurfacing is 191,667 US $ per km observed in Iceland and the lowest one 18,000 US $ per km observed in Italy.

Figure XIII.2
Single Carriageway Medium Classified Primary Roads Average Resurfacing Costs by Countries (US $/Km) (2016 prices)
67. In the above map resurfacing cost of single carriageway medium classified secondary roads are shown.

68. From the following bar charts, it is seen that the highest average unit cost is 130,000 US $ per km observed in Sweden and the lowest average unit cost for resurfacing of secondary roads is 16,000 US $ per km observed in Italy.
XIV. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads resurfacing by strengthening costs

Table XVI.1
Single Carriageway Medium Classified Roads Resurfacing by Strengthening Costs
(US $/Km) 2016 prices

<table>
<thead>
<tr>
<th></th>
<th>MCR Primary Roads</th>
<th>MCR Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>1,691,187</td>
<td>661,462</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>182,359</td>
<td>178,901</td>
</tr>
<tr>
<td>FINLAND</td>
<td>493,873</td>
<td>493,873</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>34,000</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>245,712</td>
<td>149,527</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>440,000</td>
<td>300,000</td>
</tr>
<tr>
<td>TURKEY</td>
<td>198,862</td>
<td>153,628</td>
</tr>
</tbody>
</table>

69. In the above table single carriageway medium classified roads which are primary roads and secondary roads resurfacing by strengthening cost by countries are given. As it is seen Croatia, Estonia, Finland, Latvia, Sweden and Türkiye provided data for primary roads and Bulgaria, Estonia, Iceland, Italy, Latvia, Sweden and Türkiye provided data for single carriageway secondary roads resurfacing by strengthening.

70. The following map shows primary roads resurfacing by strengthening costs by colour.

Figure XVI.1
Single Carriageway Medium Classified Primary Roads Average Resurfacing by Strengthening Costs Map (US $/Km) (2016 prices)
71. It is seen from the following bar charts the highest average unit cost of resurfacing by strengthening costs is 661,462 US $ per km observed in Croatia and the lowest average 84,000 US $ per km observed in Italy.

Figure XVI.2
Single Carriageway Medium Classified Primary Roads Average Resurfacing by Strengthening Costs by Countries (US $/Km) (2016 prices)

72. In above map resurfacing by strengthening cost of single carriageway secondary roads are coloured. From the following chart, unit cost by countries as average are given. The highest average unit cost is 321,127 US $ per km observed in Bulgaria and the lowest average one is 47,000 US $ per km observed in Italy.

Figure XIV.4
Single Carriageway Medium Classified Secondary Roads Average Resurfacing by Strengthening Costs Map (US $/Km) (2016 prices)
XV. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads pavement replacement costs

Table XV.1
Single Carriageway Medium Classified Roads Pavement Replacement Costs (US $/Km) 2016 prices

<table>
<thead>
<tr>
<th>Pavement Replacement</th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>975,919</td>
<td>409,747</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>344,262</td>
<td>212,880</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>350,000</td>
</tr>
<tr>
<td>LATVIA</td>
<td>645,182</td>
<td>1,203,380</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>167,546</td>
<td>41,961</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>320,000</td>
<td>250,000</td>
</tr>
<tr>
<td>TURKEY</td>
<td>341,526</td>
<td>258,953</td>
</tr>
</tbody>
</table>

73. In the above table single carriageway medium classified asphalt roads which are primary roads and secondary roads pavement replacement cost by countries are given. As it is seen Croatia, Iceland, Italy, Latvia, the Russian Federation, Sweden and Türkiye provided data for primary roads and Iceland, Italy, Latvia, the Russian Federation, Sweden and Türkiye provided data for secondary roads pavement replacement costs.
74. The following map shows primary single carriageway roads pavement replacement cost by colour.

Figure XV.2
Single Carriageway Medium Classified Primary Roads Average Pavement Replacement Costs Map (US $/Km) (2016 prices)

75. It is seen from the following bar charts the highest average unit cost of pavement replacement is 1,203,380 US $ per km observed in Latvia and the lowest one 41,961 US $ per km observed in the Russian Federation. The ratio between them is 28.68.

Figure XV.3
Single Carriageway Medium Classified Primary Roads Average Pavement Replacement Costs by Countries (US $/Km) (2016 prices)
76. In the above map, pavement replacement costs for single carriageway asphalt secondary roads are shown by color.

77. From the following bar charts, average unit costs and unit cost by countries are given. The highest average unit cost is 966,475 US $ per km observed in Latvia and the lowest one 47,098 US $ per km observed in the Russian Federation. On the other hand, the ratio between them is 20.52.
XVI. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads reconditioning costs

Table XVI.1
Single Carriageway Medium Classified Roads Reconditioning Costs (US $/Km) 2016 prices

<table>
<thead>
<tr>
<th></th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>1,931,737</td>
<td>2,626,736</td>
</tr>
<tr>
<td>CROATIA</td>
<td>1,204,634</td>
<td>608,841</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>359,135</td>
<td>306,717</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>1,298,268</td>
<td>102,142</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TURKEY</td>
<td>437,571</td>
<td>350,850</td>
</tr>
</tbody>
</table>

78. In the above table single carriageway medium classified asphalt roads which are primary roads and secondary roads reconditioning costs by countries are given. As it is seen from above table Bulgaria, Croatia, Iceland, the Russian Federation and Türkiye provided data for primary roads and Bulgaria, the Russian Federation and Türkiye provided data for secondary roads reconditioning costs.

79. The following map shows primary single carriageway roads reconditioning costs by colour.

Figure XVI.1
Single Carriageway Medium Classified Primary Roads Average Reconditioning Costs Map (US $/Km) (2016 prices)

80. It is seen in the following bar charts the highest average unit cost of reconditioning cost is 608,841 US $ per km observed in Croatia and the lowest one 102,142 US $ per km observed in the Russian Federation. The ratio between them is 5.96.
81. In above map reconditioning cost of single carriageway asphalt secondary roads are shown by colour. From the following bar charts unit cost by countries as average, maximum and minimum are given. The average unit costs are not so different from each other. The ratio between highest average unit cost and lowest average unit costs is 3.5.
XVII. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads reconstruction costs

Table XVII.1
Single Carriageway Medium Classified Roads Reconstruction Costs (US $/Km) 2016 prices

<table>
<thead>
<tr>
<th>Reconstruction</th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CROATIA</td>
<td>4,318,708</td>
<td>2,555,241</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>635,622</td>
<td>292,101</td>
</tr>
<tr>
<td>FINLAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ICELAND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>500,000</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>1,120,159</td>
<td>375,541</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>-</td>
<td>1,000,000</td>
</tr>
<tr>
<td>TURKEY</td>
<td>616,713</td>
<td>467,679</td>
</tr>
</tbody>
</table>

82. In the above table single carriageway medium classified asphalt roads which are primary roads and secondary roads reconstruction cost by countries are given. As it is seen Croatia, Estonia, Italy, the Russian Federation, Sweden and Türkiye provided data for primary roads and Estonia, Iceland, Italy, the Russian Federation, Sweden and Türkiye provided data for secondary roads reconstruction costs.

83. The following map shows primary single carriageway roads reconstruction costs coloured.
It is seen in the following bar charts the highest average unit cost of single carriageway primary roads reconstruction cost is 2,555,241 US $ per km observed in Croatia and the lowest average one 292,101 US $ per km observed in Estonia. The ratio between them is 8.45.

Figure XVII.2
Single Carriageway Medium Classified Primary Roads Average Reconstruction Costs by Countries (US $/Km) (2016 prices)
85. In above map reconstruction cost of single carriageway secondary roads are shown by colour. From the following bar charts unit cost by countries as average, maximum and minimum are given. The highest average unit cost is 1,300,000 US $ per km observed in Sweden and the lowest one 177,877 US $ per km observed in the Russian Federation. The ratio between them is 7.3.

Figure XVII.5
Single Carriageway Medium Classified Secondary Roads Average Reconstruction Costs by Countries (US $/Km) (2016 prices)

86. In the above table single carriageway medium classified roads which are primary roads and secondary roads new construction cost by countries are given. As it is seen

XVIII. Analysis about single carriageway asphalt roads construction costs by work types

Benchmarking single carriageway medium classified roads new construction costs

Table XVIII.1
Single Carriageway Medium Classified Roads New Construction Costs (US $/Km) 2016 prices

<table>
<thead>
<tr>
<th>Country</th>
<th>MCR_Primary Roads</th>
<th>MCR_Secondary Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>-</td>
<td>1,211,225</td>
</tr>
<tr>
<td>CROATIA</td>
<td>4,107,840</td>
<td>3,775,979</td>
</tr>
<tr>
<td>CYPRUS</td>
<td>1,700,000</td>
<td>-</td>
</tr>
<tr>
<td>ESTONIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FINLAND</td>
<td>3,702,669</td>
<td>3,125,615</td>
</tr>
<tr>
<td>ICELAND</td>
<td>2,150,000</td>
<td>1,194,000</td>
</tr>
<tr>
<td>ITALY</td>
<td>-</td>
<td>380,000</td>
</tr>
<tr>
<td>LATVIA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF MOLDOVA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RUSSIAN FEDERATION</td>
<td>1,144,112</td>
<td>613,188</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>3,300,000</td>
<td>3,300,000</td>
</tr>
<tr>
<td>TURKEY</td>
<td>1,114,553</td>
<td>864,903</td>
</tr>
</tbody>
</table>
Bulgaria, Croatia, Cyprus, Finland, Iceland, Italy, the Russian Federation, Sweden and Türkiye provided data for primary roads and Cyprus, Finland, Italy, the Russian Federation, Sweden and Türkiye provided data for secondary roads new construction costs.

87. The following map shows primary single carriageway roads new construction costs by colour.

Figure XVIII.2
*Single Carriageway Medium Classified Primary Roads Average New Construction Costs Map (US $/Km) (2016 prices)*

88. The following bar charts show Croatia’s, Finland’s and Sweden’s average unit cost of single carriageway primary road new construction costs are higher comparing with other countries. The average of averages is 1,484,989 US $ per km and 1.87 times lower than the highest one and 2.42 times higher than the lowest one. The highest average is observed in Croatia and the lowest average is observed in the Russian Federation.

Figure XVIII.3
*Single Carriageway Medium Classified Primary Roads Average New Construction Costs Map (US $/Km) (2016 prices)*
89. In above map new construction cost of single carriageway asphalt secondary roads are shown by colour. From the following bar chart unit cost by countries as average, maximum and minimum are given. The highest average unit cost is 1,300,000 US $ per km observed in Sweden and the lowest average 192,578 US $ per km observed in the Russian Federation. The ratio between them is 6.75.

XIX. Analysis about road superstructures construction costs by infrastructure type.

Benchmarking road infrastructures, tunnels and bridges unit construction cost

90. In the following paragraphs construction cost benchmarking analysis are presented for tunnels and bridges by table and bar charts. In following table unit construction costs of
tunnels and bridges by countries are given in terms of $ per m for tunnels and $ per m2 for bridges. This table is produced based on data received from countries.

### Table XIX.1
Unit Construction Costs of Tunnels and Bridges by Countries

<table>
<thead>
<tr>
<th></th>
<th>Unit construction cost of tunnels (us $/m)</th>
<th>Unit construction cost of bridges (us $/m2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single tube tunnel</td>
<td>Twin tube tunnel</td>
</tr>
<tr>
<td>Austria</td>
<td>14 216</td>
<td>-</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Croatia</td>
<td>15 182</td>
<td>24 045</td>
</tr>
<tr>
<td>Cyprus</td>
<td>-</td>
<td>20 000</td>
</tr>
<tr>
<td>Estonia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Finland</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iceland</td>
<td>15 400</td>
<td>-</td>
</tr>
<tr>
<td>Italy</td>
<td>18 900</td>
<td>31 500</td>
</tr>
<tr>
<td>Latvia</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Republic of Moldova</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Russian federation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>25 000</td>
<td>40 000</td>
</tr>
<tr>
<td>Türkiye</td>
<td>9 922</td>
<td>19 827</td>
</tr>
<tr>
<td>Average</td>
<td>16 437</td>
<td>27 074</td>
</tr>
</tbody>
</table>

A. **Tunnels unit construction costs benchmarking**

**Figure XIX.1**

**Single Tube Tunnels Unit Construction Costs by Countries (US $/M) (2016 prices)**

91. In the above bar chart single tube tunnel unit cost by countries are given. The average unit costs are pretty much similar. The overall one is 16,437 US$ per m. The highest one is observed in Sweden as 25,000 US $ per m and the lowest one observed in Türkiye as 9,922 US $ per m. The ratio between them is 2.5.
92. In the above bar chart however twin tube tunnel unit cost by countries are given. The overall average unit cost is 27,074 US $ per m. The highest one is observed in Sweden as 40,000 US $ per m and the lowest one observed in Türkiye as 19,827 US $ per m. The ratio between them is 2.

93. Unit cost of underwater tunnel is given in above bar chart. Only Türkiye provided data. The average cost is 86,562 US $ per m.
B. Bridges construction costs benchmarking

Figure XIX.4
Precasted and Pre-stressed Simple Beam Bridges Unit Construction Costs by Countries (US $/M2) (2016 prices)

In the above bar chart, precasted and pre-stressed simple beam unit costs by countries are given. The overall average unit cost is 1,801 US $ per m². The highest one is observed in Iceland as 3,690 US $ per m² and the lowest one observed in Türkiye as 698 US $ per m². The ratio between them is 5.3.

Figure XIX.5
Balanced Cantilever Bridges Unit Construction Costs by Countries (US $/M2) (2016 prices)

In the above bar chart however balanced cantilever bridge unit costs by countries are given. The overall average unit cost is 2,176 US $ per m². The highest one is observed in Germany as 2,583 US $ per m² and the lowest one observed in Estonia as 1,416 US $ per m². The ratio between them is 1.8.
96. Unit construction cost of cable stayed bridge data is provided by Germany and Türkiye only. The overall average is 6,328 US $ per m². The ratio between these two countries is m is 3.21.

Figure XIX.7
Suspension Bridges Unit Construction Costs by Countries (US $/M²) (2016 prices)

97. As it is seen in above bar chart only Türkiye provided suspension bridge construction cost which is 9,644 US $ per m².
98. In the above bar chart however pedestrian bridge unit costs by countries are given. The overall average unit cost is 5,164 US $ per m2. The highest one is observed in Republic of Moldova as 16,542 US $ per m2 and the lowest one observed in Latvia as 1,050 US $ per m2.
Annex VII

Chapter 4/ Section B - Benchmarking analysis of rail and inland waterways infrastructure construction costs in the ECE region

I. Introduction

1. An important part of the mandate of the Group of Experts on Benchmarking Transport Infrastructure Construction Costs (GE.4) was to collect and analyse data to prepare a benchmarking analysis of transport infrastructure construction costs in the United Nations Economic Commission for Europe (ECE) region for each inland transport mode – road, rail, inland waterways – including intermodal terminals, freight/logistics centres and ports. The current chapter provides an overview of the analysis of rail, and inland waterways infrastructure construction costs received from a group of fifteen ECE member States. The Polish National Rail Infrastructure Manager (PKP PLK S.A.) has taken the lead on the railway sector data analysis while the Ministry of Sea, Transport and Infrastructure of Croatia has supported the inland waterways sector data analysis.

II. Rail infrastructure costs

2. This section contains information on the responses of individual countries.

3. Values have been calculated as mean values from all relevant projects started in the period 2007–2016. Values have been provided in $US 2016 prices; value added cost and design costs should be excluded.

A. Bulgaria

4. Bulgaria has responded to part A of the questionnaire providing with the information on the cost of infrastructure elements for upgrade (for speeds between 120 and 160 km/h) and renewal (for speeds less than 120 km/h).
Table 1
Cost of infrastructure elements for upgrade in Bulgaria

<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>Cost (US$/km or US$/unit)</th>
<th>Type of Line</th>
<th>Organisation Responsible for Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>earthwork (US$/km)</td>
<td>401,472.71</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>track and track bed (US$/km)</td>
<td>1,207,588.78</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>one-sided turnouts (US$/unit)</td>
<td>39,769.62</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>traction electric power engineering (US$/km)</td>
<td>347,610.35</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>reinforced concrete bridges (US$/m)</td>
<td>13,431.79</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>single tube tunnels (US$/m)</td>
<td>17,230.11</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>twin tube tunnels (US$/m)</td>
<td>20,691.60</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>elevators (US$/unit)</td>
<td>65,463.61</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>escalators (US$/unit)</td>
<td>94,132.95</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>signalling and telecommunication systems (US$/km)</td>
<td>340,876.53</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>signal boxes (US$/unit)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>telecommunications and IT (ERTMS) (US$/km)</td>
<td>192,250.58</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>railway infrastructure in ports and terminals (US$/m)</td>
<td>477.52</td>
<td>signal, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>railway stations (excluding facilities for train operations) (US$/m²)</td>
<td>523.37</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>other (please specify) overpasses (US$/unit)</td>
<td>1,650,081.15</td>
<td>double, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
</tbody>
</table>

Figure 1
Cost of upgrades of infrastructure elements expressed in US $/km in Bulgaria

5. Figure 1 demonstrates infrastructure elements expressed in US $/km:
   • telecommunications and IT
   • signalling systems
   • traction electric power engineering
   • earthwork
   • track and track bed.

6. The lowest cost in this category is telecommunications and IT whilst the most expensive is track and track bed. The other three elements are almost equal in cost.
Figure 2
Cost of upgrades of infrastructure elements expressed in US $/m in Bulgaria

7. The figure demonstrates eleven categories expressed in US $/m:
   • railway infrastructure in ports and terminals;
   • reinforced concrete bridges;
   • single tube tunnels;
   • twin tube tunnels.

8. The most notable difference is between railway infrastructure in ports and terminals and the other three categories.

Figure 3
Cost of upgrades of the infrastructure elements expressed in US $/m² in Bulgaria

9. One element is presented in US $/m² - railway stations (excluding facilities for train operations).
Figure 4
Cost of upgrades of infrastructure elements expressed in US $/unit in Bulgaria

10. Figure 4 demonstrates infrastructure elements expressed in US $/unit:
    • one-sided turnouts;
    • elevators;
    • escalators;
    • other overpasses.

11. The cost of overpasses is significantly higher than that of the first three categories.

Figure 5
Cost of renewal of the infrastructure elements expressed in US $/km in Bulgaria

12. Two of the elements expressed in $US $/km can be compared – track and track bed are almost twice as costly as traction electric power engineering.
### Table 2
Cost of infrastructure elements for renewal in Bulgaria

<table>
<thead>
<tr>
<th>Element</th>
<th>V&lt;120</th>
<th>type of line</th>
<th>organisation responsible for construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>preparatory work (removal of trees and bushes, demolition etc.) (US$/m²)</td>
<td>0.87</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>track and track bed (US$/km)</td>
<td>477.235.42</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>one-sided turnouts (US$/unit)</td>
<td>92.265.51</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>diamond crossing turnouts (US$/unit)</td>
<td>117.187.81</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>timber turnout sleepers (US$/unit)</td>
<td>3.225.56</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>traction electric power engineering (US$/km)</td>
<td>263.569.63</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>steel bridges (US$/m)</td>
<td>837.81</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>single tube tunnels (US$/m)</td>
<td>5313.22</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>culverts (US$/m)</td>
<td>766.91</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>active level crossings – automatic with user-side warning (US$/unit)</td>
<td>238.617.71</td>
<td>single, electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>pedestrian passages - footbridges (US$/m)</td>
<td>2.179.38</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
<tr>
<td>standard platforms, height≤76 cm (US$/m)</td>
<td>477.24</td>
<td>electrified, gauge 1435 mm</td>
<td>SE NRIC</td>
</tr>
</tbody>
</table>

### Figure 6
Cost of renewal of infrastructure elements expressed in US $/m in Bulgaria

![Graph showing cost of renewal of infrastructure elements expressed in US $/m in Bulgaria](image)

13. Five infrastructure elements expressed in US $/m are shown in this graph:
   - standard platforms;
   - culverts;
   - steel bridges;
   - pedestrian passages – footbridges;
   - single tube tunnels.
14. The cost of the first three elements are nearly the same level. Amongst all elements expressed in metres the tunnels are the most expensive.

Figure 7
Cost of renewal of infrastructure elements expressed in US $/m² in Bulgaria

15. One element is presented in US $/m² - preparatory work (removal of trees and bushes demolition etc.).

Figure 8
Cost of renewal of infrastructure elements expressed in US $/unit in Bulgaria

16. Figure 8 demonstrates infrastructure elements expressed in US $/unit:
   - timber turnout sleepers;
   - one-sided turnouts;
   - diamond crossing turnouts;
   - active level crossings – automatic with user-side warning.

17. The cost of level crossings is the highest – twice as much as that of turnouts.

Table 3
Cost of infrastructure elements for renewal and upgrade in Bulgaria
18. There are four elements to be compared for upgrade and renewal – single tube tunnels, one-sided turnouts, traction electric power engineering, and track and track bed. Notably the cost of one-sided turnouts for upgrade is less than in the case of renewal. One-sided turnouts are cheaper for upgrade in comparison to traction electric power engineering which is 31.9 per cent more expensive for upgrade. Track and track bed are also significantly more expensive for upgrade – 153 per cent.

<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>Upgrade (US$/km)</th>
<th>Renewal (US$/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>single tube tunnels</td>
<td>92 265.51</td>
<td>5 313.22</td>
</tr>
<tr>
<td>one-sided turnouts</td>
<td>263 569.63</td>
<td>17 230.11</td>
</tr>
<tr>
<td>traction electric power engineering</td>
<td>477 235.42</td>
<td>1 207 548.78</td>
</tr>
<tr>
<td>track and track bed</td>
<td>263 569.63</td>
<td>17 230.11</td>
</tr>
</tbody>
</table>

Figure 9
Comparison of cost of infrastructure elements for renewal and upgrade in Bulgaria
19. Projects implemented in Bulgaria

Table 4
Cost of projects implemented in Bulgaria

<table>
<thead>
<tr>
<th>Start date</th>
<th>End date</th>
<th>Construction costs of the project</th>
<th>Currency</th>
<th>Other</th>
<th>Costs of bridges/viaducts</th>
<th>Costs of stations</th>
<th>Costs of over/underpasses</th>
<th>Costs of 1km bridges/viaducts</th>
<th>Costs of one stations</th>
<th>Costs of one over/underpasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>2016</td>
<td>248 306 228.23</td>
<td>USD</td>
<td>232 618 826.25</td>
<td>9 914 872.32</td>
<td>1 656 067.99</td>
<td>4 116 461.66</td>
<td>9 329 449.38</td>
<td>331 213.60</td>
<td>411 646.17</td>
</tr>
<tr>
<td>2007</td>
<td>2012</td>
<td>175 242 368.00</td>
<td>USD</td>
<td>153 808 055.15</td>
<td>16 411 447.59</td>
<td>881 940.37</td>
<td>4 140 924.89</td>
<td>32 200 776.18</td>
<td>97 993.37</td>
<td>295 780.35</td>
</tr>
<tr>
<td>2009</td>
<td>2015</td>
<td>48 061 210.85</td>
<td>USD</td>
<td>38 569 144.17</td>
<td>9 462 646.75</td>
<td>29 419.92</td>
<td>0.00</td>
<td>10 924 573.13</td>
<td>29 419.92</td>
<td>n/a</td>
</tr>
<tr>
<td>2011</td>
<td>2016</td>
<td>255 653 174.58</td>
<td>USD</td>
<td>255 002 161.92</td>
<td>231 504.60</td>
<td>419 508.06</td>
<td>0.00</td>
<td>18 520 368.38</td>
<td>83 901.61</td>
<td>n/a</td>
</tr>
<tr>
<td>2011</td>
<td>2016</td>
<td>174 548 152.31</td>
<td>USD</td>
<td>165 940 047.76</td>
<td>7 145 002.06</td>
<td>0.00</td>
<td>1 463 102.49</td>
<td>10 683 316.48</td>
<td>n/a</td>
<td>209 014.64</td>
</tr>
<tr>
<td>2013</td>
<td>2016</td>
<td>59 391 461.82</td>
<td>USD</td>
<td>28 956 899.74</td>
<td>0.00</td>
<td>29 570 193.93</td>
<td>864 368.15</td>
<td>n/a</td>
<td>n/a</td>
<td>432 184.08</td>
</tr>
</tbody>
</table>
20. Figure 10 demonstrates the allocation of costs for the projects implemented in Bulgaria:

- Reconstruction and electrification of Plovdiv - Svilengrad railway line along corridors IV and IX: Phase 2 Parvomay - Svilengrad section;
- Electrification and reconstruction of the railway line Plovdiv – Svilengrad on Transport Corridors IV and IX Phase I: section Krumovo – Dimitrovgrad;
- Electrification and upgrading of Svilengrad - TUR railway line;
- Rehabilitation of sections of railway infrastructure along Plovdiv - Burgas railway line;
- Modernization of the railway section Septemvri - Plovdiv - part of the Trans European railway network;
- Rehabilitation of station facilities along TEN-T: Sofia Central station Burgas station Pazardzhik station phase 2.

21. They were divided into costs of the construction of bridges viaducts stations overpasses and underpasses for selected projects. The remainder of the costs were classified as ‘others’ which constitute the most significant of all costs.

B. Croatia

22. Croatia has shared information on new construction upgrades and renewal. The costs are divided into those of stations level crossings tunnels bridges viaducts and others. The ‘others’ category dominates and stations also constitute a significant portion.
<table>
<thead>
<tr>
<th>Project Description</th>
<th>Start date</th>
<th>End date</th>
<th>Construction costs of the project</th>
<th>Currency</th>
<th>Line speed design</th>
<th>Rail work type</th>
<th>Type of line tracks</th>
<th>Others</th>
<th>Costs of tunnels</th>
<th>Costs of bridges/viaducts</th>
<th>Costs of level crossings</th>
<th>Costs of over/underpasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of a new railway line for suburban traffic on section Gradec – Sveti Ivan Zabno</td>
<td>26.08.2015</td>
<td>18.07.2018</td>
<td>31 562 961.99 USD V&lt;120 construction non-electrified</td>
<td>1</td>
<td>24 970 051.27</td>
<td>2 360 789.69 971 731.50</td>
<td>3 260 389.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinkovci to Tovarnik to State Border Railway</td>
<td></td>
<td></td>
<td>120&lt;V ≤160 km/h renewal electrified</td>
<td>2</td>
<td>60 540 546.26</td>
<td>585 174.91 9 735 000.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rehabilitation 18.08.2008. 12.12.2011. 70 860 721.17 USD</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>13 954 936.71</td>
<td>334 974.05 2 710 554.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section renewal Moravice - (Skrad)</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>13 954 936.71</td>
<td>334 974.05 2 710 554.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>Start date</td>
<td>End date</td>
<td>Construction costs of the project</td>
<td>Currency</td>
<td>Line speed design</td>
<td>Rail work type</td>
<td>Number of tracks</td>
<td>Costs of bridges/viaducts</td>
<td>Costs of level crossings</td>
<td>Costs of stations</td>
<td>Costs of over/underpasses</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------------------</td>
<td>---------------</td>
<td>-----------------------------------</td>
<td>----------</td>
<td>-------------------</td>
<td>----------------</td>
<td>------------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td>------------------</td>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td>Botovo - State Botovo - Dugo Selo line</td>
<td>24.05.2011.</td>
<td>11.06.2013.</td>
<td>27 888 850.30 USD km/h renewal electrified</td>
<td>120&lt;V ≤160</td>
<td>26 233 257.24</td>
<td></td>
<td></td>
<td>340 229.40 1 315 363.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section renewal Zagreb Borongaj - (Dugo Selo)</td>
<td>01.09.2013.</td>
<td>01.07.2015.</td>
<td>34 824 880.24 USD km/h renewal electrified</td>
<td>120&lt;V ≤160</td>
<td>28 167 404.29</td>
<td></td>
<td></td>
<td>477 475.95 6 180 000.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zagreb Main Station - Dugo Selo line</td>
<td>03.07.2013.</td>
<td>29.05.2014.</td>
<td>9 675 000.00 USD km/h renewal electrified</td>
<td>120&lt;V ≤160</td>
<td>6 245 925.00</td>
<td></td>
<td></td>
<td>80 400.00 3 348 675.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novska line 03.07.2013.</td>
<td>13.03.2013.</td>
<td>30.05.2014.</td>
<td>6 045 000.00 USD V&lt;120 renewal electrified</td>
<td>120&lt;V ≤160</td>
<td>5 974 800.00</td>
<td></td>
<td></td>
<td>70 200.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okučani to Novska Railway Rehabilitation and Upgrade</td>
<td>31.07.2012.</td>
<td>30.11.2016.</td>
<td>37 014 792.46 USD km/h upgrade electrified</td>
<td>120&lt;V ≤160</td>
<td>26 229 798.82</td>
<td></td>
<td></td>
<td>504.30 8 895 280.77 349 208.59</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>Start date</td>
<td>End date</td>
<td>Construction costs of the project</td>
<td>Currency</td>
<td>Line speed design</td>
<td>Rail work type</td>
<td>Type of line tracks</td>
<td>Others</td>
<td>Costs of bridges/viaducts</td>
<td>Costs of level crossings</td>
<td>Costs of stations</td>
<td>Costs of over/underpasses</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>----------</td>
<td>----------------------------------</td>
<td>----------</td>
<td>-------------------</td>
<td>---------------</td>
<td>---------------------</td>
<td>--------</td>
<td>--------------------------</td>
<td>------------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Zagreb Main Railway Station - reconstruction (modernisation) of signalling and interlocking system in scope of IPA Fund 02.11.2010.</td>
<td>09.11.2017.</td>
<td>10 870 480.50</td>
<td>USD</td>
<td>km/h</td>
<td>upgrade electrified</td>
<td>2</td>
<td>0.00</td>
<td>480.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reconstruction of existing and construction of second track on section Dugo Selo - Križevci State Border - Botovo - Dugo Selo line</td>
<td>25.07.2016.</td>
<td>planned</td>
<td>120&lt;V ≤160</td>
<td>km/h</td>
<td>upgrade electrified</td>
<td>2</td>
<td>132 110 000.00</td>
<td>2 090</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modernisation and section upgrade of Oštarije - Knin - Split line</td>
<td>2009.</td>
<td>2020, 261 600 000.00 USD</td>
<td>V&lt;120</td>
<td>upgrade electrified</td>
<td>1 253 800 000.00</td>
<td>6 000 000.00</td>
<td>000.00</td>
<td>1 800</td>
<td>000.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 11
Allocation of costs for new construction projects in Croatia

![Graph showing allocation of costs for new construction projects in Croatia]

23. Figure 11 demonstrates the allocation of costs for the construction of a new railway line for suburban traffic on the section Gradec – Sveti Ivan Žabno. The most significant are costs classified as ‘others’. However the cost of construction of stations is also meaningful.

Figure 12
Allocation of costs for the renewal projects in Croatia

![Graph showing allocation of costs for the renewal projects in Croatia]

24. This figure refers to the renewal projects:
   - Vinkovci to Tovarnik to State Border Railway Rehabilitation;
   - Section renewal Moravice - (Skrad) Zagreb Main Station - Rijeka line;
   - Section renewal Ogulin - (Moravice) Zagreb Main Station - Rijeka line;
• Section renewal Lokve- (Drivenik) Zagreb Main Station - Rijeka line;
• Section renewal Koprivnica - Botovo - State Border State Border - Botovo - Dugo Selo line;
• Section renewal (Križevci)- (Koprivnica) State Border - Botovo - Dugo Selo line;
• Section renewal Zagreb Borongaj - (Dugo Selo) Zagreb Main Station - Dugo Selo line;
• Section renewal Velika Gorica - (Turopolje) Zagreb Main Station - Sisak - Novska line;
• Section renewal Klara - (Zagreb MS) Zagreb Main Station - Sisak - Novska line.

25. Here the same situation as with new construction can be observed – ‘others’ are the most expensive elements whilst amongst the named costs stations are the most significant.

Figure 13
Allocation of costs for upgrade projects in Croatia

26. Figure 13 demonstrates the allocation of costs of the upgrade of the following projects:
• Okučani to Novska Railway Rehabilitation and Upgrade;
• Zagreb Main Railway Station - reconstruction (modernisation) of signalling and interlocking system in scope of IPA Fund;
• Reconstruction of existing and construction of second track on section Dugo Selo - Križevci;
• State Border - Botovo - Dugo Selo line;
• Modernisation and section upgrade of Oštarije - Knin - Split line.

27. One project is the reconstruction of the Zagreb Main Railway Station so there is only one category shown here. The size of costs of the remaining three projects is insignificant between new construction and renewal.
C. Finland

28. Finland has provided information about new construction and upgrades.

Table 6
Cost of projects implemented in Finland

<table>
<thead>
<tr>
<th>Project</th>
<th>Start date*</th>
<th>End date**</th>
<th>Construction costs of the project</th>
<th>Currency</th>
<th>Low speed design</th>
<th>Rail work type</th>
<th>Type of line</th>
<th>Number of tracks</th>
<th>Others</th>
<th>Costs of tunnels</th>
<th>Costs of bridges/viaducts</th>
<th>Costs of level crossings</th>
<th>Costs of stations</th>
<th>Costs of over/underpasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring Rail Line</td>
<td>2009-09-06</td>
<td>2021-07-01</td>
<td>881 100 000,00</td>
<td>USD</td>
<td>V=120</td>
<td>new construction</td>
<td>electrified</td>
<td>2</td>
<td></td>
<td>152 341 000,00</td>
<td>208 710 000,00</td>
<td>51 700 000,00</td>
<td>0,00</td>
<td>319 900 000,00</td>
</tr>
<tr>
<td>Riihimäki triangle line</td>
<td>2016-03-20</td>
<td>2016-12-31</td>
<td>13 200 000,00</td>
<td>USD</td>
<td>V=120</td>
<td>new construction</td>
<td>electrified</td>
<td>1</td>
<td></td>
<td>12 078 000,00</td>
<td>770 000,00</td>
<td>0,00</td>
<td>262 000,00</td>
<td>0,00</td>
</tr>
<tr>
<td>Railway project Seinäjoki–Oulu</td>
<td>2013-02-27</td>
<td>2016-12-31</td>
<td>948 000 000,00</td>
<td>USD</td>
<td>120+V=300 km/h</td>
<td>upgrade</td>
<td>electrified</td>
<td>1</td>
<td></td>
<td>602 300 000,00</td>
<td>0,00</td>
<td>33 000 000,00</td>
<td>20 700 000,00</td>
<td>55 000,00</td>
</tr>
<tr>
<td>new project Mäntyluoto–Vantaanjoki</td>
<td>2010-09-01</td>
<td>2013-05-17</td>
<td>13 000 000,00</td>
<td>USD</td>
<td>V=120</td>
<td>upgrade</td>
<td>electrified</td>
<td>1</td>
<td></td>
<td>17 305 000,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>495 000,00</td>
</tr>
<tr>
<td>Railway project Lohja–Jomala</td>
<td>2009-02-01</td>
<td>2020-08-01</td>
<td>123 000 000,00</td>
<td>USD</td>
<td>120+V=300 km/h</td>
<td>upgrade</td>
<td>electrified</td>
<td>2</td>
<td></td>
<td>139 323 000,00</td>
<td>0,00</td>
<td>1 100 000,00</td>
<td>3 940 000,00</td>
<td>86 300,00</td>
</tr>
</tbody>
</table>

Figure 14
Allocation of costs for new construction projects in Finland

- Others
- Costs of bridges/viaducts
- Costs of tunnels
- Costs of level crossings
- Costs of stations
- Costs of over/underpasses
29. This figure represents the new construction of two lines:
   • the Ring Rail Line;
   • the Riihimäki triangle line.

30. In the Ring Rail Line the most expensive cost was the construction of stations. Also tunnels represent a significant amount of expenditure. The third category is other costs the fourth is the cost of bridges or viaducts and finally the least expensive is over or underpasses. It is noteworthy that no costs for level crossings occur.

31. The second line was much less expensive to construct where most expenditure was not classified and the remainder was spent on level crossings.

Figure 15
Allocation of costs for upgrade projects in Finland

32. Figure 21 demonstrates the upgrade projects:
   • Railway project Seinäjoki–Oulu;
   • Railway project Huopalahti-Vantaankoski;
   • Railway project Lahti-Luumaki.

33. The most expensive is the first project and most of its costs are not classified. Construction of stations is the costliest element of the Lahti-Luumaki project. Minor funds were spent on bridges or viaducts level crossings and over or underpasses. The second project is significantly less costly and except for the cost of stations the costs are unclassified. In the third project there are stations level crossings and over or underpasses. Other costs are unclassified.

D. Poland

34. Poland has responded to version A of the questionnaire providing the costs of different categories of infrastructure elements. Version B of the questionnaire is covered in the TER section.

35. The Polish rail infrastructure manager PKP Polskie Linie Kolejowe S.A. has been implementing the largest programme of railway upgrades in recent years. Therefore the upgrade component has been achieved.
<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>V=120</th>
<th>120&lt;V≤160 km/h</th>
<th>160&lt;V≤200 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatory work (removal of trees and bushes, demolition etc.) (US$/unit)</td>
<td>26.61</td>
<td>26.61</td>
<td>26.61</td>
</tr>
<tr>
<td>Earthwork (US$/m²)</td>
<td>14.49</td>
<td>14.49</td>
<td>14.49</td>
</tr>
<tr>
<td>Track and track bed (US$/km)</td>
<td>306 804.28</td>
<td>336 262.65</td>
<td>353 159.80</td>
</tr>
<tr>
<td>One-sided turnout (US$/unit)</td>
<td>63 862.84</td>
<td>86 755.14</td>
<td>93 333.33</td>
</tr>
<tr>
<td>Diamond crossing turnout (US$/unit)</td>
<td>61 594.20</td>
<td>61 594.20</td>
<td>n/a</td>
</tr>
<tr>
<td>Prestressed concrete turnout sleepers (US$/m)</td>
<td>45.86</td>
<td>45.86</td>
<td>45.86</td>
</tr>
<tr>
<td>Timber turnout sleepers (US$/m³)</td>
<td>579.71</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Traction electric power engineering (US$/km)</td>
<td>181 723.77</td>
<td>360 827.30</td>
<td>360 827.30</td>
</tr>
<tr>
<td>Removal of wired infrastructure collision (US$/km)</td>
<td>99 577.86</td>
<td>99 577.86</td>
<td>99 577.86</td>
</tr>
<tr>
<td>Steel bridges (US$/m)</td>
<td>33 497.50</td>
<td>33 497.50</td>
<td>33 497.50</td>
</tr>
<tr>
<td>Composite bridges (US$/m)</td>
<td>33 869.27</td>
<td>33 869.27</td>
<td>33 869.27</td>
</tr>
<tr>
<td>Reinforced concrete bridges (US$/m)</td>
<td>22 345.58</td>
<td>22 345.58</td>
<td>22 345.58</td>
</tr>
<tr>
<td>Single tube tunnels (US$/m)</td>
<td>25 217.39</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Twin tube tunnels (US$/m)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Underwater tunnels (US$/m)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Viaducts (US$/m)</td>
<td>48 772.56</td>
<td>48 772.56</td>
<td>48 772.56</td>
</tr>
<tr>
<td>Culverts (US$/m)</td>
<td>7 404.16</td>
<td>7 404.16</td>
<td>7 404.16</td>
</tr>
<tr>
<td>Retaining structures (US$/m³)</td>
<td>266.23</td>
<td>266.23</td>
<td>266.23</td>
</tr>
<tr>
<td>Passive level crossings (US$/unit)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Active level crossings - manual (US$/unit)</td>
<td>279 590.83</td>
<td>279 590.83</td>
<td>n/a</td>
</tr>
<tr>
<td>Active level crossings - automatic with user-side warning (US$/unit)</td>
<td>367 980.29</td>
<td>367 980.29</td>
<td>n/a</td>
</tr>
<tr>
<td>Active level crossings - automatic with user-side protection (US$/unit)</td>
<td>337 037.32</td>
<td>337 037.32</td>
<td>n/a</td>
</tr>
<tr>
<td>Active level crossings - rail-side protected (US$/unit)</td>
<td>231 336.66</td>
<td>231 336.66</td>
<td>n/a</td>
</tr>
<tr>
<td>Pedestrian passages - footbridges (US$/m)</td>
<td>9 181.56</td>
<td>9 181.56</td>
<td>9 181.56</td>
</tr>
<tr>
<td>Pedestrian passages - tunnels (US$/m)</td>
<td>27 698.61</td>
<td>27 698.61</td>
<td>n/a</td>
</tr>
<tr>
<td>Ecopassages (US$/m)</td>
<td>5 779.63</td>
<td>5 779.63</td>
<td>5 779.63</td>
</tr>
<tr>
<td>Standard platforms, height ≤ 76 cm (US$/m)</td>
<td>931.68</td>
<td>931.68</td>
<td>931.68</td>
</tr>
<tr>
<td>Other platforms (US$/m)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Elevators (US$/unit)</td>
<td>59 202.36</td>
<td>59 202.36</td>
<td>59 202.36</td>
</tr>
<tr>
<td>Escalators (US$/unit)</td>
<td>220 025.51</td>
<td>220 025.51</td>
<td>220 025.51</td>
</tr>
<tr>
<td>Signalling systems (US$/km)</td>
<td>499 797.28</td>
<td>499 797.28</td>
<td>528 782.79</td>
</tr>
<tr>
<td>Signal boxes (US$/unit)</td>
<td>727 147.88</td>
<td>727 147.88</td>
<td>727 147.88</td>
</tr>
<tr>
<td>Telecommunications and IT (US$/km)</td>
<td>63 526.23</td>
<td>63 526.23</td>
<td>63 526.23</td>
</tr>
<tr>
<td>Passenger information systems (US$/unit)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Lighting installations (US$/unit)</td>
<td>831.09</td>
<td>831.09</td>
<td>831.09</td>
</tr>
</tbody>
</table>
The figure demonstrates five types of infrastructure element expressed in USD $/km:
- telecommunications and IT;
- removal of wired infrastructure collision;
- traction electric power engineering;
- track and track bed;
- signalling systems.

The most expensive category is the signalling system and the cost is irrelevant to the speed. The cost of the signalling system increases by 5.8 per cent (approx. 30 000 USD $) only for the highest speed.

The cost of track and track bed increases by 9.6 per cent and 5 per cent respectively for higher speeds.

The case of traction electric power engineering is noteworthy as the cost of this work is half as much for speeds lower than 120 km/h.

The figure reveals that the cost of Information Technology as well as that related to the removal of wired infrastructure collision is at the same level for all speed categories.
41. The figure demonstrates eleven categories expressed in US $/m:
   • prestressed concrete turnout sleepers;
   • standard platforms height≤76 cm;
   • eco-passages;
   • culverts;
   • pedestrian passages – footbridges;
   • reinforced concrete bridges;
   • single tube tunnels;
   • pedestrian passages – tunnels;
   • steel bridges;
   • composite bridges;
   • viaducts.

42. The cheapest categories are prestressed concrete turnout sleepers and standard platforms. The most expensive are viaducts bridges and tunnels. The cost is irrelevant to the speed.

Figure 18
Cost of upgrades of infrastructure elements expressed in US $/unit in Poland

43. Figure 18 demonstrates infrastructure elements expressed in US $/unit:
   • preparatory work (removal of trees demolition etc.);
   • lighting installations;
   • elevators;
   • diamond crossing turnouts;
   • one-sided turnouts;
   • escalators;
   • active level crossings – rail-side protected;
   • active level crossings – manual;
   • active level crossings – automatic with user-side protection;
• active level crossings – automatic with user-side warning;
• signal boxes.

44. Except for one-sided turnouts there is no relationship between cost and speed.
45. The lowest share of cost is for preparatory work and lighting installation whilst the greatest share is for signal boxes.

Figure 19
Cost of upgrades of infrastructure elements expressed in US $/m³ in Poland

46. Three elements are expressed in US $/m³:
• earthwork;
• retaining structures;
• timber turnout sleepers.

47. None of the costs are dependent on the speed. The graphs demonstrate that the cost of most of the elements does not depend on the speed designed for a specific line.

E. Serbia

48. Serbia has provided information about new construction and upgrades.
Table 8
Projects implemented in Serbia

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Start date*</th>
<th>End date**</th>
<th>Construction costs of the project (year)</th>
<th>Currency</th>
<th>Line speed design (km/h)</th>
<th>Rail work type</th>
<th>Type of line of tracks</th>
<th>Number of tracks</th>
<th>Costs of tunnels/bridges/viaducts</th>
<th>Costs of level crossings</th>
<th>Costs of stations</th>
<th>Costs of over/underpasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of a new bridge over the Velika Morava section Gilje-Čuprija-Paracin</td>
<td>23/04/2014</td>
<td>07/05/2015</td>
<td>161.29 USD</td>
<td>USD</td>
<td>120&lt;V≤160</td>
<td>new</td>
<td>construction</td>
<td>2</td>
<td>0</td>
<td>10 002 161</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction and modernization of sections Gilje - Čuprija - Paracin - construction works</td>
<td>11/02/2013</td>
<td>10/08/2014</td>
<td>173.41 USD</td>
<td>USD</td>
<td>120&lt;V≤160</td>
<td>new</td>
<td>construction</td>
<td>2</td>
<td>20 779 452</td>
<td>0</td>
<td>0</td>
<td>2 235 721</td>
</tr>
<tr>
<td>Construction of the second track of the railway Belgrade - Pancevo</td>
<td>12/03/2014</td>
<td>24/02/2017</td>
<td>473.58 USD</td>
<td>USD</td>
<td>120&lt;V≤160</td>
<td>new</td>
<td>construction</td>
<td>2</td>
<td>59 737 898</td>
<td>0</td>
<td>21 314 347</td>
<td>929 716 762 942</td>
</tr>
<tr>
<td>Reconstruction and modernization sections Batajnica - Golubinci</td>
<td>08/12/2008</td>
<td>01/11/2009</td>
<td>110.05 USD</td>
<td>USD</td>
<td>V&lt;120</td>
<td>upgrade</td>
<td>electrified</td>
<td>2</td>
<td>18 850 110</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction of the northern section of Corridor X</td>
<td>19/02/2015</td>
<td>30/10/2015</td>
<td>716.71 USD</td>
<td>USD</td>
<td>V&lt;120</td>
<td>upgrade</td>
<td>electrified</td>
<td>2</td>
<td>10 749 929</td>
<td>0</td>
<td>0</td>
<td>21 788 00 00 00</td>
</tr>
<tr>
<td>Project Description</td>
<td>Start date*</td>
<td>End date**</td>
<td>Construction costs of the project</td>
<td>Currency (year)</td>
<td>Line speed design</td>
<td>Rail work type</td>
<td>Type of line of tracks</td>
<td>Number</td>
<td>Others</td>
<td>Costs of tunnels/bridges/viaducts</td>
<td>Costs of level crossings</td>
<td>Costs of stations</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>----------------------------------</td>
<td>-----------------</td>
<td>------------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>---------</td>
<td>--------</td>
<td>-------------------------------</td>
<td>------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Reconstruction of the northern section of Corridor X - Mala Krsna - Ruma</td>
<td>14/10/2014</td>
<td>01/06/2016</td>
<td>2016 17 275 473.77 USD</td>
<td>EUR 17 275 473.77</td>
<td>V&lt;120 upgrade electrified</td>
<td>1 17 190 756</td>
<td>0</td>
<td>0</td>
<td>84 718</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction of the northern section of Corridor X - Velika Planina</td>
<td>06/12/2013</td>
<td>02/09/2015</td>
<td>2015 10 106 360.79 USD</td>
<td>EUR 10 106 360.79</td>
<td>V&lt;120 upgrade electrified</td>
<td>1 9 853 154</td>
<td>0</td>
<td>0</td>
<td>253 207</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction of the southern section of Corridor X - Vinarce- Leskovac</td>
<td>10/11/2015</td>
<td>23/04/2017</td>
<td>2017 9 220 175.19 EUR</td>
<td>EUR 9 220 175.19</td>
<td>V&lt;120 upgrade electrified</td>
<td>1 8 755 886</td>
<td>0</td>
<td>0</td>
<td>464 289</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction of the southern section of Corridor X - Vranjska - Banja - Ristovac</td>
<td>20/05/2016</td>
<td>14/03/2017</td>
<td>2017 11 770 951.52 USD</td>
<td>EUR 11 770 951.52</td>
<td>V&lt;120 upgrade electrified</td>
<td>1 11 488 900</td>
<td>0</td>
<td>0</td>
<td>282 052</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reconstruction of the southern section of Corridor X - Golubinci - Ruma</td>
<td>20/04/2016</td>
<td>14/03/2017</td>
<td>2017 8 356 499.41 USD</td>
<td>EUR 8 356 499.41</td>
<td>V&lt;120 upgrade electrified</td>
<td>1 8 275 721</td>
<td>0</td>
<td>0</td>
<td>80 779</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Project</td>
<td>Start date*</td>
<td>End date**</td>
<td>Construction costs of project</td>
<td>Currency (year)</td>
<td>Line speed design</td>
<td>Rail work type</td>
<td>Type of line of tracks</td>
<td>Number</td>
<td>Costs of tunnels/bridges/viaducts</td>
<td>Costs of level crossings</td>
<td>Costs of stations</td>
<td>Costs of over/underpasses</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>--------------------------------</td>
<td>----------------</td>
<td>-------------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>--------------------------</td>
<td>-----------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Bujanovac-Bukarevac</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
49. This figure refers to the new construction projects:
   • Construction of a new bridge over the Velika Morava section Gilje-Ćuprija-Paraćin;
   • Reconstruction and modernization of sections Gilje - Ćuprija - Paraćin - construction works;
   • Construction of the second track of the railway Belgrade – Pancevo.

50. For the last two projects ‘others’ are the most expensive elements whilst amongst the named costs over/underpasses are the most significant.
Figure 21

Allocation of costs for upgrade projects in Serbia

Figure 21 demonstrates the allocation of costs for the upgrade projects implemented in Serbia:

- Reconstruction and modernization sections Batajnica - Golubinci;
- Reconstruction of the northern section of Corridor X - Golubinci-Ruma;
- Reconstruction of the northern section of Corridor X - Mala Krsna-Velika Plana;
- Reconstruction of the northern section of Corridor X - Sopot Kosmajski-Kovačevac;
- Reconstruction of the southern section of Corridor X - Vinarce-Leskovac-Đorđevo;
- Reconstruction of the southern section of Corridor X - Vranjska Banja-Ristovac;
- Reconstruction of the southern section of Corridor X - Bujanovac-Bukarevac;
- Reconstruction of the Belgrade-Vrbnica railway section Resnik - Valjevo (Phase 1);
- Rehabilitation of the railway track in the length of 1.3 km from Ćuprija to Paraćin and construction of a new track in the length of 1.8 km from Zmić to Paraćin.

They were divided into costs of the upgrade of over/underpasses stations level crossings bridges and viaducts. The remainder of the costs were classified as ‘others’ which for three projects constitute the most significant of all costs. For four other projects the level crossings are the most expensive elements. For the first two – costs of bridges and viaducts.

F. Slovenia

Slovenia has completed both parts of the questionnaire providing the costs of particular elements of infrastructure and of a project of reconstruction and modernisation.
Table 9
Cost of infrastructure elements for upgrade in Slovenia

<table>
<thead>
<tr>
<th>Element</th>
<th>Cost (US$/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>removal of wired infrastructure collision</td>
<td>$20 121.30</td>
</tr>
<tr>
<td>telecommunications and IT</td>
<td>$63 840.00</td>
</tr>
<tr>
<td>earthwork</td>
<td>$243 985.84</td>
</tr>
<tr>
<td>traction electric power engineering</td>
<td>$311 982.89</td>
</tr>
<tr>
<td>signalling systems</td>
<td>$532 000.00</td>
</tr>
<tr>
<td>track and track bed</td>
<td>$693 685.44</td>
</tr>
<tr>
<td>other platforms</td>
<td>$260 68.88</td>
</tr>
<tr>
<td>standard platforms (height≤76 cm)</td>
<td>$955 47.91</td>
</tr>
<tr>
<td>culverts</td>
<td>$3 439.91</td>
</tr>
<tr>
<td>retaining structures</td>
<td>$5 234.88</td>
</tr>
<tr>
<td>pedestrian passages - footbridges</td>
<td>$5 640.26</td>
</tr>
<tr>
<td>viaducts</td>
<td>$14 342.72</td>
</tr>
<tr>
<td>reinforced concrete bridges</td>
<td>$14 672.56</td>
</tr>
<tr>
<td>pedestrian passages - tunnels</td>
<td>$15 100.29</td>
</tr>
<tr>
<td>preparatory work (removal of trees and bushes)</td>
<td>$17 02.02</td>
</tr>
<tr>
<td>railway stations (excluding facilities for train</td>
<td>$159 60.00</td>
</tr>
<tr>
<td>operations)</td>
<td>($US$/m²)</td>
</tr>
<tr>
<td>prestressed concrete turnout sleepers</td>
<td>$43 62.39</td>
</tr>
<tr>
<td>timber turnout sleepers</td>
<td>$56 39.48</td>
</tr>
<tr>
<td>elevators</td>
<td>$28 196.00</td>
</tr>
<tr>
<td>passenger information systems</td>
<td>$31 920.00</td>
</tr>
<tr>
<td>escalators</td>
<td>$59 392.48</td>
</tr>
<tr>
<td>one-sided turnouts</td>
<td>$112 072.18</td>
</tr>
<tr>
<td>active level crossings – automatic with user-side</td>
<td>$532 000.00</td>
</tr>
<tr>
<td>protection</td>
<td>($US$/unit)</td>
</tr>
</tbody>
</table>

Figure 22
Cost of upgrade of infrastructure elements expressed in US$/km in Slovenia

54. Figure 22 demonstrates infrastructure elements expressed in US$/km:
   - removal of wired infrastructure collision;
   - telecommunications and IT;
   - earthwork;
• traction electric power engineering;
• signalling systems;
• track and track bed.

55. The lowest cost in this category is removal of wired infrastructure collision and telecommunications and IT whilst the most expensive is track and track bed.

Figure 23
Cost of upgrade of infrastructure elements expressed in US$/m in Slovenia

56. Eight infrastructure elements expressed in US$/m are shown in this graph:

- platforms including the standard ones;
- culverts;
- retaining structures;
- pedestrian passages – footbridges;
- viaducts;
- reinforced concrete bridges;
- pedestrian passages - tunnels.

57. The cost of the last three elements is at almost the same level. Amongst all elements expressed in metres the viaducts bridges and tunnels are the most expensive.
The figure represents two elements of which the cost is expressed in US$/m². These are preparatory work and railway stations.

The figure demonstrates the following infrastructure elements expressed in US$/unit:

- prestressed concrete turnout sleepers;
- timber turnout sleepers;
- elevators;
- passenger information systems;
- escalators;
- one-sided turnouts;
- active level crossings – automatic with user-side protection.

The most expensive are level crossings. What is worth emphasising is that escalators are double expensive than elevators.

Project implemented in Slovenia.
62. Slovenia shared the information about the reconstruction and electrification Pragersko - Hodoš and modernisation of level crossings.
Table 10
Cost of project implemented in Slovenia

<table>
<thead>
<tr>
<th>Project</th>
<th>Start date*</th>
<th>End date**</th>
<th>Construction costs of the project</th>
<th>Currency</th>
<th>Prices of (year)</th>
<th>Line speed design</th>
<th>Rail work type</th>
<th>Type of line of tracks</th>
<th>Number of tracks</th>
<th>Others</th>
<th>Costs of bridges/viaducts</th>
<th>Costs of level crossings</th>
<th>Costs of stations</th>
<th>Costs of over/under passes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconstruction and electrification</td>
<td>17/04/2009</td>
<td>05/06/2016</td>
<td>Pragersko - Hodoš and modernisation of level crossings</td>
<td>414 930 712</td>
<td>USD 2016</td>
<td>120&lt;V ≤160 km/h upgrade electrified</td>
<td>1</td>
<td>309 408 042</td>
<td>5 420 029</td>
<td>8 801 713</td>
<td>89 170 610</td>
<td>2 130 318</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


63. In the project Pragersko - Hodoš apart from the other cost the most expensive one was the construction of stations. Also cost of level crossings bridges and viaducts occurs. The least expensive are over or underpasses.

G. Türkiye

64. Türkiye has completed both parts of the questionnaire providing the costs of elements of infrastructure.
Table 11
Cost of infrastructure elements for new construction in Türkiye

<table>
<thead>
<tr>
<th>Element</th>
<th>V&lt;120</th>
<th>120&lt;V≤160 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>telecommunications and IT</td>
<td>US$/km</td>
<td></td>
</tr>
<tr>
<td>traction electric power engineering</td>
<td>US$/km</td>
<td></td>
</tr>
<tr>
<td>signalling systems</td>
<td>US$/km</td>
<td></td>
</tr>
<tr>
<td>track and track bed</td>
<td>US$/km</td>
<td></td>
</tr>
<tr>
<td>earthwork</td>
<td>US$/km</td>
<td></td>
</tr>
<tr>
<td>pedestrian passages - footbridges</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>ramps</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>retaining structures</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>sidings</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>railway infrastructure in ports and terminals</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>culverts</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>reinforced concrete bridges</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>single tube tunnels</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>twin tube tunnels</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>viaducts</td>
<td>US$/m</td>
<td></td>
</tr>
<tr>
<td>preparatory work (removal of trees and bushes, demolition etc.) (US$/m²)</td>
<td>US$/m²</td>
<td></td>
</tr>
<tr>
<td>prestressed concrete turnout sleepers</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>passive level crossings</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>lighting installations</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>active level crossings – manual</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>active level crossings – automatic with user-side warning</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>active level crossings – automatic with user-side protection</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>one-sided turnout</td>
<td>US$/unit</td>
<td></td>
</tr>
<tr>
<td>diamond crossing turnout</td>
<td>US$/unit</td>
<td></td>
</tr>
</tbody>
</table>

Figure 27
Cost of new construction of infrastructure elements expressed in US $/km in Türkiye

Figure 27 demonstrates costs expressed in US $/km:
- telecommunications and IT;
- traction electric power engineering;
- signalling systems;

65.
• track and track bed;
• earthwork.

66. All of these costs increase with higher speeds. The most visible difference is for traction electric power engineering and track and track bed.

Figure 28
Cost of new construction of infrastructure elements expressed in US $/m in Türkiye

67. The figure represents the following infrastructure elements of which the cost is expressed in US $/m:
• pedestrian passages – footbridges;
• ramps;
• retaining structures;
• sidings;
• railway infrastructure in ports and terminals;
• culverts;
• reinforced concrete bridges;
• single tube tunnels;
• twin tube tunnels;
• viaducts.

68. This is another example of higher costs for higher speed projects. The only exception is railway infrastructure in ports and terminals in which the cost for both speed ranges is equal.

Figure 29
Cost of new construction of infrastructure elements expressed in US $/m² in Türkiye
69. One infrastructure element is measured in US $/m² and price and speed do not correlate.

Figure 30
Cost of new construction of infrastructure elements expressed in US $/unit

70. This figure demonstrates elements expressed in US $/unit:

- prestressed concrete turnout sleepers;
- passive level crossings;
- lighting installations;
- active level crossings – manual;
- active level crossings – automatic with user-side warning;
- active level crossings – automatic with user-side protection;
- one-sided turnouts;
- diamond crossing turnouts.

71. The costs of many elements are equal for the construction of new infrastructure for speeds between 120 and 160 km/h in comparison with speeds less than 120 km/h. However three categories represent higher costs for higher speed. This is the case for sleepers and turnouts.

72. Projects implemented in Türkiye:

Table 12
Cost of projects implemented in Türkiye

<table>
<thead>
<tr>
<th>Project</th>
<th>Start date</th>
<th>End date</th>
<th>Construction cost of the project (USD)</th>
<th>Currency</th>
<th>Low speed design</th>
<th>Rail net type</th>
<th>Type of line</th>
<th>Number of tracks</th>
<th>Length of the project (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baku–Baku Hcre Railway Project</td>
<td>2007</td>
<td>2012</td>
<td>467 274 000</td>
<td>2016 V≤120</td>
<td>new construction</td>
<td>electrified</td>
<td>2</td>
<td>60,145</td>
<td></td>
</tr>
<tr>
<td>Armutluçeşme CB Railway Project</td>
<td>2007</td>
<td>2016</td>
<td>48 000 000</td>
<td>2016 V≤160</td>
<td>new construction</td>
<td>non-electrified</td>
<td>1</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Erzincan–Hızırca Railway Project</td>
<td>2007</td>
<td>2012</td>
<td>60 000 000</td>
<td>2016 V≤160</td>
<td>new construction</td>
<td>non-electrified</td>
<td>1</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
73. Since 2007 Türkiye has implemented two new construction projects and one remains in progress:

- Baku-Tbilisi-Kars Railway Project;
- Kemalpaşa OSB Railway Project;
- Tekirdağ-Muratlı Railway Project.

74. The difference between the project in progress and the two completed is that the former is electrified and double-tracked whereas the latter are not. The cost of the project in progress is much higher when its length is accounted for.

II. Bulgaria, Poland, Slovenia

75. Taking into account that all these countries have provided information on the cost of upgrades for speeds between 120 and 160 km/h this data was able to be compared.

Table 13
Cost of infrastructure elements for upgrade in Bulgaria, Poland and Slovenia

<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>120&lt;V≤160 km/h</th>
<th>120&lt;V≤160 km/h</th>
<th>120&lt;V≤160 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>telecommunications and IT</td>
<td>US$/km</td>
<td>192 250 58</td>
<td>63 526 23</td>
</tr>
<tr>
<td>signalling systems</td>
<td>US$/km</td>
<td>340 876 53</td>
<td>499 797 28</td>
</tr>
<tr>
<td>traction electric power engineering</td>
<td>US$/km</td>
<td>347 610 33</td>
<td>360 827 30</td>
</tr>
<tr>
<td>track and track bed</td>
<td>US$/km</td>
<td>1 207 548 78</td>
<td>336 262 65</td>
</tr>
<tr>
<td>removal of wired infrastructure</td>
<td>US$/km</td>
<td>99 577 86</td>
<td>20 121 30</td>
</tr>
<tr>
<td>railway infrastructure collision</td>
<td>US$/km</td>
<td></td>
<td>99 577 86</td>
</tr>
<tr>
<td>railway infrastructure in ports and terminals</td>
<td>US$/m</td>
<td>477 54</td>
<td>-</td>
</tr>
<tr>
<td>reinforced concrete bridges</td>
<td>US$/m</td>
<td>13 431 79</td>
<td>22 345 58</td>
</tr>
<tr>
<td>single tube tunnels</td>
<td>US$/m</td>
<td>17 230 11</td>
<td>-</td>
</tr>
<tr>
<td>twin tube tunnels</td>
<td>US$/m</td>
<td>20 691 60</td>
<td>-</td>
</tr>
<tr>
<td>railway stations (excluding facilities for</td>
<td>US$/m²</td>
<td>523 37</td>
<td>159 60</td>
</tr>
<tr>
<td>train operations)</td>
<td>US$/unit</td>
<td>39 769 62</td>
<td>86 755 14</td>
</tr>
<tr>
<td>one-sided turnouts</td>
<td>US$/unit</td>
<td>65 463 61</td>
<td>59 202 36</td>
</tr>
<tr>
<td>elevators</td>
<td>US$/unit</td>
<td>94 132 93</td>
<td>220 025 51</td>
</tr>
</tbody>
</table>
Figure 32
Comparison of upgrade of infrastructure elements expressed in US$/km in Bulgaria, Poland and Slovenia

Figure 33
Comparison of upgrade of infrastructure elements expressed in US$/m in Bulgaria, Poland and Slovenia
Figure 34
Comparison of upgrade of infrastructure elements expressed in US$/unit in Bulgaria Poland and Slovenia

<table>
<thead>
<tr>
<th>Infrastructure Element</th>
<th>Bulgaria</th>
<th>Poland</th>
<th>Slovenia</th>
</tr>
</thead>
<tbody>
<tr>
<td>one-sided turnouts</td>
<td>50,000</td>
<td>100,000</td>
<td>150,000</td>
</tr>
<tr>
<td>elevators</td>
<td>100,000</td>
<td>150,000</td>
<td>200,000</td>
</tr>
<tr>
<td>escalators</td>
<td>200,000</td>
<td>250,000</td>
<td>300,000</td>
</tr>
</tbody>
</table>

76. Telecommunications and IT (almost the same values in Poland and Slovenia) as well as track and track bed are significantly more expensive in Bulgaria whereas reinforced concrete bridges (comparable values in Bulgaria and Slovenia) and especially escalators are much more expensive in Poland. Slovenia has only one element which is significantly more expensive – one-sided turnouts this element is the cheapest in Bulgaria. Signalling systems are also the cheapest elements in Bulgaria. In Poland and Slovenia this value is comparable.

The cost of traction electric power engineering is comparable in all countries. The cost of elevators is comparable in Bulgaria and Poland whilst double cheaper in Slovenia. Removal of wired infrastructure collision can be compared only in Poland and Slovenia – it is more expensive in Poland.

77. This section has been developed according to the data collected amongst countries participating in the ECO-ECE-ISdB GIS project.
I. Azerbaijan

Table 14
Cost of projects in Azerbaijan and their length

78. Azerbaijan has shared information on five projects including the construction of two new railway lines:

- New railway line Baku-Tabilisi-Kars (BTK) (renewal);
- Marabda-Akhalkali railway section (renewal);
- Akhalkali railway station (renewal);
- Akhalkali-Kartsakhi section (new construction);
- New railway line Astara (Azerbaijan) - Astara (Iran) (new construction).

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Cost of project in USD</th>
<th>Length of the project in km</th>
<th>Number of bridges in the project</th>
<th>Number of culverts in the project</th>
<th>Cost of railway/bridge/signal/alignment in USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>New railway line Baku-Tabilisi-Kars (BTK) (renewal)</td>
<td>1,250,000,000</td>
<td>267</td>
<td>3</td>
<td>25</td>
<td>35,250,000</td>
</tr>
<tr>
<td>Marabda-Akhalkali railway section (renewal)</td>
<td>1,000,000,000</td>
<td>156</td>
<td>2</td>
<td>15</td>
<td>30,147,000</td>
</tr>
<tr>
<td>Akhalkali-Kartsakhi section (new construction)</td>
<td>1,000,000,000</td>
<td>32</td>
<td>2</td>
<td>21</td>
<td>32,168,000</td>
</tr>
<tr>
<td>New railway line Astara (Azerbaijan) - Astara (Iran) (new construction)</td>
<td>250,000,000</td>
<td>15.5</td>
<td>1</td>
<td>5</td>
<td>25,000,000</td>
</tr>
</tbody>
</table>
Figure 35
Cost of the projects in Azerbaijan vs. length

- New railway line Baku-Tabilisi-Kars (BTK) [renewal]
- Marabda-Akhalkali railway section [renewal]
- Akhalkali railway station [renewal]
- Akhalkali-Kartsakhki section [new construction]
- New railway line Astara (Azerbaijan) - Astara (Iran) [new construction]
78. 79. The cost of particular projects is not proportional to their lengths however. The most efficient in this regard is the renewal of Marabda-Akhalkali railway section.

Figure 36
Cost of 1 km of rail tracks in Azerbaijan vs. cost of tunnels

80. As an example the cost of one km of track and tunnel were compared. The cost of the tunnel is about ten times higher than cost of track.

J. Kazakhstan

81. Kazakhstan has sent information about several large-scale projects – mostly pertaining to the construction of infrastructure:

- Construction of the "Uzen-State Border of Republic of Turkmenistan" railway line;
- Construction of the new "Zhetygen-Korgas State Border of Republic of Kazakhstan" railway line;
- Construction of the new "Zhezkazgan-Beyneu" railway line;
- Construction of the new "Arkalyk-Shubarkul" railway line;
- Construction of the new "Borzhakty-Ersay" railway line;
- Construction of the "Almaty 1-Shu" second track line;
- Construction of the ferry complex at Kuryk Port and operation of standardized passenger ferries;
- Development of the Astana railway station including the construction of railway platform and facilities.

Table 15
Cost of projects implemented in Kazakhstan

<table>
<thead>
<tr>
<th>Project</th>
<th>Currency (Kazakhstan Tenge)</th>
<th>Costs of rails, bridges and tunnels</th>
<th>Costs of construction of stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of the &quot;Uzen-State Border of Republic of Turkmenistan&quot; railway line</td>
<td>1,165,081</td>
<td>543,735</td>
<td>561,347</td>
</tr>
<tr>
<td>Construction of the new &quot;Zhetygen-Korgas State Border of Republic of Kazakhstan&quot; railway line</td>
<td>3,034,022</td>
<td>2,066,005</td>
<td>968,018</td>
</tr>
<tr>
<td>Construction of the new &quot;Zhezkazgan-Beyneu&quot; railway line</td>
<td>6,614,699</td>
<td>4,205,042</td>
<td>2,509,657</td>
</tr>
<tr>
<td>Construction of the new &quot;Arkalyk-Shubarkul&quot; railway line</td>
<td>1,409,163</td>
<td>815,791</td>
<td>593,372</td>
</tr>
<tr>
<td>Construction of the new &quot;Borzhakty-Ersay&quot; railway line</td>
<td>61,811</td>
<td>25,773</td>
<td>36,038</td>
</tr>
<tr>
<td>Construction of the &quot;Almaty 1-Shu&quot; second track line</td>
<td>329,793</td>
<td>329,793</td>
<td>0</td>
</tr>
<tr>
<td>Project: &quot;Construction of the ferry complex at Kuryk Port and operation of standardized passenger ferries.&quot;</td>
<td>732,931</td>
<td>15,718</td>
<td>717,213</td>
</tr>
<tr>
<td>Project: &quot;Development of the Astana railway station, including the construction of railway platform and facilities&quot;</td>
<td>1,800,897</td>
<td>0</td>
<td>1,800,897</td>
</tr>
</tbody>
</table>
81. 82. The most expensive is the construction of the new "Zhezkazgan-Beyneu" railway line. A large part of this cost is allocated to the construction of stations.

Table 16
Cost of modernisation of infrastructure in Kazakhstan in 2007-2016 and total length of the projects

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>27 248 184</td>
<td>31 846 217</td>
<td>17 006 263</td>
<td>36 162 690</td>
<td>43 300 265</td>
<td>67 487 938</td>
<td>51 659 136</td>
<td>57 883 206</td>
<td>59 602 347</td>
<td>33 623 567</td>
</tr>
<tr>
<td>Capital / spent upon state-validated feasibility studies</td>
<td>25 795 773</td>
<td>25 255 379</td>
<td>24 392 582</td>
<td>29 497 732</td>
<td>24 199 301</td>
<td>42 228 276</td>
<td>29 800 204</td>
<td>43 900 205</td>
<td>14 122 527</td>
<td>29 622 815</td>
</tr>
<tr>
<td>Capital / spent (101)</td>
<td>45 400</td>
<td>1 722 056</td>
<td>204 961</td>
<td>449 209</td>
<td>3 018 502</td>
<td>11 688 030</td>
<td>2 637 281</td>
<td>1 301 436</td>
<td>183 523</td>
<td>339 494</td>
</tr>
<tr>
<td>Modernization of railway crossings</td>
<td>26 780</td>
<td>16 517</td>
<td>27 459</td>
<td>0</td>
<td>0</td>
<td>13 622</td>
<td>98 908</td>
<td>101 985</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Renewal of equipment</td>
<td>1 055 653</td>
<td>5 223 925</td>
<td>2 819 945</td>
<td>6 166 867</td>
<td>8 102 863</td>
<td>12 570 959</td>
<td>9 441 976</td>
<td>10 936 196</td>
<td>5 401 304</td>
<td>4 440 128</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>2007 km</th>
<th>2008 km</th>
<th>2009 km</th>
<th>2010 km</th>
<th>2011 km</th>
<th>2012 km</th>
<th>2013 km</th>
<th>2014 km</th>
<th>2015 km</th>
<th>2016 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>578</td>
<td>467</td>
<td>528</td>
<td>668</td>
<td>652</td>
<td>652</td>
<td>659</td>
<td>313</td>
<td>380</td>
<td>380</td>
</tr>
</tbody>
</table>
Figure 38
Data on modernisation of infrastructure in Kazakhstan in 2007-2016 and total length of the projects

83. Figure 38 demonstrates that the cost of the projects is coherent with their lengths.

K. Tajikistan

84. Tajikistan shared the information about three projects:
   • Rehabilitation / Improvement of Rohri – Sibi Section;
   • Rehabilitation / Improvement of Sibi– Spezand Section;
   • Rehabilitation / Improvement of Spezand – Taftan Section.

Table 17
Cost of projects implemented in Tajikistan

<table>
<thead>
<tr>
<th>Project</th>
<th>Construction cost of the project</th>
<th>Cost of rails</th>
<th>Cost of tunnels</th>
<th>Cost of bridge works</th>
<th>Cost of level crossings</th>
<th>Cost of seismic protection</th>
<th>Cost of final adjustments</th>
<th>Total length of the project in km</th>
<th>Length of the project excluding bridges and tunnels in km</th>
<th>Length of bridge in km</th>
<th>Length of tunnel in km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitation / Improvement of Rohri – Sibi Section</td>
<td>345 000 000</td>
<td>259 000 000</td>
<td>0</td>
<td>54 000 000</td>
<td>5 000 000</td>
<td>15 000 000</td>
<td>2 000 000</td>
<td>239,190</td>
<td>231,730</td>
<td>0</td>
<td>7,460</td>
</tr>
<tr>
<td>Rehabilitation / Improvement of Sibi– Spezand Section</td>
<td>496 000 000</td>
<td>253 000 000</td>
<td>114 000 000</td>
<td>67 000 000</td>
<td>60 000 000</td>
<td>9 000 000</td>
<td>1,500 000</td>
<td>116,240</td>
<td>83,149</td>
<td>22,652</td>
<td>10,539</td>
</tr>
<tr>
<td>Rehabilitation / Improvement of Spezand – Taftan Section</td>
<td>560 000 000</td>
<td>359 000 000</td>
<td>40 000 000</td>
<td>37 000 000</td>
<td>1 000 000</td>
<td>22 000 000</td>
<td>1,500 000</td>
<td>629,695</td>
<td>628,230</td>
<td>4,465</td>
<td>5,803</td>
</tr>
</tbody>
</table>
Figure 39
Cost of the projects in Tajikistan (US $)

85. Figure 39 demonstrates that the majority of expenditures were spent on work and material related to tracks. The cost of tunnels bridges and viaducts is also significant. One of the three projects mentioned—the rehabilitation/improvement of the Sibi-Spezand section—is more expensive per km than the two others.

Figure 40
Cost of rail tracks (US $) vs. length

86. In the first and the third project the cost in regard to the length is proportional whilst the cost of the second project is higher when its length is accounted for.

L. Turkmenistan

87. Turkmenistan has submitted information about two projects:

- North-South Railway Project
- Construction of the Bereket-Etrek Railway Project.
III. Trans-European Railway (TER) project

89. For the purpose of works conducted by the Group of Experts on Benchmarking Transport Infrastructure Construction Costs the data of the Trans-European Railway project—which is also run within ECE—has been used. The main objective of the project is to develop a coherent and efficient rail and intermodal transport system connecting Central and Eastern Europe with other European countries. Hence it has been of great importance to have up-to-date knowledge on the development of the TER network. The data presented has been collected since 2012 so that there is knowledge about projects that have been put into operation since 2011 for the purpose of the Annual TER Network Report. It contains basic information – such as the name length and cost of a project. TER classifies projects into two categories: ‘upgrading’ and ‘modernisation’. The use of either term however refers to the same thing – conducting major modification works which improve the overall performance of the infrastructure. For the purpose of this material ‘upgrading’ is used as the primary term. Only a handful of the projects concerned the construction of new infrastructure.

Table 19
Cost of projects put into operation by TER countries in 2011

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLAND</td>
<td>Modernization of C301 line Tamów–Leszczów (Tamów–Stróże section)</td>
<td>13,00</td>
<td>18 092 100,00</td>
<td>1 391 700,00</td>
</tr>
<tr>
<td>SLOVAKIA</td>
<td>Modernization of line Žilina – Krasno nad Kysucou</td>
<td>20,00</td>
<td>225 455 400,00</td>
<td>11 272 770,00</td>
</tr>
<tr>
<td>SLOVENIA</td>
<td>Modernization of line Pečvence – Omež – Project A</td>
<td>40,00</td>
<td>132 211 500,00</td>
<td>3 306 267,50</td>
</tr>
</tbody>
</table>
Three projects were put into operation in 2011:

- Modernization of C30/1 line Tarnów-Lelechów (Tarnów-Stróże section) (Poland);
- Modernization of line Zilina – Krasno nad Kysucou (Slovakia);
- Modernization of line Pragersko – Ormož – Project A (Slovenia).

Slovakia implemented relatively expensive project taking into account its length whilst the projects of Poland and Slovenia are not as costly in regard to their length.

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Kufstein-Wörgl-Innsbruck</td>
<td>65.00</td>
<td>3 053 300 000,00</td>
<td>46 973 846,15</td>
</tr>
<tr>
<td>Austria</td>
<td>Wien-St.Pölten</td>
<td>61.00</td>
<td>2 000 393 600,00</td>
<td>32 793 337,70</td>
</tr>
<tr>
<td>HERZ</td>
<td>Doboj-Doboj, track overhaul and reconstruction of section Doboj-Jezernica to TER standards</td>
<td>78.00</td>
<td>64 280 000,00</td>
<td>824 102,56</td>
</tr>
<tr>
<td>Poland</td>
<td>Modernization of E80 line (Węgliniec-Zgorzelec, Węgliniec-Legnica sections)</td>
<td>110.00</td>
<td>356 390 000,00</td>
<td>3 330 872,73</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Section Nové Mesto nad Váhom - Zlatovce of the project „Modernization of railway line Nové Mesto nad Váhom - Pičovo“</td>
<td>17.00</td>
<td>338 112 800,00</td>
<td>19 888 988,24</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Railway station Trenčianske Teplice and section Trenčianske Teplice - Baláta of the project „Modernization of railway line Nové Mesto nad Váhom - Pičovo“</td>
<td>20.00</td>
<td>338 112 800,00</td>
<td>16 905 640,00</td>
</tr>
</tbody>
</table>
This figure demonstrates projects put into operation by four countries in 2012:

- Kufstein-Wörgl-Innsbruck (Austria);
- Wien-St. Pölten (Austria);
- Doboj-Dobrljin track overhaul and reconstruction of section Doboj-Josavka to TER standards (Bosnia and Herzegovina);
- Modernization of E30 line (Węgliniec-Zgorzelec Węgliniec-Legnica sections) (Poland);
- Section Nové Mesto nad Váhom - Zlatovce of the project "Modernization of railway line Nové Mesto nad Váhom – Púchov (Slovenia)";
- Railway station Trenčianská Teplá and section Trenčianska Teplá - Beluša of the project "Modernization of railway line Nové Mesto nad Váhom - Púchov (Slovenia)".

The projects of Bosnia and Herzegovina and Poland were implemented at relatively low level of expenditures regarding the length. The projects undertaken by Austria and Slovenia were more costly in this regard.

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLAND</td>
<td>Project and development of ETCS 1 on E65 line (CMK) (Grodzisk Mazowiecki-Zawiercie section)</td>
<td>224,00</td>
<td>17 266 600,00</td>
<td>77 083,04</td>
</tr>
</tbody>
</table>
94. Only one project was put into operation in 2013 – the Polish one - Project and development of a European Train Control System (ETCS) 1 on the E65 line (CMK) (Grodzisk Mazowiecki-Zawiercie section). Its cost is relatively high considering its length.

Table 22
Cost of projects put into operation by TER countries in 2014

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>CZECH REPUBLIC</td>
<td>Modernization of line Bencev - Czeske Budejovice, section C.Budejovice - Nemunice</td>
<td>3.00</td>
<td>59 756 000,00</td>
<td>19 952 000,00</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Upgrading of line State border - Chob - Pleus, section Pleus through line</td>
<td>4.00</td>
<td>77 070 400,00</td>
<td>19 267 600,00</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Upgrading of line Pleus - Praha, section Zlíchov - Polevany</td>
<td>21.00</td>
<td>264 801 200,00</td>
<td>12 591 961,90</td>
</tr>
<tr>
<td>SLOVAKIA</td>
<td>Modernization of line Nove Mesto nad Vahom - Puhlov, section Trenčianska Tepla - Bohus</td>
<td>20.30</td>
<td>384 023 200,00</td>
<td>19 201 160,00</td>
</tr>
<tr>
<td>TURKEY</td>
<td>Ankara-Istanbul High Speed Railway Project</td>
<td>513.00</td>
<td>3 667 888 000,00</td>
<td>7 149 099,40</td>
</tr>
</tbody>
</table>
Figure 45
Cost of projects put into operation by TER countries in 2014 vs. length

95. Five projects were put into operation in 2014:
   - Modernization of line Benesov - Ceske Budejovice section C.Budejovice – Nemanice (Czechia);
   - Upgrading of line State border – Cheb - Plzen section Plzen throughfare (Czechia);
   - Upgrading of line Plzen – Praha section Zbiroh – Rokycany (Czechia);
   - Modernization of line Nove Mesto nad Vahom – Puchov section Trencianska Tepla – Belusa (Slovakia);
   - Ankara-Istanbul High Speed Railway Project (Türkiye).

96. There is a large difference between the project of Türkiye and those of Czechia and Slovakia regarding the cost versus length. The latter ones were more costly concerning their length.

Table 23
Cost of projects put into operation by TER countries in 2015

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUSTRIA</td>
<td>Modernization of line Benesov - Ceske Budejovice section C.Budejovice – Nemanice</td>
<td>12.00</td>
<td>132,042,000.00</td>
<td>11,005,333,33</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Upgrading of line State border – Cheb - Plzen section Plzen throughfare</td>
<td>9.00</td>
<td>52,088,000.00</td>
<td>7,915,111,11</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>Upgrading of line Plzen – Praha section Zbiroh – Rokycany (Czechia)</td>
<td>30.00</td>
<td>12,205,000.00</td>
<td>3,212,000.00</td>
</tr>
<tr>
<td>AUSTRIA</td>
<td>Modernization of line Nove Mesto nad Vahom – Puchov section Trencianska Tepla – Belusa (Slovakia)</td>
<td>45.00</td>
<td>2,475,408,000.00</td>
<td>30,007,111,11</td>
</tr>
<tr>
<td>TURKEY</td>
<td>Ankara-Istanbul High Speed Railway Project (Türkiye)</td>
<td>10.00</td>
<td>2,411,200.00</td>
<td>1,512,750.00</td>
</tr>
</tbody>
</table>

212
In 2015 the projects were much more numerous:

- Gloggnitz – Murzzuschlag (Austria);
- Wernstein – state border construction (Austria);
- Stadlau – state border electrification planning (Austria);
- Kundl – Radfeld – Baumkirchen (4-track Unterinntal project) (Austria);
- Schlossbachgraben – Angertal (Austria);
- Rehabilitation of Doboj – Sarajevo line section Podlugovi – Sarajevo (Bosnia and Herzegovina);
- Modernization of line Benesov - Ceske Budejovice (Czechia);
- Upgrading of line State border – Cheb phase 1 (Czechia);
- Modernization of signalling and power supply sections Palemonas – Rokai and Kaunas – Kybertai (Lithuania);
- Construction of 2nd track on Kulupenai – Kretinga line (Lithuania);
- Construction of 2nd track on Pavenciai – Raudenai line (Lithuania);
- Construction of 2nd track on Telsiai – Duseikiai line (Lithuania);
- Construction of new standard gauge (Rail Baltica) line on border crossing sections (Lithuania);
- Modernization of E65/CE65 line section Warszawa – Gdynia LCS Ciechanow (Poland);
- Modernization of E65/CE65 line section Warszawa – Gdynia LCS Ilawa LCS Malbork (Poland);
- Modernization of E65/CE65 line section Warszawa – Gdynia LCS Gdansk LCS Gdynia (Poland).

Approximately two thirds of these projects are cost efficient when their length is accounted for. The most advantageous in this regard one the project of Lithuania on modernisation of signalling and power supply. A modernisation project of Poland is outstanding but also the Austrian one the scope of which is planning of work. The most expensive in regard to length is the other projects of Austria and Lithuania.
Table 24
Cost of projects put into operation by TER country - Bulgaria - in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>BULGARIA</td>
<td>Electrification and upgrading of Plovdiv – Svilengrad line Phase I and II</td>
<td>141</td>
<td>406,122,200</td>
<td>2,880,299</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>Electrification and upgrading of Svilengrad – Turkish border line</td>
<td>18</td>
<td>47,583,800</td>
<td>2,643,544</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>Phase I Rehabilitation of railway infrastructure along sections of the Plovdiv – Burgas railway line</td>
<td>177</td>
<td>270,010,400</td>
<td>1,525,482</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>Modernization of the railway section Septemvri – Plovdiv – part of the TransEuropean railway network</td>
<td>61</td>
<td>175,949,400</td>
<td>2,884,416</td>
</tr>
</tbody>
</table>

Figure 47
Cost of projects put into operation by TER country - Bulgaria - in 2016 vs. length

99. Figure 47 demonstrates projects of Bulgaria put into operation in 2016:
   • Electrification and upgrading of Plovdiv – Svilengrad line Phase I and II;
   • Electrification and upgrading of Svilengrad – Turkish border line;
   • Phase I Rehabilitation of railway infrastructure along sections of the Plovdiv -Burgas railway line;
   • Modernization of the railway section Septemvri – Plovdiv – part of the TransEuropean railway network.

100. Only one project is relatively expensive regarding the length. The other three are more cost efficient in this regard.
Table 25
Cost of projects put into operation by TER country - Czechia - in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>CZECH REPUBLIC</td>
<td>Bystrice nad Olsi – Cesky Tesin, phase II, station Cesky Tesin</td>
<td>2</td>
<td>68 609 200</td>
<td>34 304 600</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Beroun – Plzen – Cheb, introduction of GSM-R system</td>
<td>185</td>
<td>23 238 600</td>
<td>125 614</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Modernization of line Praha – Plzen, section Rohyany - Plzen</td>
<td>282</td>
<td>79 675 200</td>
<td>282 536</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Modernization of line Praha – Česka Trebova, junction Usti nad Orlici</td>
<td>2</td>
<td>58 649 800</td>
<td>29 324 900</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Usti nad Orlici – Letohrad, modernization</td>
<td>13</td>
<td>26 558 400</td>
<td>2 042 954</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Teplice nad Becvou – Hustopece nad Becvou, modernization</td>
<td>8</td>
<td>32 091 400</td>
<td>4 011 425</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Valasske Mezirici – Vsetin – Horni Lidec, modernization</td>
<td>34</td>
<td>33 198 000</td>
<td>976 412</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Brno Mladerice – Brno Zidenice, modernization</td>
<td>3</td>
<td>38 731 000</td>
<td>12 910 333</td>
</tr>
<tr>
<td>CZECH REPUBLIC</td>
<td>Prague Bubeneč – Praha Holesovice, modernization</td>
<td>3</td>
<td>50 903 600</td>
<td>16 967 867</td>
</tr>
</tbody>
</table>

Figure 48
Cost of projects put into operation by TER country - Czechia - in 2016 vs. length

101. There are nine projects put into operation by Czechia in 2016:
  • Bystrice nad Olsi – Cesky Tesin phase II station Cesky Tesin;
  • Beroun – Plzen – Cheb introduction of GSM-R system;
  • Modernization of line Praha – Plzen section;
  • Modernization of line Praha – Česka Trebova;
  • Usti nad Orlici – Letohrad;
  • Teplice nad Becvou – Hustopece nad Becvou modernization;
  • Valasske Mezirici – Vsetin – Horni Lidec modernization;
• Brno Malomerice – Brno Zidenice modernization;
• Praha Bubenec – Praha Holesovice modernization.

102. The cost of four of them is much higher in regard to the length in comparison to the other projects. The project concerning introduction of GSM-R is of relatively low cost in this regard.

Table 26
Cost of projects put into operation by TER country - Poland - in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLAND</td>
<td>Modernization of E30 line (Bielawa Dolna - Horka section), construction of bridge on Nysa Luzycka + electrification, phase II</td>
<td>1</td>
<td>5 533 000</td>
<td>5 000 000</td>
</tr>
<tr>
<td>POLAND</td>
<td>Modernization of E30/CE30 line (Krakow - Rzeszow section), phase III phase I</td>
<td>139</td>
<td>774 620 000</td>
<td>5 035 971</td>
</tr>
<tr>
<td>POLAND</td>
<td>Modernization of E59 line Wroclaw - Poznan, phase III (Czempin - Poznan section) phase I</td>
<td>32</td>
<td>88 528 000</td>
<td>2 500 000</td>
</tr>
<tr>
<td>POLAND</td>
<td>Modernization of E59 line Wroclaw – Poznan, phase II (Wroclaw - Dolnoslaskie Voivodeship border section)</td>
<td>58</td>
<td>240 132 200</td>
<td>3 741 379</td>
</tr>
</tbody>
</table>

103. Poland put four projects into operation in 2016:
• Modernization of E30 line (Bielawa Dolna - Horka section) construction of bridge on Nysa Luzycka + electrification phase II;
• Modernization of E30/CE30 line (Krakow - Rzeszow section) phase III phase I;
• Modernization of E59 line Wroclaw - Poznan phase III (Czempin - Poznan section) phase I;
• Modernization of E59 line Wroclaw – Poznan phase II (Wroclaw - Dolnoslaskie Voivodeship border section).

104. The first one is of relatively high cost when it comes to its length. The other three are cost-efficient when their length is accounted for.
Table 27
Cost of projects put into operation by TER country - Serbia - in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERBIA</td>
<td>Reconstruction of the line Beograd – Sid, section Golubinci – Ruma</td>
<td>18</td>
<td>13 279 200</td>
<td>666 667</td>
</tr>
<tr>
<td>SERBIA</td>
<td>Reconstruction of the single track and construction of the second track on the line Pancicevacki Most - Pancovo Glavna, reconstruction of stations Knjaca, Ovca, Pancovo bridge, construction of the new bridge over Tamis river</td>
<td>15</td>
<td>89 634 600</td>
<td>5 400 000</td>
</tr>
<tr>
<td>SERBIA</td>
<td>Reconstruction of existing track and construction of the second track with the construction of a new bridge on the Velika Morava river</td>
<td>10</td>
<td>46 477 200</td>
<td>4 200 000</td>
</tr>
<tr>
<td>SERBIA</td>
<td>Reconstruction of two sections of rail line Beograd – Nis: Sopot Kosmajski - Kovecevac and Mala Krsna - Velika Plana</td>
<td>48</td>
<td>26 558 400</td>
<td>500 000</td>
</tr>
<tr>
<td>SERBIA</td>
<td>Reconstruction of three sections of rail line Nis – Presevo – FYROM border: Vinarce – Dordevo, Vranjska Banja – Ristovac, Bujanovac – Bulevarac</td>
<td>47</td>
<td>36 517 800</td>
<td>702 128</td>
</tr>
</tbody>
</table>

Figure 50
Cost of projects put into operation by TER country - Serbia - in 2016 vs. length

105. There were five Serbian projects put into operation in 2016:

- Reconstruction of the line Beograd – Sid section Golubinci – Ruma;
- Reconstruction of the single track and construction of the second track on the line Pancicevacki Most - Pancovo Glavna reconstruction of stations Knjaca Ovca Pangcevo bridge construction of the new bridge over Tamis river;
• Reconstruction of existing track and construction of the second track with the construction of a new bridge on the Velika Morava river;

• Reconstruction of two sections of rail line Beograd - Nis: Sopot Kosmajski - Kovacevac and Mala Krsna - Velika Plana;

• Reconstruction of three sections of rail line Nis – Presevo – North Macedonia border: Vinarce – Đorđevo Vranjska Banja – Ristovac Bujanovac – Bukarevac.

106. All of these projects are costly efficient in regard to their length.

Table 28
Cost of projects put into operation by TER countries - Lithuania Slovakia Türkiye - in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Project description</th>
<th>Length (in km)</th>
<th>Construction cost in USD</th>
<th>Cost of 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>LITHUANIA</td>
<td>Construction of second track on Kyviskes – Vaciunai line (Vilnius station bypass)</td>
<td>50</td>
<td>67 502 600</td>
<td>1 350 052</td>
</tr>
<tr>
<td>SLOVAKIA</td>
<td>Modernization of the section Belusa - Puchov</td>
<td>9</td>
<td>96 274 200</td>
<td>10 697 133</td>
</tr>
<tr>
<td>TURKEY</td>
<td>Irmak – Karabuk – Zonguldak, rehabilitation and signalling</td>
<td>415</td>
<td>243 452 000</td>
<td>586 631</td>
</tr>
</tbody>
</table>

Figure 51
Cost of projects put into operation by TER countries - Lithuania Slovakia Türkiye - in 2016 vs. length

107. This figure reveals three projects of different countries put into operation in 2016:

• Construction of second track on Kyviskes – Vaciunai line (Vilnius station bypass) (Lithuania);

• Modernization of the section Belusa – Puchov (Slovakia);
Irmak – Karabuk – Zonguldak rehabilitation and signalling (Türkiye).

108. The project of Türkiye is the costliest efficient in this group of countries whilst the project of Slovakia is the most expensive in regard to the length.

IV. Inland Waterways Costs

109. For the purpose of works conducted by the Group of Experts on Benchmarking Transport Infrastructure Construction Costs data from various European countries that have operational inland waterways has been used. It is greatly important to have up-to-date knowledge on the development of IW network and information on IW ports. In this document we received gathered and analysed data from the following countries: Austria Croatia Czechia Luxemburg Poland and Slovakia. Questionnaire was sent out to public administrations port authorities Harbour Master’s Offices river commissions etc. with inquiry about inland waterways infrastructure and IWW ports infrastructure construction updates and maintenance costs. The data isn’t as extensive and detailed as we had hoped to gather. With that being said our benchmarking analysis is not as thorough as the Group intended it to be; most of the data provided by enumerated countries is unfortunately incomparable.

Table 29
Maintenance costs of inland waterways infrastructure in Austria and Luxemburg

<table>
<thead>
<tr>
<th>Breakdown Costs</th>
<th>Unit Cost</th>
<th>Breakdown Costs</th>
<th>Average AT</th>
<th>Average LUX</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINEERING WORKS $/lump sum</td>
<td>ENGINEERING WORKS ($/lump sum)</td>
<td>110 714.59</td>
<td>6 155.00</td>
<td></td>
</tr>
<tr>
<td>AIDS TO NAVIGATION $/lump sum</td>
<td>AIDS TO NAVIGATION ($/lump sum)</td>
<td>211 496.22</td>
<td>54 284.00</td>
<td></td>
</tr>
<tr>
<td>BANK &amp; BOTTOM PROTECTION Imperviousness $/m2</td>
<td>BANK &amp; BOTTOM PROTECTION Imperviousness ($/m2)</td>
<td>34.32</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>MOORING PLACES $/m2</td>
<td>MOORING PLACES ($/m2)</td>
<td>1.49</td>
<td>66.83</td>
<td></td>
</tr>
<tr>
<td>DREDGING REMEDIAL WORK $/m3</td>
<td>DREDGING REMEDIAL WORK ($/m3)</td>
<td>8.99</td>
<td>105.00</td>
<td></td>
</tr>
<tr>
<td>QUAY WALLS $/m2</td>
<td>QUAY WALLS ($/m2)</td>
<td>9 321.62</td>
<td>66.00</td>
<td></td>
</tr>
</tbody>
</table>

110. As show in the table 19 we can see that Austria as a country quite oriented on inland waterways invests quite a sum for maintenance of its IW in general but the prices in comparison to Luxemburg are more favourable. Luxemburg on the other hand invests smaller amounts on its IW maintenance operations but the prices for it are much higher.

Table 30
Construction costs of inland waterways infrastructure in Austria and Croatia

<table>
<thead>
<tr>
<th>Breakdown Costs</th>
<th>Unit Cost</th>
<th>Breakdown Costs</th>
<th>Average AT</th>
<th>Average HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging $/m3</td>
<td>Dredging ($/m3)</td>
<td>10.52</td>
<td>8.00</td>
<td></td>
</tr>
<tr>
<td>Pilots building Operation towers including radar VHF etc $/Unit</td>
<td>Pilots building Operation towers including radar VHF etc ($/Unit)</td>
<td>108 400.00</td>
<td>769 231.00</td>
<td></td>
</tr>
</tbody>
</table>
111. As shown in Table 30 and Figures 52 and 53 it is visible that Austria spends more in average on dredging operations (along the waterway) than Croatia. As regards to pilots building operation towers including radar, VHF etc. prices and costs in Croatia are much higher in average in comparison to Austria.

Table 31
Construction costs of port infrastructure in Port Authority Slavonski Brod and Port Authority Osijek Croatia

<table>
<thead>
<tr>
<th>Breakdown Items</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container terminal HR_PA SB ($/unit)</td>
<td>2,900,000</td>
</tr>
<tr>
<td>General cargo terminal HR_PA OS ($/unit)</td>
<td>4,200,000</td>
</tr>
</tbody>
</table>
In Table 31 and Figure 54 we have shown some port construction costs in Croatian port authorities Slavonski Brod and Osijek. PA Slavonski Brod is situated on Sava river and PA Osijek on Drava river both tributaries to the Danube. It’s visible that costs ($/unit) are higher for construction of general cargo terminal in Osijek than for container terminal in Slavonski Brod.
Annex VIII

Chapter 5/ Section A - Conclusions and recommendations / overview of sustainability options

I. Introduction

1. At its twelfth session (November 2021), the Group received more information about the recently established Geographic Information System (GIS) based International Transport Infrastructure Observatory (ITIO). The secretariat provided a detailed description of the Observatory, its purpose, functions, user groups and operational modalities. The Group requested the secretariat to prepare ahead of its next session a short note providing food-for-thought on the potential that this GIS platform offers to host and visualise benchmarking analytical data and information on national and regional benchmarking best practices. The present document which will serve as Chapter 5/ section A of the final report provides such an overview.

II. Continuation of the work of the Group as part of the International Transport Infrastructure Observatory

3. The recently established International Transport Infrastructure Observatory (ITIO) offers a multi-stakeholder, web-based Geographic Information System (GIS) platform which hosts data on a large variety of transport infrastructure networks and nodes across different modes including road, rail, inland waterways, ports, airports, intermodal terminals, logistics centres and border crossing points. A geographic information system (GIS) is a system that creates, manages, analyses, and maps all types of data. GIS connects data to a map, integrating location data with all types of descriptive information. This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making. (Esri, 2021).

4. The main objectives of the Observatory are:

   (a) Support the implementation of pillars 1, 2 and 4 of the ITC Strategy until 2030, envisaging the role of the ITC as: a United Nations Platform for regional and global inland transport conventions, a United Nations Platform for supporting new technologies and innovations in inland transport and a United Nations Platform for promoting sustainable regional and interregional inland transport connectivity and mobility, respectively.

   (b) Support the implementation of Sustainable Development Goal (SDG) 9 on “Building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation”; SDG 11 on “Making cities and human settlements inclusive, safe, resilient and sustainable; SDG 13 on “Taking urgent action to combat climate change and its impacts”; and SDG 17 on “Strengthening the means of implementation and revitalizing the global partnership for sustainable development”.

   (c) Offer to the United Nations system and Governments an innovative and inclusive tool that further facilitates transport infrastructure financing and enhances regional and interregional connectivity.

5. The main pillars of services that ITIO provides are being summarized in the schema below:
Figure I

**ITIO pillars of services**

![ITIO pillars of services](image)

*Source: ECE*

(a) Offering an electronic repository of ECE inland transport conventions, project outputs, and deliverables of designated Groups of Experts:

- More specifically, the observatory provides an electronic platform that will be catalytical for the ongoing digitalization of different United Nations inland transport agreements and conventions, especially those covering infrastructure (AGR\textsuperscript{26}, AGC\textsuperscript{27}, AGTC\textsuperscript{28} and AGN\textsuperscript{29}) but also border crossing facilitation instruments such as TIR\textsuperscript{30}/eTIR (customs systems location).

- Furthermore, it offers a digital environment that helps visualize specific outputs and deliverables, such as the work done in the framework of the TEM\textsuperscript{31}, TER\textsuperscript{32} and EATL\textsuperscript{33} projects but also the tangible outputs produced by the Group of Experts on Assessment of Climate Change Impacts and Adaptation for Inland (GE.3) and the Group of Experts on Benchmarking Transport Infrastructure Construction Costs (GE.4).

(b) Promoting sustainable regional and interregional connectivity: the observatory provides the possibility to all regional and interregional organizations to create their own maps illustrating their transport infrastructure initiatives, corridors, projects, reports and studies and anything else they consider useful for the purpose of further enhancing regional connectivity. This will enhance cooperation among the different transport infrastructure initiatives in Europe, Asia, and Africa.

(c) Financing transport infrastructure: the observatory operates as a marketplace for financing transport infrastructure by providing an electronic interface between Multilateral Development Banks and Governments. Governments can upload their transport infrastructure projects in need of funding as well as select which MDBs they wish to reach out to. By adding or removing GIS layers, data on transport infrastructure networks can be combined with data about the national and/or regional ratification and implementation rate of specific transport legal instruments or with the impact that climate change may have on planned infrastructure projects. For MDBs, the observatory functions as a clearing house granting them direct access to a centralized information platform assisting them to decide which projects to consider for funding. A secured electronic communication platform will be provided enabling all users to reach out to each other and exchange information.

\textsuperscript{26} European Agreement on Main International Traffic Arteries
\textsuperscript{27} European Agreement on Main International Railway Lines
\textsuperscript{28} European Agreement on Important International Combined Transport Lines and Related Installations
\textsuperscript{29} European Agreement on Main. Inland Waterways of International. Importance
\textsuperscript{30} Convention on International Transport of Goods Under Cover of TIR Carnets
\textsuperscript{31} Trans-European Motorways project
\textsuperscript{32} Trans-European Railways project
\textsuperscript{33} Euro-Asian Transport Links
III. ITIO user categories, profiles, and functionalities

6. Four user groups are foreseen in the observatory:
   (a) Governments
   (b) Multilateral Development Banks
   (c) Regional Cooperation Organizations
   (d) The wider public

7. Each of these user groups have access to a distinct set of functionalities, services, and possibilities. For Governments, MDBs and Regional Cooperation Organizations (RCOs) access will be granted to officially nominated/accredited representatives only. A username and password will be provided only after receipt of nominations by the secretariat. The public, academia, private sector, independent experts, and others will not have to register but will only have access to high-level data and information. Upon entering the observatory, they may be invited through an optional online survey to provide some background and profile information for statistical purposes (reasons for using the observatory, their location, professional affiliation etc.).

V. ITIO Government users

Figure II

Government user interface

Source: ECE

8. For the sake of this document, a brief overview of ITIO functionalities will be given for Government users only. Government users include accredited representatives from Governments agencies (e.g. Ministries of Transport, Infrastructure, Public Works and/or Investment Agencies). Only accredited Government representatives/national focal points are granted access to the observatory with a username / password.

9. Government users inter alia benefit from the following functionalities:

A. Access and edit national data

10. Generate maps which visualise a large variety of transport infrastructure networks and nodes across different modes including road, rail, inland waterways, ports, airports, intermodal terminals, logistics centres and border crossing points in the Euro-Asian region, the Middle East and North Africa.
B. Visualize infrastructure networks and generate pop-up windows with technical data per network segment

Source: ECE
C. Create new transport infrastructure projects to be uploaded for fundraising purposes

Figure V
Application to upload new transport projects, data fields to be filled pop-up

Source: ECE

11. Data fields to be filled for road projects, includes Section 1 “Route technical characteristics” and Section 2 “Project information”. While section 2 is identical for project proposals relating to all modes of transport, section 1 differs by mode.

Section 1. Route Technical Characteristics:

1. Location (latitude/longitude)
2. Start point/node/city
3. End point/node/city
4. Major intermediate (economic) centres
5. Road Classification
6. Length (in km)
7. Number of carriageways
8. Number of lanes
9. Design Speed/Average speed (km/h)
10. Annual Average Daily Traffic
11. Estimated percentage of freight vehicles
12. Annual Average Daily Traffic (passengers)
13. Annual Average Daily Traffic (tons)
14. Minimum overbridge height clearance
15. Maximum axle load
16. Road toll implementation: Yes/No

Section 2. Project Information

17. Project cost (USD)
18. Expected Starting Date
19. Expected Completion Date
20. Internal Rate of Return (IRR)
21. Project’s stage: Construction Tendering Study/Design Planning Identification
22. Expected Funding Sources (and the percentage of funding for each one)
23. Importance to regional connectivity, national economy and social needs

12. Data fields to be filled for railway projects, include:

Section 1. Route Technical Characteristics:
1. Location (latitude/longitude)
2. Start point/node/city
3. End point/node/city
4. Length (in km)
5. Track gauge (mm)
6. Number of tracks
7. Traction: Electrified Non-Electrified
9. Maximum allowed speed - passenger trains
10. Maximum allowed speed - freight trains
11. Average Daily Train Traffic - Passenger trains
12. Average Daily Train Traffic - Freight trains
13. Volume of cargo moved (tons and TEUs)
14. Number of passenger journeys

13. Data fields to be filled for inland waterway projects include:

Section 1. Route Technical Characteristics:
Route Name: Waterway name: Network e.g. (a) EATL Route: (b) other international route: (c) national importance: (d) combination of (a), (b), (c).

Route Description:

Section 1. Project Technical Characteristics:
1. Location (latitude/longitude or alternatively a map)
2. Start point/node/city
3. End point/node/city
4. Length (in km)
5. Maximum admissible at Low Navigable Water Level (LNWL)
6. Minimum bridge clearance at High Navigable Water Level (HNWL)
7. Lock dimensions
8. Permitted operational speed (km/h)
9. Annual vessel traffic
10. Annual freight tonnage
VI. Next steps

14. Develop additional functionalities for the ITIO, including related to visualising the benchmarking data and analysis prepared by the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs (GE.4/WP.5).

15. Benefits to the ITIO include:

   • Transport infrastructure construction cost data either at national/country level (i.e. average for a 10-year period) or at specific project level are of high interest both to Government users as they can compare and evaluate the costs of their own infrastructure projects with the associated costs in countries in their immediate (sub-)region as well as to International Financial Institutions (IFIs) and Multilateral Development Banks (MDBs) who may be interested in funding national and or (sub-)regional projects and want to understand how a given project proposal compares to project proposals from other countries.

   • Adding a GIS layer to the ITIO that would provide such information would increase the attractiveness and usability of the platform and would also add value to Governments and MDBs since the benchmarking of transport infrastructure construction costs is a critical step for having realistic construction costs and a stable investment program without unexpected cost increases. The use of benchmarking of construction costs could also be useful for cost estimates as well as for control of projects’ costs.

16. Benefits to GE.4:

   • As the Group by May 2022 concluded its mandate, uploading its analysis and data findings onto the ITIO may be the best way to ensure that the work of the Group becomes sustainable and would in addition to resulting in a written report also live on in a virtual/ GIS based environment.

   • Moreover, ITIO could offer an automated user dashboard function that would allow Governments, in a secured IT environment, to continue sharing transport infrastructure construction cost information with one another.

17. Short overview of benchmarking visualisation options:

   • GE.4 has gathered and analysed two types of transport infrastructure construction cost datasets: i) Multiple year country averages and ii) Specific project data (including
information on a geographical start and end point of a specific infrastructure project). The latter option provides better options for visualisation in a GIS environment as the infrastructure segment that is subject of a planned or ongoing construction project could be shown on a map. The former will be illustrated at national/country level through a pop-up window which would illustrate average cost data.
Annex IX

Chapter 5/ Section B - Findings, conclusions, and recommendations of the Group of Experts on Benchmarking Transport Infrastructure Construction Costs

I. Introduction

1. This document lists main findings, conclusions and recommendations identified by the Group of Experts on Benchmarking of Transport Infrastructure Construction Costs. It also provides an overview of some of the challenges experienced by the Group in the implementation of its mandate. This document will serve as Chapter 5/ Section B of the final report.

II. General

2. The Group of Experts on Benchmarking of Transport Infrastructure Construction Costs was established in the framework of the Working Party on Transport Trends and Economics following a workshop held in Geneva from 8–10 September 2014 on “Good practices and new tools for Financing Transport Infrastructure”. During the workshop it was agreed by the participants that the benchmarking of transport infrastructure construction costs is significant for having realistic construction cost estimates and a stable investment program without unforeseen cost increases.

3. The first session of the Group was held in Geneva on 31 October–1 November 2016. During its first session the Group decided that its study report should focus on three main parts:

   (a) Identify models, methodologies, tools and good practices for evaluating, calculating and analyzing inland transport infrastructure construction costs;

   (b) Identify and list terminologies used in the ECE region for construction costs of inland transport infrastructure; if possible, create a glossary of agreed terminologies and related explanations;

   (c) Collect and analyze data in order to prepare a benchmarking of transport infrastructure construction costs in the ECE region for each inland transport mode – road, rail, inland waterways – including intermodal terminals, freight/logistics centers and ports; analyze and describe the conditions/parameters under which these costs have been calculated.

4. For the road sector Türkiye, for the rail sector Poland and for inland waterways sector Croatia were designated as lead countries. Ten sessions of the Group were held in Geneva, the eleventh session was cancelled because of COVID-19 pandemic. Instead, two informal virtual meetings of the Group were organized by the secretariat.

5. Even though transport infrastructure costs include costs for construction, rehabilitation, upgrade, renewal, maintenance, and operation, only the first four categories of costs were considered, and it was suggested that the maintenance and operation costs could potentially be addressed in the format of a different Group.

6. All definitions are included in a consolidated list of terminologies on benchmarking of road, rail, inland waterway, ports, and intermodal terminals construction costs prepared by the Group.

7. Lead countries Türkiye and Poland prepared the road and rail questionnaires which were disseminated by the secretariat for data collection purposes. A set of four open questions was also prepared and distributed in order to collect information on national benchmarking methodologies and approaches.
8. The Group observed that some ECE member States were reluctant to share their data for benchmarking purposes. Even though benchmarking is used in the public sector starting from the 1990s it is a relatively new tool for public sector in the field of infrastructure development.

9. The biggest challenge the Group faced in conducting the study was to create a sense of mutual understanding. Each country has its own standards to construct infrastructure and collect and structure cost data. For benchmarking of different countries or organizations, it is always to be expected that data may not be directly comparable.

10. Another challenge faced by the Group was the limited data availability.

11. A possible follow-up study may focus on maintenance and operation cost of transport infrastructures. This type of data is easier to find and access.

12. On the other hand, list of terminologies for maintenance and operation costs of roads, rails and IW were prepared by lead countries and agreed by the group.

13. The questionnaire forms to collect data on maintenance and operation costs by lead countries were also prepared and agreed by the group.

III. Road sector specifics

14. The Group conducted its work as follows:

   (a) Identifying the parameters that affect the costs of a project is of critical importance. Superstructures such as tunnels and viaducts tend to have a major impact on the overall cost level of a project. The lead country for roads, Türkiye, suggested that for analytical purposes, costs should be designated through descriptive analysis instead of regression analysis because cost data does not follow normal distribution.

   (b) Road infrastructure was defined as including High-Capacity Roads (Motorways-Expressways), Medium Capacity Roads/Primary Roads and Medium Capacity Roads/ Secondary Roads.

   (c) The Group decided that for analytical purposes infrastructure rehabilitation projects may also be considered since, in many countries, they are funded from capital budget. It was agreed to clearly define the distinction between investment and maintenance not to compare apples and peaches. Accordingly, road infrastructures work types were classified as follows: resurfacing, resurfacing by strengthening, pavement replacement, reconditioning, reconstruction, capacity improvement and new construction.

   (d) The Group decided to focus its analysis on realized costs of construction projects for the period 2007–2016. The Group also decided that overall costs should exclude design costs, land acquisition costs, value added costs and costs of superstructures like tunnels, viaducts and bridges. Once the errors were removed and the costs were standardized to 2016, all construction cost data was turned into 2016 USD prices by using GDP Deflators. The GDP price deflator was used as it presents a more accurate picture of economies where currency values may be in flux.

   (e) As agreed by the Group terrain type is also an important parameter in calculating construction costs. It was decided however not to consider this parameter because of a lack of a sufficient number of projects. The Group decided to separate superstructure construction costs like tunnels, viaducts and bridges from overall road construction costs.

   (f) In order to benchmark road infrastructure construction costs, the cost unit was determined as US $ per km for single carriageway roads and US $ per lane x km for double carriageway roads and for tunnels US $ per m and for bridges US $ per m².

   (g) For road tunnels, they are classified as single tube tunnel, twin tube tunnel, under water tunnels and for road bridges, they are classified as precasted and pre-stressed simple beam, balanced cantilever bridge, cable stayed bridge, suspension bridge and pedestrian bridge.
(h) The Group decided to also include benchmarking parameters such as surface area, population, population density, GNP, GNP per capita, annual budget, annual operating and investment budget rates, total road network, the length of annually completed road network, length of tunnels and bridges, etc.

15. 14 countries namely Austria, Bulgaria, Croatia, Cyprus, Estonia, Finland, Germany, Iceland, Italy, Latvia, Republic of Moldova, Sweden, Russian Federation and Türkiye shared their road infrastructure construction cost data. However, in some cases data was missing or may have been misrepresented or inaccurate which complicated the actual data analysis. For instance, some countries may not have excluded some cost as superstructures such as tunnels, bridges.

16. The findings of the benchmarking analysis of road data of the Group are listed below:

(a) For Single Carriageway Roads:

(i) The highest observed cost for new construction of a primary single carriageway roads is 4.5 million US $ per km and the lowest one is 475,697 US $ per km. The highest one is nine times higher than the lowest one. The average of single carriageway primary roads new construction cost from nine ECE member States (Bulgaria, Croatia, Cyprus, Finland, Iceland, Italy, Russian Federation, Sweden, and Türkiye) is 1,484,989 US $ per km.

(ii) The highest observed cost of new construction for secondary single carriageway roads is 2 million US $ per km, while the lowest one is 14,769 US $ per km. The highest one is thus 135 times higher than the lowest one. Such a difference was not anticipated by the Group. The average of single carriageway of secondary roads new construction cost from 6 ECE member States (Cyprus, Finland, Italy, Russian Federation, Sweden, and Türkiye) is 682,949 US $ per km.

(iii) Regarding all road work types, it is also observed that the lowest cost for primary roads is 323 US $ per km for reconditioning and the highest one is 4,507,840 US $ per km for new construction.

(iv) Regarding all work types, it is also observed that the lowest cost for secondary roads is as 40 US $ per km for pavement replacement and the highest one is 2 million US $ per km for new construction.

(v) Average construction cost of primary single carriageway roads by work types gradually increases as for resurfacing 101,158 US $ per km, resurfacing by strengthening 291,627 US $ per km, pavement replacement 392,432 US $ per km, reconditioning 337,432 US $ per km, reconstruction 1,023,430 US $ per km and new construction 1,484,989 US $ per km. There is only one unexpected result which is reconditioning costs.

(vi) Average construction cost of secondary single carriageway roads by work types gradually increases as for resurfacing 68,378 US $ per km, resurfacing by strengthening 183,316 US $ per km, pavement replacement 315,973 US $ per km, reconditioning 203,163 US $ per km, reconstruction 449,025 US $ per km and new construction 682,949 US $ per km. There is only one confusing result which is reconditioning cost.

(b) For Double Carriageway Roads:

(i) The highest cost of new construction cost for motorways is 7.8 million US $ per lane x km and the lowest one is 371,013 US $ per lane x km. The highest one is 21 times higher than the lowest one. The average of double carriageway motorways new construction cost from nine ECE member countries (Austria, Bulgaria, Croatia, Cyprus, Finland, Italy, Russian Federation, Sweden, and Türkiye) is 2,157,667 US $ per lane x km.

(ii) The highest cost for new construction of double carriageway primary roads is 3.96 million US $ per lane x km and the lowest one is 134,716 US $ per lane x km. The highest one is 29 times higher than the lowest one. The average of double
carriageway primary roads new construction cost from four member countries (Croatia, Finland, Russian Federation, and Türkiye) is 1,423,171 US $ per lane x km.

(iii) The highest cost of new construction cost for double carriageway secondary roads is 1.95 million US $ per lane x km and the lowest one is 160,557 US $ per lane x km. The highest one is 12 times higher than the lowest one. The average of double carriageway of secondary roads new construction cost from three ECE member States (Bulgaria, Russian Federation and Türkiye) is 923,639 US $ per lane x km.

(iv) Regarding all work types, it is also observed that the lowest cost for motorways is as 15,684 US $ per lane x km for resurfacing and the highest one is 11,018,275 US $ per lane x km for expansion (capacity improvement).

(v) Regarding all work types, it is also observed that the lowest cost for double carriageway primary roads is as 4,231 US $ per lane x km for resurfacing and the highest one is 6,755,612 US $ per lane x km for expansion (capacity improvement).

(vi) Regarding all work types, it is also observed that the lowest cost for double carriageway secondary roads is as 3,385 US $ per lane x km for resurfacing and the highest one is 1,948,808 US $ per lane x km for new construction.

(vii) Average construction cost of motorways by work types gradually increases as for resurfacing 135,282 US $ per lane x km, resurfacing by strengthening 203,185 US $ per lane x km, pavement replacement 314,373 US $ per lane x km, reconditioning 493,218 US $ per lane x km, expansion 1,683,017 US $ per lane x km and new construction 2,157,667 US $ per lane x km.

(viii) Average construction cost of primary double carriageway roads by work types gradually increases as for resurfacing 11,807 US $ per lane x km, resurfacing by strengthening 76,814 US $ per lane x km, pavement replacement 167,925 US $ per lane x km, reconditioning 905,827 US $ per lane x km, reconstruction 211,809 US $ per lane x km and new construction 1,423,171 US $ per lane x km. There is only one confusing result which is for reconstruction.

(ix) Average construction cost of secondary double carriageway roads by work types gradually increases as for resurfacing 10,442 US $ per lane x km, resurfacing by strengthening 1,405,245 US $ per lane x km, pavement replacement 173,901 US $ per lane x km, reconditioning 597,085 US $ per lane x km, reconstruction 259,279 US $ per lane x km and new construction 923,639 US $ per lane x km. There are two confusing result one is for resurfacing by strengthening the other one is for reconditioning.

(c) For Superstructures Bridges and Tunnels Construction Costs:

(i) Superstructures costs were analyzed as bridges and tunnels construction cost. Bridges cost unit is US $ per m², tunnels cost unit is US $ per m.

(ii) For single tube tunnels six countries (Austria, Croatia, Iceland, Italy, Sweden, and Türkiye), for twin tube tunnels five countries (Croatia, Cyprus, Italy, Sweden and Türkiye) for underwater tunnels one country (Türkiye) provided data.

(iii) For single tube tunnels the highest cost is 20,000 US $ per m and the lowest one is 19,827 US $ per m. The average cost for single tube tunnel is 27,024 US $ per m. The highest cost is two times higher than the lowest one.

(iv) For twin tube tunnels the highest cost is 40,000 US $ per m observed and the lowest one is 9,922 US $ per m. The average cost for single tube tunnel is 16,437 US $ per m. There is not significant difference between the highest cost and the lowest one.

(v) Bridges costs were analyzed as precasted and pre-stressed simple beam, balanced cantilever bridge, cable stayed bridge, suspension bridge and pedestrian bridge.

(vi) Eight countries namely Croatia, Cyprus, Estonia, Iceland, Italy, Republic of Moldova, Sweden, and Türkiye provided data for precasted and pre-stressed simple
beam construction costs. The average of eight countries is 1,801 US $ per m². The highest one is observed in Iceland as 3,690 US $ per m², on the other hand the lowest one is observed in Türkiye as 698 US $ per m². The highest cost is 5 times higher than the lowest one.

(vii) Four countries namely Cyprus, Estonia, Germany, and Türkiye provided data for Balanced Cantilever Bridge Construction Costs. The average of four countries is 2,176 US $ per m². The highest is 2,583 US $ per m², and the lowest one is 1,416 US $ per m². The highest cost is 1.8 times higher than the lowest one.

(viii) Two countries namely Germany and Türkiye provided data for Cable Stayed Bridge Construction Costs. The average of two countries is 6,328 US $ per m².

(ix) Only one country, Türkiye provided data for suspension bridge construction costs which was at 9,644 US $ per m².

(x) Five countries namely Iceland, Latvia, Republic of Moldova, Sweden, and Türkiye. The average of five countries is 5,164 US $ per m². The highest one that is observed is 16,542 US $ per m² and the lowest one is 1,050 US $ per m². The highest one is 15 times higher than the lowest one.

From the above analysis it can be concluded that some construction costs of road infrastructures are not comparable across ECE member States. This result shows that mutual understanding is still a challenge. Data and results need to be further calibrated.

Regarding other benchmarking parameters such as GNP per capita and population density a correlation between actual cost and the size of economies and of countries was not established. This may in part be due to limited data availability because of which the data boxplot analysis could not be applied.

The present study has however proven its value and it is therefore recommended to continue the data collection efforts of the Group. In doing so, efforts need to be made to make sure that there is a better understanding among ECE member States wishing to submit additional data regarding the exact requirements. Better and more data would allow an even better analysis and results.

IV. Rail sector specifics

The railway is a very complex system with many different elements – track and track bed, catenary system, signalling and telecommunication systems, turnouts, bridges, tunnels, culverts, passages, level crossings, eco-passages, terminals, stations etc.

Each railway line has its characteristics and technical parameters to be fulfilled. Furthermore, there are differences among ECE member States when it comes to track gauge, axle load, electrification system, signalling system etc.

Therefore, each line is different, and a different approach is adopted for its construction, upgrade or renewal. As a result, the costs are calculated individually and are difficult to be compared.

For the purpose of this report Azerbaijan, Bulgaria, Croatia, Finland, Kazakhstan, Poland, Serbia, Slovenia, Tajikistan, Türkiye, and Turkmenistan kindly provided data on their investment projects in the railway sector. Some of this data was collected within the ECO-ECE-ISdB GIS project. Additionally, the data of the ECE Trans-European Railway (TER) project was acquired and analysed as well.

Data analysis was made for each country separately with the exception of Bulgaria, Slovenia, and Poland, where several infrastructure elements were to be compared. All countries provided information on the cost of upgrades for speeds between 120 and 160 km/h. The analysis revealed that some elements are more expensive in particular country, and others are comparable.

In case of the Polish upgrade projects the infrastructure elements for different speed ranges (V<120 km/h, 120<V≤160 km/h, 160<V≤200 km/h) were compared. The interesting
conclusion is that many of the elements are irrelevant to the speed. For Bulgaria, four infrastructure elements were compared for renewal and upgrade – three of them are more expensive for upgrade.

26. For Bulgaria, Croatia, Finland, Serbia, and Slovenia the allocation of costs of different categories was analysed on the example of the specific projects. In the example of Türkiye, it is demonstrated that in the case of new construction, most of the infrastructure elements designed for higher speed are more expensive. Therefore, a different conclusion was reached than in the case of Poland. It needs to be emphasised that Türkiye implemented new construction, whilst Poland undertook upgrading work.

27. Furthermore, in Türkiye three projects were analysed in terms of their cost in relation to their length. The cost of one project was much higher than the length that was accounted for.

28. Kazakhstan provided information about specific projects putting the costs of rails, bridges, and tunnels in one group and stations in another. There was also demonstrated the coherence between the cost of the projects and their length.

29. For Tajikistan, the allocation of costs of three projects was analysed, alongside with the relevance between cost of the rail tracks and the project length.

30. The relevance between total costs of the projects and their length was analysed for Turkmenistan and Azerbaijan. In Turkmenistan cost of the projects was proportional to their lengths. In Azerbaijan the cost of particular projects were not proportional to their lengths. In addition, also the cost of tracks and tunnels in Azerbaijan were integrated in the analysis.

31. The data presented by TER has been collected since 2012, so it includes knowledge about projects that have been put into operation since 2011. It contains information about length and costs of the projects which was used in the analysis.

32. As it was mentioned, most of the data was difficult to compare due to the specific and complex character of railway systems. Nonetheless, the study provides a very good basis for extending the scope of the costs analysis and launch a more focused research on individual projects, requiring more detailed information presented in the form of the case studies.

V. Inland waterways sector specifics

33. Inland waterways transport is, in comparison to road or air transport, seen as more environmentally friendly and energy efficient, and can therefore greatly contribute to socio-economic development of EU.

34. Inland navigation offers opportunities to move, cargos firstly and passengers likewise, instead of roads, in an energy-efficient manner. With that being said, IWT can contribute to mitigating road congestion.

35. For purpose of this report Austria, Croatia, Czechia, Luxemburg, Poland and Slovakia provided data about inland waterways infrastructure and IWW ports infrastructure construction, updates and maintenance costs.

36. Regarding average maintenance costs of inland waterways infrastructure, we compared data from Austria and Luxemburg as the data from other countries wasn’t as complete and thus comparable. Austria invests larger sums in IW maintenance then Luxemburg but at more favourable prices.

37. As for construction costs of IW infrastructure, we compared the data received from Austria and Croatia. Similar to comparison above, prices for dredging, pilots building, operation towers including radar, VHF etc. are more favourable (lower) in Austria.

38. Regarding IW ports infrastructure construction, updates and maintenance costs, the differences among the data received were too large for quality comparison. For that reason we chose to analyse Croatian Port Authority data. We can conclude that average price of construction of container terminal ($/unit) (PA Slavonski Brod) is lower than the average price ($/unit) for construction of general cargo terminal (PA Osijek).
39. As mentioned before, most of the data was difficult to compare due to specifics of inland waterway navigation and rivers per se. Another dimension is incomparability of costs since IW projects involve many different and per location specific works and projects, which occur as needed and with provision of funds.