INFORMATION AND COMMUNICATIONS TECHNOLOGY
AND DISASTER RISK REDUCTION DIVISION

# Infrastructure Corridor Development Series:

## Part II: Toolkit for Determining the Most Promising Scenario for Infrastructure Corridor Development

Vadim Kaptur

Aida Karazhanova

ASIA-PACIFIC INFORMATION SUPERHIGHWAY

WORKING PAPER SERIES JUNE 2021

UNITED NATIONS
ESCAP
Economic and Social Commission for Asia and the Pacific

**Disclaimer:** The views expressed through the Information and Communications Technology and Disaster Risk Reduction Working Paper Series should not be reported as representing the views of the United Nations, but as views of the author(s). Working Papers describe research in progress by the author(s) and are published to elicit comments for further debate. They are issued without formal editing. The shaded areas of the map indicate ESCAP members and associate members. The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The United Nations bears no responsibility for the availability or functioning of URLs. Opinions, figures and estimates set forth in this publication are the responsibility of the authors and should not necessarily be considered as reflecting the views or carrying the endorsement of the United Nations. Any errors are the responsibility of the authors. Mention of firm names and commercial products does not imply the endorsement of the United Nations.

The Asia-Pacific Information Superhighway (AP-IS) Working Papers provide policy-relevant analysis on regional trends and challenges in support of the development of the Asia-Pacific Information Superhighway (AP-IS) and inclusive development. The findings should not be reported as representing the views of the United Nations. The views expressed herein are those of the authors. This working paper has been issued without formal editing, and the designations employed and material presented do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Correspondence concerning this working paper should be addressed to the email: escap-ids@un.org.

**Contact:**
Information and Communications Technology and Development Section
Information and Communications Technology and Disaster Risk Reduction Division
United Nations Economic and Social Commission for Asia and the Pacific
United Nations Building
Rajadamnern Nok Avenue
Bangkok 10200, Thailand
Email: escap-ids@un.org

The Economic and Social Commission for Asia and the Pacific (ESCAP) is the most inclusive intergovernmental platform in the Asia-Pacific region. The Commission promotes cooperation among its 53 member States and 9 associate members in pursuit of solutions to sustainable development challenges. ESCAP is one of the five regional commissions of the United Nations.

The ESCAP secretariat supports inclusive, resilient and sustainable development in the region by generating action-oriented knowledge, and by providing technical assistance and capacity-building services in support of national development objectives, regional agreements and the implementation of the 2030 Agenda for Sustainable Development.

The shaded areas of the map indicate ESCAP members and associate members.[1]

---

[1] The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

**Please cite this paper as:** Vadim Kaptur, Aida Karazhanova (2021). Infrastructure Corridor Series Part II: Toolkit for Determining the Most Promising Model fpr Infrastructure Corridor Development. United Nations ESCAP, IDD, July 2021. Bangkok.

Available at: http://www.unescap.org/kp

Tracking number ESCAP / 5-WP / 14

**About the author:** Dr. Vadim Kaptur, ESCAP Consultant and Vice Rector of the A.S. Popov Odessa National Academy of Telecommunications (ONAT), Ukraine and Ms. Aida Karazhanova, Economic Affairs Officer of IDD, ESCAP

June 2021

# Acknowledgements

Under the guidance of Tiziana Bonapace, Director, Information and Communications Technology and Disaster Risk Reduction Division (IDD) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), the English and Russian versions of this Infrastructure Corridor Development Series were prepared by Vadym Kaptur, ESCAP Consultant and Vice Rector of the A.S. Popov Odessa National Academy of Telecommunications (ONAT), Ukraine and Aida Karazhanova, Economic Affairs Officer of IDD, ESCAP.

Substantive comments were provided by Tae Hyung Kim, Chief, Information and Communications Technology and Development Section (IDS) of IDD and Elena Dyakonova of IDS, IDD. Christine Apikul reviewed and edited the English version of the series. Sakollerd Limkriangkrai of IDS, IDD provided administrative support and other necessary assistance to support the development of the series.

The ESCAP Secretariat expresses gratitude to the following scientific and technical consultants from A.S. Popov ONAT, Ukraine: Olena Kniazieva, Volodymir Baliar, Iryna Tymchenko, Elena Mazurkiewicz, Lubov Terletska, Tamara Kancur and Bohdana Yamniuk; to Bekhzod Rakhmatov of the Transport Division of ESCAP and Anna Lobanova of Energy Division of ESCAP, who also provided substantive inputs.

Representatives of ministries, government agencies, public and private organizations, operators, and nominated entities working in the sectors of information and communications technology and telecommunications infrastructure, road and rail transport, electricity, and oil and gas pipelines from Kazakhstan, Kyrgyzstan and Mongolia reviewed this toolkit during a series of training workshops organized in May 2021 and were the first group to be trained on two web-based toolkits – the Infrastructure Corridor Simulator and the Partnership Portal on Co-deployment.

# Table of Contents

# List of Figures

# List of Tables

# Abstract

The Regional Economic Cooperation and Integration (RECI) initiative of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) aims to promote integrated markets for goods, services, information and capital; infrastructure connectivity; financial cooperation; and economic and technical cooperation through a multidimensional and multidisciplinary approach. Promoting seamless connectivity in transport, energy and information and communications technology (ICT) is a central pillar of the RECI initiative.

As part of the RECI initiative, ESCAP is implementing a United Nations Development Account Project on "Addressing the Transboundary Dimensions of the 2030 Agenda for Sustainable Development through RECI in Asia and the Pacific" from 2018 to 2021. This project aims to develop knowledge products such as analysis reports, and build capacity of member States in promoting seamless regional connectivity with a focus on the co-deployment of ICT, transport and energy infrastructures.

Following the recommendations of the capacity building workshops for policymakers of Kazakhstan, Kyrgyzstan, Mongolia, and subregional workshop for countries in East and North-East Asia in October-November 2019, this analysis report aimed to enhance understanding for planning interstate infrastructure corridors. The scope of this report covers in-depth analysis of the co-deployment of ICT infrastructure along transport and energy infrastructure corridors and support identification of key needs and the selection of the priority projects.

In response to the needs of member States and considering the complex challenges of limited national and regional infrastructures, the key objectives of this research are to: (1) provide in-depth cross-sectoral analysis of three potential interstate infrastructure corridors in the target countries of the RECI project (Kazakhstan and Kyrgyzstan); (2) provide knowledge and capacity building in determining the most promising model for infrastructure corridor development; and (3) promote an enabling environment for infrastructure corridor development, including the co-deployment of ICT, transport and energy infrastructures.

An infrastructure corridor approach is used as an attractive smart solution to link the geographical territories, and improve regional and transboundary connectivity. An infrastructure corridor is a high-tech transportation system integrated with a wide range of ICTs to facilitate the flow of goods, services, knowledge and capital in a cost- and time-effective way towards achieving the 2030 Agenda for Sustainable Development.

This research paper is a part of the Infrastructure Corridor Development Series that supports decision makers and infrastructure owners in their decisions on the development of new infrastructure corridors. The Infrastructure Corridor Development Series is divided into three main parts:

Part 1: An in-depth analysis of three promising infrastructure corridors.

Almaty (Kazakhstan) – Cholpon-Ata (Kyrgyzstan)
Semey (Kazakhstan) – Rubtsovsk (Russian Federation)
Urzhar (Kazakhstan) – Chuguchak (China)

Part 2: A toolkit for determining the most promising scenario for infrastructure corridor development.

Part 3: Calculation results for determining the most promising scenario for infrastructure corridor development.

This is Part Two of the series provides a parametric model of a typical infrastructure corridor, including classification of its main parameters, methodology for determining the most promising model for infrastructure corridor development, and details of a web-based simulation model to automate calculations based on the methodology.

The methodology is presented in the form of algorithms and formulae connecting the basic parameters of the parametric model with indicators of economic efficiency. Selection of the most promising infrastructure corridor development scenario (or group of scenarios) is made based on a weighted average assessment of the set of indicators, including key economic indicators. In addition, the methodology considers various forms of partnerships for infrastructure corridor development.

This parametric model and methodology was introduced in May 2021 for review and feedback from participants in a series of interactive national training workshops. The participants include representatives from ministries, government agencies, public and private organizations, operators, and nominated entities working in the sectors of ICT and telecommunications infrastructure, road and rail transport, electricity, and oil and gas pipelines in Kazakhstan, Kyrgyzstan and Mongolia.

The training workshops also demonstrated two web-based tools[2] based on the methodologies and approach of this toolkit to effectively expand seamless cross-border infrastructure.

The web-based tools include:

- Infrastructure Corridor Simulator – A tool to determine the most promising scenario for the development of new infrastructure corridors;[3] and
- Partnership Portal on Co-deployment – A tool to support co-deployment of the ICT infrastructure with transport and energy infrastructures.[4]

---

[2] ESCAP, "ICT & DRR Gateway: Regional Toolkits". Available at https://drrgateway.net/regional-toolkits.

[3] Infrastructure Corridor Simulator. Available at https://broadband.shinyapps.io/SmartCorridorsSimulator/.

[4] Partnership Portal on Co-deployment. Available at https://co-deployment.online.

# Keywords

**Broadband access**: Wide bandwidth data transmission that transports multiple signals and traffic types within access network. The medium can be coaxial cable, optical fibre, radio or twisted pair (source: https://www.wikipedia.org).

**Broadband Internet access**: Internet access with a bit rate exceeding the maximum possible bit rate for modem dial-up connection via a public telephone network. It is carried out using wired, fibre-optic and wireless communications lines of various types (source: https://www.wikipedia.org).

**Cash flow**: The net amount of cash and cash equivalents transferred to and from businesses (source: https://www.investopedia.com).

**Co-deployment (infrastructure)**: The simultaneous deployment of cable ducts and/or fibre-optic cables during the construction of infrastructure such as new roads, highways, railways, power transmission lines and oil/gas pipelines (source: https://www.unescap.org).

**Design process**: A general set of steps that engineers use when creating telecommunications network designs (source: https://www.wikipedia.org).

**Discount factor**: A factor used for discounting, that is, bringing the amount of cash flow to the n-th step of a multi-step calculation of the efficiency of an investment project to a moment called the moment of decline. The discount factor shows how much money is received, taking into account the time and risk factors, the reduction of cash flow in the n-th year, based on a given discount rate (source: http://1-fin.ru).

**Electricity infrastructure / electrical grid**: An integrated network for delivering electricity from supplier to consumers (source: https://www.wikipedia.org).

**Energy infrastructure**: An organizational structure that allows large-scale transmission of energy from supplier to consumer, as well as directs and controls energy flow. It includes, but is not limited to, the oil and gas transportation infrastructure and the electricity transportation infrastructure (source: https://www.designingbuildings.co.uk).

**Fibre-optic communications line**: A fibre-optic system consisting of passive and active elements, designed to transmit information in the optical range (source: https://www.wikipedia.org).

**ICT infrastructure**: The information and communications technology (ICT) infrastructure and systems, including software, hardware, networks and websites (source: https://www.lawinsider.com).

**Inflation rate**: A steady increase in the general level of prices for goods and services in an economy over a period of time (source: https://www.wikipedia.org).

**Infrastructure corridor**: A high-tech transportation system integrated with a wide range of ICTs to facilitate the flow of goods, services, knowledge and capital in a cost- and time-effective way towards achieving the 2030 Agenda for Sustainable Development (source: https://www.unescap.org).

**Infrastructure sharing**: The sharing of real estate and fixed assets, including land, conduits, ducts, manholes and handholes, base station sites, AC networks, trunk lines, radio links, and other resources to avoid infrastructure duplication and reduce costs (source: author).

**Internet access**: The ability of individuals and organizations to connect to the Internet using computer terminals, computers and other devices; and to access services such as email and the World Wide Web (source: https://www.wikipedia.org).

**Net cash flow**: The difference between the present value of cash inflow and the present value of cash outflow over a period of time. This metric is used in capital budgeting and investment planning to analyse the profitability of projected investments or projects (source: https://www.investopedia.com).

**Parametric model**: A model that allows the establishment of a quantitative relationship between the functional and auxiliary parameters of the system (source: author).

**Project risk**: Probable event, as a result of which the decision-maker loses the ability to achieve the planned results of the project or its individual parameters having a temporary, quantitative and cost estimate (source: author).

**Road transport infrastructure**: The road network and associated physical infrastructure, such as road signs, roadway lighting and petrol stations (source: https://iea-etsap.org).

**Transport corridor**: A linear area that is defined by one or more modes of transport, such as roads, railways or public transport that share a common route (source: https://www.wikipedia.org).

# Abbreviations and Acronyms

| | |
|---|---|
| AP-IS | Asia-Pacific Information Superhighway |
| ESCAP | Economic and Social Commission for Asia and the Pacific |
| ICT | Information and Communications Technology |
| IDD | Information and Communications Technology and Disaster Risk Reduction Division |
| ONAT | Odessa National Academy of Telecommunications |
| RECI | Regional Economic Cooperation and Integration |
| USD | United States Dollar |

# 1. A Parametric Model for Infrastructure Corridors

A modern infrastructure corridor is a high-tech transportation system integrated with a wide range of information and communications technologies (ICTs) to facilitate the accelerated flow of goods, services, knowledge and capital in a cost- and time-effective way towards achieving the 2030 Agenda for Sustainable Development. More specifically, an infrastructure corridor:

- Ensures coordination of priorities for the development of transport and economic infrastructures;
- Reduces transport-related costs directly or indirectly by improving logistics flows and telecommunications, and reducing the required land acquisition;
- Develops interaction of linear infrastructure at the nodal points of the infrastructure corridor; and
- Minimizes negative environmental impact by integrating the different types of infrastructure.

This requires the co-deployment of the ICT infrastructure with transport and energy[5] infrastructures, and the building of a new generation of multiservice network as part of the infrastructure corridor. When developing an infrastructure corridor, the structural and functional properties of the technologies used across the ICT, transport and energy infrastructures must be compatible to enable their joint functioning as an integrated technological system.

Thus, prior to developing an infrastructure corridor, it is necessary to build an infrastructure corridor model to simulate technological problems related to the choice of technologies for the construction or modernization of communications routes, terminals (hubs) and telecommunications information systems along the infrastructure corridor.

## 1.1 A General Parametric Model for an Infrastructure Corridor

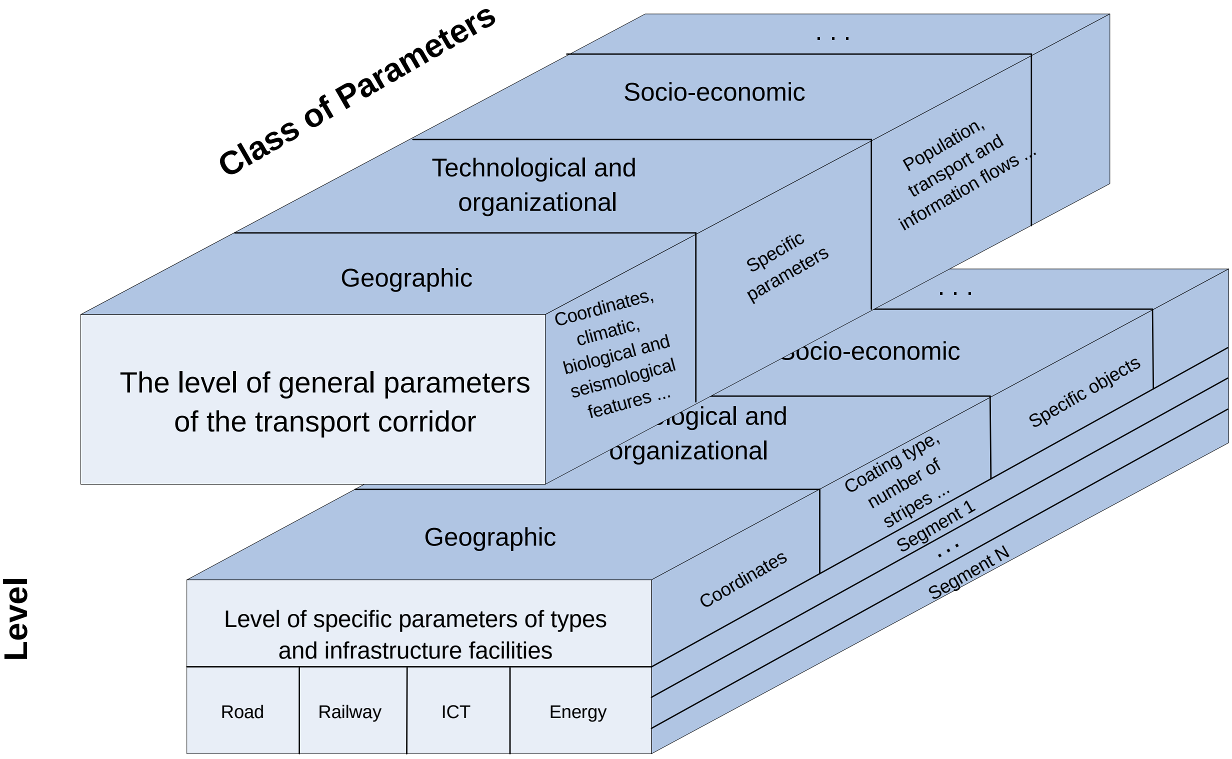
Figure 1 shows a general parametric model for a typical infrastructure corridor with a classification of the main parameters that affect the choice of technology. The parametric model takes into account the compatibility of the technologies, route topology and scale.

Structurally, the parameters can be divided into two levels – general and specific. The general parameters include characteristics of the entire infrastructure corridor, and the specific parameters are based on the type of infrastructure (e.g., ICT, road, railway and energy).

---

[5] More information on the strategic plans for energy sector development is available at https://asiapacificenergy.org/ and https://www.unescap.org/resources/policy-perspectives-2019-sustainable-energy-asia-and-pacific.

Figure 1: A general parametric model for a typical infrastructure corridor



The general parameters can be applied to the entire infrastructure corridor, or to each segment and averaged for the infrastructure corridor. The specific parameters are applied to segments of the various infrastructure types along the corridor (e.g., a segment of a road or power line).

For both levels (general and specific), the parameters can be divided into three types – "determining", "quantitative" and "indirect". The determining parameters help to determine the possibility of using certain technologies or architecture (within one technology) for the construction of an infrastructure. These parameters are useful for developing the construction strategy for the infrastructure corridor. The quantitative parameters include only quantitative (large-scale) indicators for the construction of an infrastructure or its segment, and can be used to assess the economic aspects of the construction. The indirect parameters are used to justify the values of individual parameters, and help to estimate the labour intensity of the work and the amount of materials needed for construction.

The various types of parameters can be divided into three classes – geographic parameters, technological and organizational parameters, and socioeconomic parameters. It should be noted that the classification shown in Figure 1 is dynamic and can be supplemented with additional parameters and classes of parameters, especially if they are required to determine the construction method. For example, the geographic parameters could include biological, climatic and seismological aspects, and the socioeconomic parameters could examine the settlements in the coverage area of the infrastructure corridor and the flows along the corridor (e.g., passenger flows, freight flows and data flows).

Figure 2: The relationship of infrastructure components in a typical parametric model

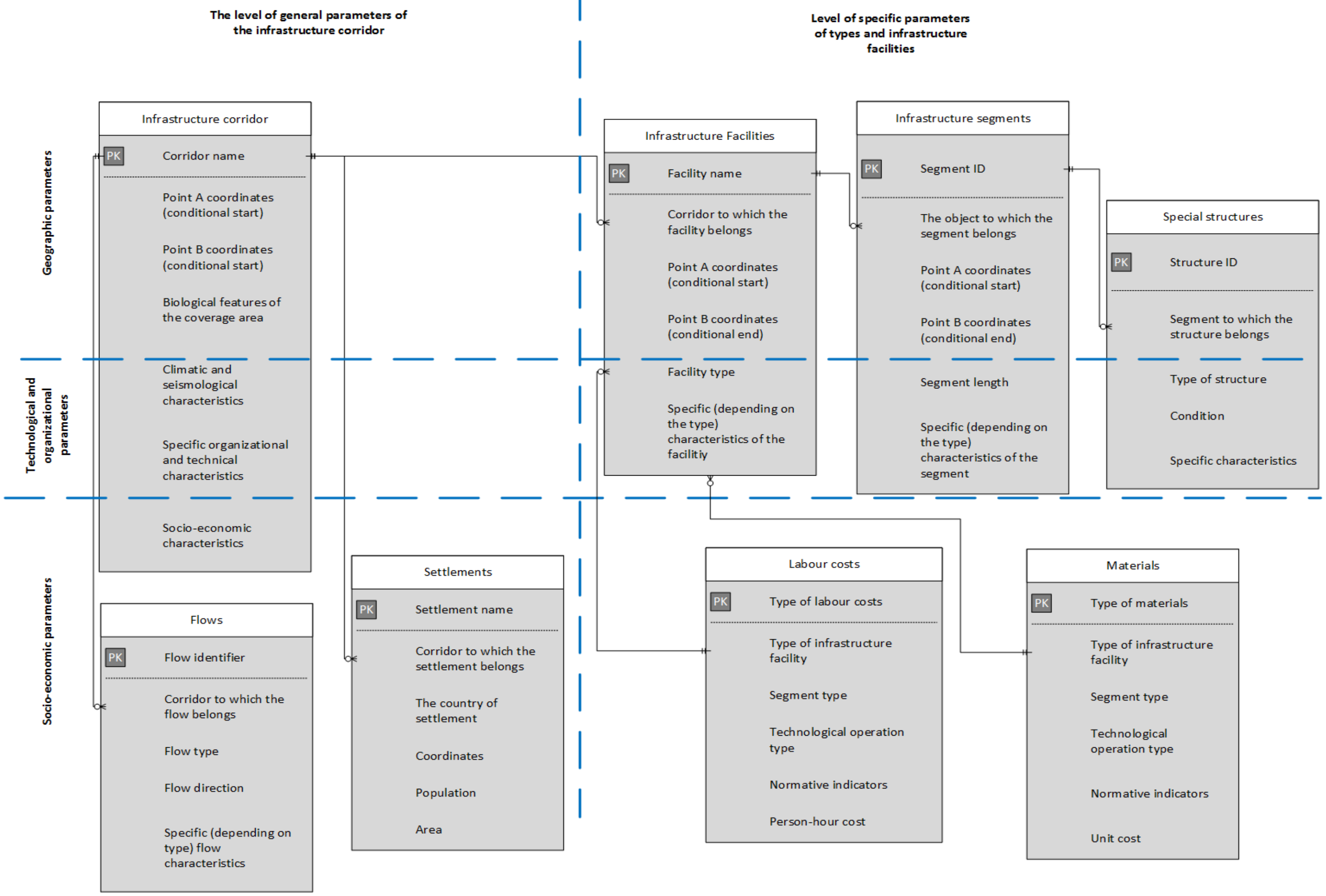


Figure 2 presents the relationship of infrastructure components in a typical parametric model for developing an infrastructure corridor. As shown in the figure, an infrastructure corridor can include existing or potential infrastructure of various types (e.g., road, railway, power line and fibre-optic cable). Moreover, each infrastructure type consists of segments that have both general parameters (e.g., geographic coordinates and length) and specific parameters. This model may include related structures such as bridges, buildings, railway stations and transformer substations.

## 1.2 Parameters of the Infrastructure Corridor

### 1.2.1 General Parameters

Table 1 provides details about the general parameters of the infrastructure corridor.

Table 1: General parameters of the infrastructure corridor

| № | Parameter name | Unit of measurement | Parameter type* | Note |
|---|---|---|---|---|
| | | *Class of geographic parameters* | | |
| 1 | Coordinates of the start of the corridor | Latitude and longitude | D, I | These parameters determine the coverage area of the infrastructure corridor, as well as the infrastructure facilities and settlements in the coverage area |
| 2 | Coordinates of the end of the corridor | Latitude and longitude | D, I | |
| 3 | Corridor width | km | D, Q, I | |
| 4 | Relief of the coverage area | Points (from 0 to 10, where 0 is flat relief throughout the coverage area and 10 is mountainous relief throughout the coverage area) | D, Q, I | This parameter shows how complex and varied the corridor's relief is and, as a result, what auxiliary engineering structures are needed (e.g., tunnels, bridges, aqueducts, cloverleaf traffic intersections) |
| 5 | Basic soils | Points (from 0 to 10, where 0 is soft soils throughout the coverage area and 10 is hard soils throughout the coverage area) | D, Q, I | This parameter shows the soil type in the corridor. The harder the soil, the greater the need for special equipment to develop the corridor |
| 6 | Availability of water resources in the coverage area | Points (from 0 to 10, where 0 is no water resources and 10 is a large amount of water resources) | D, Q, I | This parameter shows the availability of water resources, the need for which must be taken into account for all types of construction work |
| 7 | Deposits | – | D, Q, I | An array of developed, explored or mothballed mineral deposits, which are or may in the future become attractors of various flows |
| 8 | Large transport hubs | – | D, Q, I | An array of large transport hubs (e.g., ports, airports) in the coverage area, which are or may in the future become attractors of various flows |

| | | | | |
|---|---|---|---|---|
| 9 | Biological features of the coverage area | – | D, Q, I | An array of reserves or sanctuaries in the coverage area, which, on the one hand, can create obstacles in the development of the infrastructure, and on the other hand, become attractors of various flows |
| *Class of technological and organizational parameters* | | | | |
| 1 | Average January temperature in the coverage area | ºC | D, I | These parameters show the average temperatures in the coldest and warmest months. The greater the temperature range, the greater the requirements for materials to construct the infrastructure, and the shorter the period for carrying out construction work |
| 2 | Average June temperature in the coverage area | ºC | D, I | |
| 3 | Average annual rainfall in the coverage area | mm per year | D, I | These parameters determine the complexity of construction, which depends on the technologists available, and affects the cost and duration of construction work and maintenance of the infrastructure |
| 4 | Maximum wind loads | kPa | D, I | |
| 5 | Potential intensity of seismic impacts | Points on seismic intensity scale | D, I | |
| *Class of socioeconomic parameters* | | | | |
| 1 | Gross domestic product per capita in the coverage area | USD | Q, I | Indicators are taken into account both at the start and end of the corridor |
| 2 | Average salary in the coverage area and at the start of the corridor | USD / month | Q, I | |
| 3 | Income tax | % | Q | Indicators are taken into account both at the start and end of the corridor |
| 4 | Sales tax (value-added tax) | % | Q | Indicators are taken into account both at the start and end of the corridor |
| 5 | Population structure (distribution by age group) | % | Q, I | An array of percentages characterizing the distribution of the population by different age groups (7-18 years old, 18-65 years old and over 65 years old). Indicators are taken into account both at the start and end of the corridor |
| 6 | Number of households in the coverage area | Households | Q | The period average is used |
| 7 | Number of business units in the coverage area | Business units | Q | The number of business units, social facilities and local government entities is taken into account |
| 8 | Average household income in the coverage area | USD / year | Q | Indicators are taken into account both at the start and end of the corridor |
| 9 | Tariffs for communications services, transport, electricity, etc. for | USD / unit /month | Q | An array of tariffs for communications services, transport, electricity, etc. both for households and businesses. Indicators are taken into account both |

| | | | | |
|---|---|---|---|---|
| | the population | | | at the start and end of the corridor |
| 10 | Type of household expenditure (distribution by sectors of the economy) | % | Q | An array of percentages characterizing the share of cost of households (of the total average annual cost) for communications services, transport, electricity, etc. Indicators are taken into account both at the start and end of the corridor |
| 11 | Cost structure of business units, social facilities and local government entities | % | Q | An array of percentages characterizing the share of cost of business units (of the total average annual cost) for communications services, transport, electricity, etc. Indicators are taken into account both at the start and end of the corridor |
| 12 | Average volume of service use | Conventional units | Q | An array of average volumes of service use by households and business units, as recorded by state statistics bodies (e.g., the average consumption of kW of electricity by households) |
| 13 | Temporary (seasonal) demand for communications, transport and electricity services | % | Q, I | An array of percentages characterizing the share and duration of the seasonal (e.g., in the summer period) increase in demand for communications, transport and electricity services. Indicators are taken into account both at the start and end of the corridor |
| 14 | Economic and technological flows in the coverage area | – | Q | An array of economic and technological flows (e.g., passenger flows, freight flows, data flows) in the corridor's coverage area, including information on the type of flow, its direction, intensity at different times of the year, and detailed statistical data to determine the level of its unevenness (e.g., hourly statistics over a year) |
| 15 | Settlements in the coverage area | – | Q, I | An array of settlements in the corridor's coverage area, including information about the population, area and specific industrial facilities located in the settlements, as well as the type of settlement (e.g., city, town, village) and the prevailing type of development |

Notes: * D = Determining Parameter; Q = Quantitative Parameter; and I = Indirect Parameter.

### 1.2.2 Specific Parameters

Table 2 provides details about the specific parameters by type of infrastructure.

Table 2: Specific parameters by type of infrastructure

| № | Parameter name | Unit of measurement | Infrastructure type | Parameter type* | Note |
|---|---|---|---|---|---|
| | | | *Class of geographic parameters* | | |
| 1 | Coordinates of the start of an infrastructure or its segment | Latitude and longitude | Any | D | These parameters determine the location of the infrastructure or its segment, as well as the settlements in the vicinity and special structures (existing or planned) within the segment |
| 2 | Coordinates of the end of an infrastructure or its segment | Latitude and longitude | Any | D | |
| | | | *Class of technological and organizational parameters* | | |
| 1 | Segment length | km | Any | Q | These parameters can be used to estimate the cost of construction or reconstruction, and operation of the infrastructure segment |
| 2 | Number of lines in both directions | – | Highway | Q, I | |
| 3 | Volume | $m^3$ | Pipelines, gas pipelines | Q, I | |
| 4 | Performance | $m^3/h$ | Gas pipelines | Q, I | |
| 5 | Electrification level | – | Railway | D, I | |
| 6 | Voltage level | kV | Power line | D, I | |
| 7 | Bandwidth of the information highway | Fibre count | Fibre optic | D, Q, I | |
| 8 | Availability of cable ducts | – | Road, railway | D, I | These parameters can be used to assess the potential for co-deployment of road transport infrastructure with ICT infrastructure in a segment |
| 9 | Communications service coverage | – | Road, railway | D, I | |
| 10 | Special structures | – | Any | Q | An array of special structures located along the segment, including information about the type of structure (e.g., bridge, aqueduct, interchange, refuelling, stop, parking, station), information about its condition (level of deterioration) and other specific characteristics |
| | | | *Class of socioeconomic parameters* | | |
| 1 | Labour intensity and cost to construct and operate a new infrastructure, or reconstruct and/or maintain | – | Any | Q | An array of technological operations for the construction, reconstruction and/or maintenance of a segment of an infrastructure, including information about the name and type of technological operation, |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | an existing infrastructure |  |  |  | the labour cost (in person-hours) for a conventional unit of measurement (e.g., metre of route length, metre of tunnel), and the average cost of one person-hour for an operation of this type (taking into account the region of the work being carried out) |
| 2 | Number of materials and special means to construct and operate a new infrastructure, or reconstruct and/or maintain an existing infrastructure | – | Any | Q | An array of the amount of materials and special tools used for the construction, reconstruction and/or maintenance of a segment of an infrastructure, including information about the name and type of material, the amount of material of this type in an appropriate unit of measurement (e.g., metre of route length, metre of tunnel), and the average cost per unit of material (taking into account the region of the work being carried out) |

Notes: * D = Determining Parameter; Q = Quantitative Parameter; and I = Indirect Parameter.

# 2. Methodology for Determining the Most Promising Scenario for Infrastructure Corridor Development

## 2.1 A Generalized Algorithm

A generalized algorithm for determining the most promising model for infrastructure corridor development is presented in Figure 3.

This algorithm uses the general parameters of the infrastructure corridor from the parametric model described in the previous section, information about existing infrastructures, and information about promising economic and technological flows along the infrastructure corridor. Information about the flows can either be based on an in-depth analysis of the current macro- and meso-economic situation in the coverage area of the infrastructure corridor, or on information about settlements, large industrial facilities and/or mineral fields in the same coverage area. The algorithm for determining the economic and technological flows is described in Section 2.2.

The first step in the algorithm determines the basic scenarios for infrastructure corridor development. This is achieved by assessing the conformity of the state of existing infrastructures with the characteristics of prospective economic and technological flows, and determining the basic characteristics of new infrastructures (if it is necessary to build them).

The scenario for infrastructure corridor development is made up of a set of sub-scenarios for the building of existing or planned infrastructures (e.g., roads, railways, power lines and fibre-optic communications lines) in the coverage area. For each infrastructure type, it can be determined whether it needs to be built (in the case that it is absent), reconstructed (e.g., to expand its capacity), or no action is needed (e.g., if it fully meets specified needs).

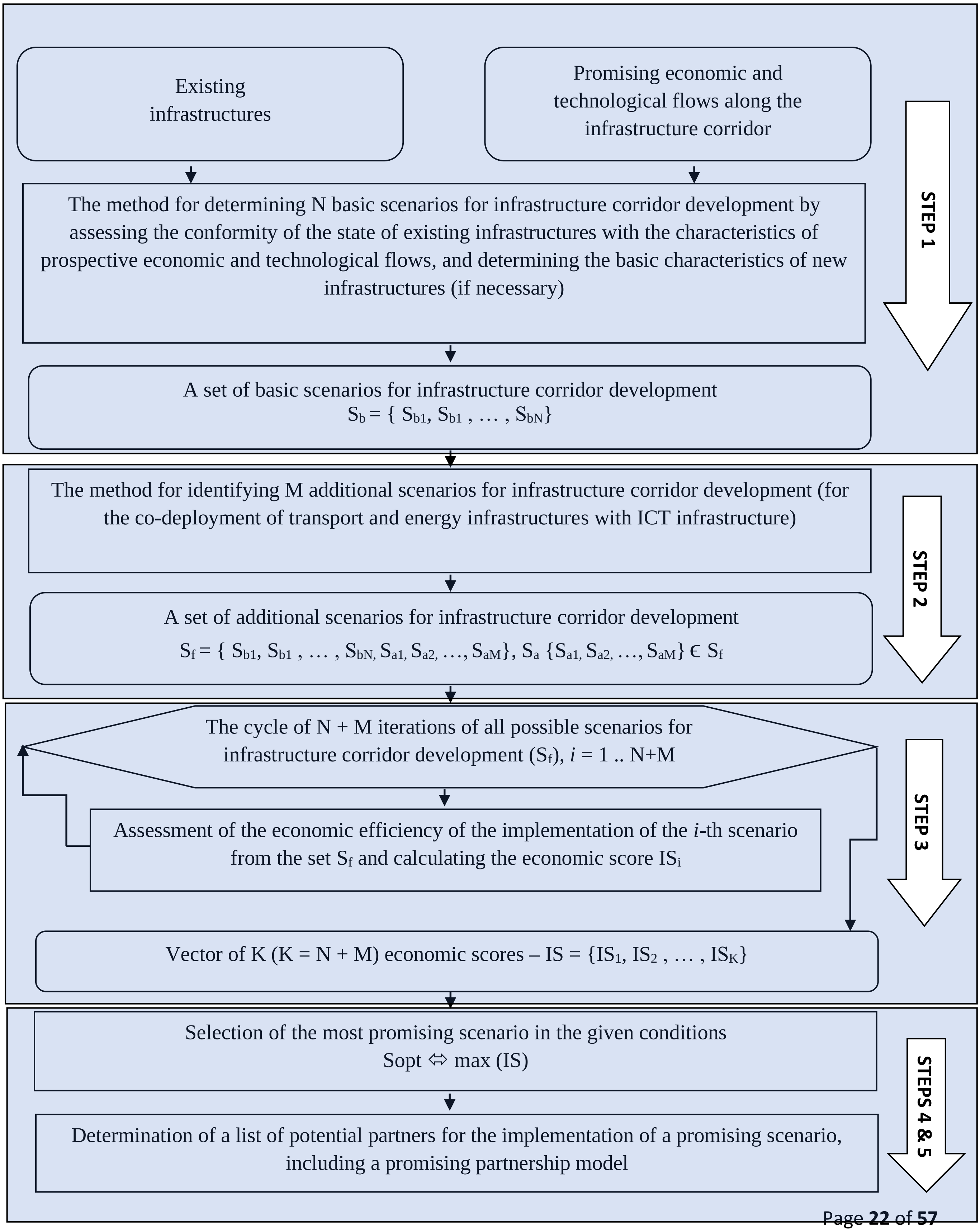
The methodology identifies only those development scenarios that fully satisfy the needs determined by the calculated or specified flows. This methodology is described in Section 2.3. It results in a multitude of basic scenarios for infrastructure corridor development in which the different infrastructure types are built or reconstructed independently of each other.

The second step identifies additional scenarios for the co-deployment of transport and energy infrastructures with the ICT infrastructure along the infrastructure corridor. The key principle of this methodology is to combine the construction process of various types of infrastructures in order to reduce costs. This methodology is also described in Section 2.3.

The third step conducts a cyclical iteration of all possible scenarios for the development of the infrastructure corridor, applying to the scenario the methodology for assessing the economic efficiency of its implementation. The result of this step is a set of economic scores to help determine the most promising scenario. The methodology for assessing the economic efficiency of infrastructure corridor implementation is described in Section 2.4.

The final steps involve selecting the most promising infrastructure corridor development scenario from an economic point of view, and developing a list of potential partners for its implementation, including identifying the most promising partnership model. This methodology is described in Section 2.5.

Figure 3: Generalized algorithm for determining the most promising model for infrastructure corridor development



## 2.2 Determination of Promising Economic and Technological Flows Along the Infrastructure Corridor

The economic and technological flows refer to the simplest flow elements in a certain direction. In the context of infrastructure corridors, the types of flow considered include:

- Passenger traffic – Movement of passengers in one direction of the route;
- Freight traffic – Movement of goods in one direction of the route;
- Electric flow – Transmission of electric power by the electrical grid; and
- Data flow – Transmission of data by communications channels.

In some cases, it is advisable to divide these flows into transit and full cycle flows (in a specific corridor). A key characteristic of any kind of economic and technological flow is its intensity, which can be uneven and is often based on a function of time (e.g., month, day of the week, time of day).

The basis for determining promising economic and technological flows is to assess demand based on the presence of the flow elements in the coverage area, which include passengers, freight, electric power and/or data. It is also important to assess the linkages between these flow elements and the users of the flow along the infrastructure corridor.

In order to determine the appropriate intensities, it is necessary to assess the potential demand for the flow elements. Information about the maximum flow is needed to ensure the sufficient capacity of infrastructure facilities. Information about the minimum flow is also needed to determine the optimal placement of infrastructure facilities, assess the feasibility of their construction (in case they have not been built), and identify the personnel to recruit during periods of minimum load (to avoid downtime and/or unprofitable use of assets). Additionally, the information can resolve the issue of differentiation in tariff policy (e.g., in the case of charging a fee) by redistributing the load along the infrastructure corridor.

The methodology is explained in stages below.

### 2.2.1 Stage 1: Determination of the Potential Demand for Flow Elements

The calculations for potential demand for flow elements are based on statistical data about existing flows and their spatial and temporal characteristics. The demand for infrastructure services may fluctuate due to various factors, such as time (e.g., season and rest regime) and social factors (e.g., holidays and vacation campaigns). Therefore, it is necessary to calculate the maximum and minimum possible load on the flow.

The potential maximum demand can be estimated using the following formula:

$$PD = [(UV_{H} \times QH) + (UV_{B} \times QB)] \times NUFmax$$

- $UV_H$ – Average volume of service use of a specific flow by households (as recorded by state statistics bodies, e.g., average consumption of kW of electricity by households);

- QH – Number of households in a given region (average for the period);

- $UV_B$ – Average volume of service use of a specific flow by business units, social facilities and local government entities (as recorded by state statistics bodies, e.g., average consumption of kW of electricity for industrial purposes);

- QB – Number of business units, social facilities and local government entities; and

- NUFmax – The non-uniformity factor taking into account the maximum flow concentration caused by uneven load, which can be calculated by the following formula:

$$NUFmax = Kmcmax \times Kdcmax \times Khcmax$$

- Кmcmax – The highest concentration factor by months of the year, which is selected as the maximum of all the obtained values of Кmci

  Кmci = Qdi / Q

  - Qdi – Average daily load in i-th month; and
  - Q – Average daily load for the year, Q = QΣ / 365, (QΣ – total flow load for the period).

  For example, the total load for January is 115 units, February is 110 units, March is 120 units etc., and total load for the year is 1,400 units, the calculations are as follows:

Q = QΣ / 365 = 1400 / 365 = 3.83 (average daily load per year)

Кmc jan (31 days in month) = Qdi / Q = (115 / 31) / 3.83 = 0.96;
Кmc feb (28 days in month) = Qdi / Q = (110 / 28) / 3.83= 1.025;
Кmc march (31 days in month) = Qdi / Q = (120 / 31) / 3.83 = 1.01; etc.

Since February is the month with the maximum Кmc value, then Кmc max = 1.025.

- Кdcmax – The highest concentration factor by days of the week, which is selected as the maximum of all obtained values Кdci

  Кdci = Qwi / Q

  - Qwi – Average daily load in the month of the highest load.

  For example, February is the month with the highest load:

  on Mondays: Week 1 – 3.92; Week 2 – 3.8; Week 3 – 3.8; Week 4 – 3.9

  on Tuesdays: Week 1 – 3.3; Week 2 – 3.1; Week 3 – 2.9; Week 4 – 3.0
  – etc.

  Average on Mondays – (3.92 + 3.8 + 3.8 + 3.9) / 4 = 3.85
  Average on Tuesdays – (3.3 + 3.1 + 2.9 + 3.0) / 4 = 3.75
  etc.

  Since Mondays have the highest load:
  Кdc first monday i = Qwi / Q = 3.92 / 3.83 = 1,023
  Кdc second monday i = Qwi / Q = 3.8 / 3.83 = 0.992
  Кdc third monday i = Qwi / Q = 3.8 / 3.83 = 0.992
  Кdc fourth monday i = Qwi / Q = 3.9 / 3.83 = 1.018

  Thus, the maximum value is the first Monday in February, Кdcmax = 1.023.

- Кhcmax – The highest concentration factor by hours of the day, which is selected as the maximum of all the obtained values Кhci

  Кhci = Qhi / Q

  - Qhi – Load in i-th hour; and
  - Qh – Average hourly load per year.

For example, on the first Monday in February (hourly, based on load):

1.00h – 0.05 units
3.00h – 0.02 units
…
8.00h – 0.1 units
…
10.00h – 0.12 units
…
12.00h – 0.15 units
…
15.00h – 0.17 units
etc.

Qh = Q / 24 = (QΣ / 365) / 24 = (1400 / 365) / 24 = 0.159

Кhc1 = Qhi / Q = 0.05 / 0.159 = 0.314
Кhc2 = Qhi / Q = 0.02 / 0.159 = 0.125

…

$Khc15 = Qhi / Q = 0.17 / 0.159 = 1.069$

The maximum load is at 15.00h, then $Khcmax = 1.069$

Thus, the first Monday in February at 15.00h is the peak load for the year.

Then, $NUFmax = Kmcmax \times Kdcmax \times Kdcmax = 1.025 \times 1.023 \times 1.069 = 1.12$

As a result, the maximum possible flow taking into account the maximum possible load caused by unevenness is obtained.

The potential minimum demand can be estimated using the following formula:

$$PD = [(UV_{H} \times QH) + (UV_{B} \times QB)] \times NUFmin$$

- $UV_{H}$ – Average volume of service use of a specific flow by households (as recorded by state statistics bodies, e.g., average consumption of kW of electricity by households);
- QH – Number of households in a given region (average for the period);
- $UV_{B}$ – Average volume of service use of a specific flow by business units, social facilities and local government entities (as recorded by state statistics bodies, e.g., average consumption of kW of electricity for industrial purposes);
- QB – Number of business units, social facilities and local government entities; and
- NUFmin – The non-uniformity factor taking into account the minimum flow concentration caused by uneven load, which can be calculated by the following formula:

  $$NUFmin = Kmcmin \times Kdcmin \times Khcmin$$

  - Kmcmin – The lowest concentration factor by months of the year, which is selected as the minimum of all the obtained values Kmci

    $$Kmci = Qdi / Q$$

    - Qdi – Average daily load in i-th month; and
    - Q – Average daily load for the period, $Q = Q\Sigma / 365$, ($Q\Sigma$ – total flow load for the period).
  - Kdcmin – The lowest concentration factor by days of the week, which is selected as the minimum of all obtained values Kdci

    $$Kdci = Qwi / Q$$

    - Qwi – Average daily load in the month of the lowest load.
  - Khcmin – The lowest concentration factor by hours of the day, which is selected as the minimum of all the obtained values Khci

    $$Khci = Qhi / Q$$

    - Qhi – Average hourly load on the day of lowest load.

The flow (maximum and minimum) can also be estimated in monetary terms using the following formula:

$$PDM' = [(d_{H} \times A_{H} \times QH) + (E_{B} \times QB)] \times NUFmax/min$$

- $d_{H}$ – Share of household spending on services of a specific flow;
- $A_{H}$ – Average household income (in national or other currency);
- QH – Number of households in a given region (average for the period);
- $E_{B}$ – Average cost of business units, social facilities and local government entities for services of a specific flow;

- QB – Number of business units, social facilities and local government entities; and

- NUFmax/min – The non-uniformity factor that takes into account the concentration (maximum or minimum) of the flow load caused by the uneven load.

Alternatively, the maximum and minimum possible cash flow during the period of maximum and minimum load can be calculated by introducing tariffs for relevant services into the formula, as follows:

$$PDM'' = [(UV_{\text{Н}} \times QH \times TP) + (UV_{\text{В}} \times QB \times TB)] \times NUF_{max/min}$$

- TP – Tariff for relevant services for households; and
- TB – Tariff for related services for businesses.

**An Example of Stage 1 Calculation**

This example aims to define the maximum possible flow for Internet traffic in monetary terms during the period of maximum load along the Almaty → Cholpon-Ata route using the formula:

$$PDM'' = [(UV_{\text{Н}} \times QH \times TP) + (UV_{\text{В}} \times QB \times TB)] \times NUF_{max}$$

- $UV_{\text{Н}}$ – Average volume of Internet traffic of households along the Almaty → Cholpon-Ata route per year – 30 GB;

- QH – Number of households in the region – 565,000 units;

- $UV_{\text{В}}$ – Average volume of Internet traffic of business units along the Almaty → Cholpon-Ata route per year – 100 GB;

- QB – Number of business units in the region – 4,000 units;

- TP – Tariff of Internet services for households (average per GB) – USD12; and

- TB – Tariff of Internet services for business units (average per GB) – USD36.

The formula for $NUF_{max}$ is:

$$NUF_{max} = K_{mcmax} \times K_{dcmax} \times K_{hcmax}$$

- Q – Average daily load for the period, $Q = Q_{\Sigma} / 365 = 17{,}350{,}000 / 365 = 47{,}534.24$ ($Q_{\Sigma}$ – total flow load for the period, $30 \times 565{,}000 + 100 \times 4{,}000 = 17{,}350{,}000$ GB).

Assuming that the highest concentration factor by months of the year $K_{mcmax} = 1.025$; highest concentration factor by day of the week $K_{dcmax} = 1.023$; and highest concentration factor by hours of the day $K_{hcmax} = 1.069$:

$$NUF_{max} = 1.025 \times 1.023 \times 1.069 = 1.1209$$

Therefore,

$$PDM'' = [(UV_{\text{Н}} \times QH \times TP) + (UV_{\text{В}} \times QB \times TB)] \times NUF_{max}$$
$$= [(30 \times 565{,}000 \times 12) + (100 \times 4{,}000 \times 36)] \times 1.1209 = \text{USD}244{,}132 \text{ million}$$

Based on the calculations, the maximum possible Internet traffic flow along the Almaty → Cholpon-Ata route is valued at USD244,132 million.

### 2.2.2 Stage 2: Determination of the Potential Increase or Decrease of Flow Due to Various Factors

The Delphi method can be applied to determine the potential increase or decrease of flow elements along the infrastructure corridor due to various factors, including geopolitical, macroeconomic, social and climatic factors.

The Delphi method is a process used to forecast impact by surveying and consolidating the opinions of a group of experts following receipt of information on existing traffic flows (e.g., volume of a particular type of service in physical or monetary terms, obtained from official statistical sources), and on the level of development of the economy, tourism, energy, ICT and other aspects, directly or indirectly related to the functioning of the infrastructure corridor. The experts assess the impact of various factors on traffic flow along the infrastructure corridor over several rounds of discussions, and the results are aggregated and shared.

It is recommended that the results are presented in the form of correction factors (Cf) to the existing volume of traffic flow. Thus, if experts believe that traffic flow will remain at the same level, the coefficient is Cf = 1. For decreased traffic, the coefficient is Cf < 1, and for increased traffic, the coefficient is Cf > 1.

The correction factor (Corf) reflects possible traffic changes due to various factors. For example, if the presence of alternative routes reduce traffic along the infrastructure corridor then Corf < 1. The active development of intercountry cooperation, import and export growth, and other favourable factors will contribute to Corf > 1.

Information received from experts in the form of coefficients Cfi and Corfi for each infrastructure corridor flow are arranged in order from smallest to largest. The coefficient that is the median among the obtained estimates Cfi and Corfi can be considered representative of experts' opinion.

As a result, the calculation for Ti, Tj or any other traffic flow is as follows:

$$Ti = Tsi \times Cfi \times Corfi$$

- Tsi – Statistical data on existing traffic volumes in a given direction (flow) from one point of the infrastructure corridor to another along existing alternative routes.

**An Example of Stage 2 Calculation**

At stage 1, the calculation shows that the maximum possible Internet traffic flow along the Almaty → Cholpon-Ata route is valued at USD244,132 million.

Using the Delphi method, experts are of the opinion that the development of the Almaty–Cholpon-Ata infrastructure corridor (provided that this route is the shortest of all the existing ones), may increase Internet traffic from 18 to 40 per cent due to a significant influx of tourists and business development. The median in this case is 29 per cent. Thus, $Cf_i = 1.29$.

According to experts, the correction factor $Corf_i$ is positive due to an increase in Internet traffic during the COVID-19 pandemic as many social and commercial processes transition to a remote form. Experts estimate $Corf_i$ to be 20-40 per cent (median 30 per cent). Thus, $Corf_i = 1.3$.

As a result, taking into account the current situation, the value of Internet traffic along the Almaty → Cholpon-Ata route may increase, as follows:

$$Ti = \text{USD244,132 million} \times 1.29 \times 1.3 = \text{USD409,409 million}$$

Thus, the functioning of this infrastructure corridor under the assumed conditions can increase the flow of Internet traffic by 68 per cent.

### 2.2.3 Stage 3: Determination of the Influence of Flows

To determine the interconnection between various flow elements and their influence on each other, an interflow matrix can be developed based on the theory of flow and the flow method.

The theory of flow describes the flow between each pair of nodes at the end points of the flow (network) in forward and reverse directions, even though the forward and reverse flows may not coincide in intensity.[6]

The flow method is based on the simultaneity of work execution (flow of flows) one after another at an agreed rate. A thread is made up of separate sub-threads, each executing one process. All processes are divided into linear and concentrated flows. Linear flows repeat continuously and are relatively evenly distributed (traffic). Concentrated flows are unevenly distributed along the flow (switching points, loading-unloading, disembarking passengers).[7] The interflow matrix takes into account both linear and concentrated flows.

The calculation of the elements of the interflow matrix can be made by taking into account two factors – load and distance. Each factor is determined using the corresponding coefficients for load (Kl) and distance (Kd), and their combined influence is determined by the coefficient (Kg). The formulae for calculating these coefficients are as follows:[8]

- Coefficient of interflow by load (Kl) –

$$Kl\ (i, j) = Tj / (G – Ti)$$

  - Ti – Traffic of the i-th flow;
  - Tj – Traffic of the j-th flow; and
  - G – Total traffic along the infrastructure corridor.

---

[6] Боговик А.В., Губская О.А. Шляпников А.А. Анализ методов маршрутизации и распределения потоков информации в перспективных информационно-измерительных системах. Проблемы технического обеспечения войск в современных условиях. Труды IV межвузовской научно-практической конференции. С.-Петербург, 2019. С. 122-126.

[7] Формирование матрицы информационного тяготения. Available at https://studfile.net/preview/5157346/page:5/.

[8] Поточный метод строительства дорог. Available at http://stroy-technics.ru/article/potochnyi-metod-stroitelstva-dorog.

Since there are different types of flow, it is advisable to calculate the load in monetary terms. In this case, the normalization condition must be observed, as follows:

$$\sum_j T(i, j) = 1, i \neq j$$

- Coefficient of interflow by distance (Kd) –

$$Kd(i, j) = [\sum_j (1/d(i, j))]^{-1} / d(i, j)$$

  - d (i, j) – Distance between points of flow, namely points of concentrated processes.

From the coefficients calculated, an interflow matrix can be formed, as shown in Table 3.

Table 3: Template for interflow matrix

| | Flow i, 1 | Flow i, 2 | … | Flow i, n |
|---|---|---|---|---|
| Flow j, 1 | | | | |
| Flow j, 2 | | | | |
| … | | | | |
| Flow j, m | | | | |

When the calculated coefficients of interflow are greater, the interconnection between the flows will also be greater. Therefore, it is advisable to develop these flows in parallel and form uniform standards for their operation.

**An Example of Stage 3 Calculation**

This example aims to create the interflow matrix by load for linear processes along the Almaty–Cholpon-Ata infrastructure corridor, assuming the following flows:

- Tourist and other passenger traffic;
- Freight flow (freight transportation);
- Energy flow (electricity consumption); and
- Data flow (Internet traffic).

The load will be calculated in monetary terms. The methodology for calculating the load (e.g., Internet traffic) is given above in the examples for stages 1 and 2. This example calculates the above-listed flows in separate directions Almaty → Cholpon-Ata and Cholpon-Ata → Almaty. Based on statistical data, a table of flow volumes can be created (Table 4).

Based on the following formula for calculating the coefficient of interflow by load (*Kl*), the interflow matrix is created (Table 5):

$$Kl(i, j) = \frac{Tj}{G - Ti}$$

## Table 4: Flow volumes

| **Flow type** | **Statistical data, Ts (i, j) in USD million** | **Cf (i, j)** | **Corf (i, j)** | **Flow including correction factors, T (i, j)<br>Ti = Tsi × Cfi × Corfi** |
|---|---|---|---|---|
| | | *Expert assessments* | | |
| Almaty → Cholpon-Ata (*i*-th flow)* | | | | |
| Passenger transportation | 450.0 | 1.375 | 0.75 | 464.1 |
| Freight transportation | 356.1 | 1.2 | 0.8 | 341.8 |
| Internet traffic*** | 229.5 | 1.375 | 1.3 | 410.23 |
| Energy flow | 211.5 | 1 | 1.1 | 233.65 |
| Cholpon-Ata → Almaty (*j*-th flow)** | | | | |
| Passenger transportation | 200.8 | 1.25 | 0.9 | 225.9 |
| Freight transportation | 17.4 | 1.0 | 0.85 | 14.8 |
| Internet traffic | 7.5 | 1.205 | 1.35 | 12.2 |
| Energy flow | 78.6 | 1 | 1 | 78.6 |
| **Total, *G*** | | | | **1,780.28** |

Notes: * Data for 2019 from https://stat.gov.kz/ in USD at the exchange rate for the specified period.
** Data for 2019 from http://www.stat.kg/ru/ in USD at the exchange rate for the specified period.
*** Calculated in the examples above for stages 1 and 2.

## Table 5: Example of interflow matrix

| Almaty<br>Cholpon-Ata | **Passenger transportation** | **Freight transportation** | **Internet traffic** | **Energy flow** |
|---|---|---|---|---|
| **Passenger transportation** | $\frac{464.1}{1780.28-225.9}=$ **0.2985** | $\frac{341.8}{1780.28-225.9}=$ 0.2198 | $\frac{410.23}{1780.28-225.9}=$ **0.2639** | $\frac{232.65}{1780.28-225.9}=$ 0.1496 |
| **Freight transportation** | $\frac{464.1}{1780.28-14.8}=$ **0.2628** | $\frac{341.8}{1780.28-14.8}=$ 0.1936 | $\frac{410.23}{1780.28-14.8}=$ 0.2323 | $\frac{232.65}{1780.28-14.8}=$ 0.1317 |
| **Internet traffic** | $\frac{464.1}{1780.28-12.2}=$ **0.2624** | $\frac{341.8}{1780.28-12.2}=$ 0.1933 | $\frac{410.23}{1780.28-12.2}=$ 0.2320 | $\frac{232.65}{1780.28-12.2}=$ 0.1315 |
| **Energy flow** | $\frac{464.1}{1780.28-78.6}=$ **0.2727** | $\frac{341.8}{1780.28-78.6}=$ 0.2008 | $\frac{410.23}{1780.28-78.6}=$ 0.2410 | $\frac{232.65}{1780.28-78.6}=$ 0.1367 |

As the results in Table 5 show, the maximum interflow (0.2985) is observed between passenger flows. Thus, it is necessary to develop passenger transportation not only in the direction of Almaty → Cholpon-Ata (mainly of a tourist nature), but also in the direction of Cholpon-Ata → Almaty, where, based on the shortest distance of the infrastructure corridor, a significant increase in the number of passengers is likely (for business, personal travel and tourism).

Moreover, passenger transportation in the direction of Almaty → Cholpon-Ata has a high level of influence on the following flows:

- Internet traffic – 0.2639; and
- Energy flow – 0.2727.

This indicates that an increase in passenger transportation, including tourist traffic, is highly likely to lead to an increase in Internet traffic and energy flow. Thus, it is advisable to develop the ICT and energy infrastructures simultaneously with the deployment of the infrastructure corridor. There is also a significant interconnection between passenger and freight traffic in both directions. In the Almaty → Cholpon-Ata direction, there is significant interconnection between freight transportation, Internet traffic and energy flow, which necessitates the improvement of the ICT and energy infrastructures, particularly in Kyrgyzstan.

Considering that most infrastructure corridors experience two or more types of flow (e.g., a passenger flow can be a user of data flows, and freight flows can be consumers of energy flow), the quantitative cross elasticity of demand can be used to measure the degree of interdependence and mutual influence of related flows, as follows:

$$\text{Quantitative cross elasticity of demand (QED)} = \frac{\text{Percentage change in price for flow of service A}}{\text{Percentage change in price for flow of service B}}$$

Depending on the nature and degree of interconnection of flows, the QED indicator can be positive, negative or equal to zero. If QED < 0, then an increase in prices or tariffs for flow of service A will lead to a decrease in demand for services of a connected flow. For example, an increase in prices for passenger transportation will lead to a decrease in demand for data flow services consumed by users of passenger transportation services.

### 2.2.4 Stage 4: Determination of the Existing and Reserve Capacities

At this stage, the existing and reserve capacities of the various types of flow are compared (Eci) with the needs for a given flow (Nci), defined in stage 2.

In the case that existing and reserve capacities of the infrastructure, according to their technical characteristics, are capable of meeting the flow needs (Eci > Nci), it can be concluded that there is no need to deploy additional infrastructure. However, in the case that existing and reserve capacities of the infrastructure are not capable of meeting the flow needs (Eci < Nci), it can be concluded that there is a need to deploy new infrastructure.

**An Example of Stage 4 Calculation**

In the previous stages, it was determined that the functioning of the Almaty–Cholpon-Ata infrastructure corridor under the assumed conditions can increase the flow of Internet traffic by 78.74% (from USD229.5 million to USD410.23 million). Existing capacities provide 100 per cent of the demand for existing traffic, and reserve capacities can cover (approximately) another 10 per cent of traffic growth. Therefore, $Eci < Nci$. Deficit ($Di$) is for about 62 per cent of traffic. Based on the calculations, it is necessary to deploy new infrastructure to meet the expected growth in Internet traffic. To determine the required amount of additional equipment ($EcAdi$), the following formula is used:

$$EcAdi = \frac{Di}{Thri}$$

- $Di$ – Existing capacity deficit; and
- $Thri$ – Average statistical indicator (industry average or regional average) for the capacity of a unit of power (in monetary terms). This indicator can be based on existing statistical data or on information provided by specialized enterprises (e.g., the average profitable value of a piece of equipment or the average profitability of one lane of the route for one transport mode).

## 2.3 Determination of Scenarios for Infrastructure Corridor Development

In this section, various scenarios are introduced for both the development of the infrastructure corridor as a whole and the development of infrastructure facilities (e.g., roads, railways, power lines and fibre-optic communications lines) along the infrastructure corridor.

The scenario for the development of an infrastructure facility is represented as Sft, where the subscript (t) denotes the type of infrastructure, and the superscript (f) denotes possible action within the scenario. Within this framework, the focus is on four types of infrastructure:

- Road (t = rd);
- Railway (t = rw);
- Power line (t = eg); and
- Fibre-optic communications line (t = it).

However, it should be noted that the technique can potentially be extended to other types of infrastructure (e.g., oil and gas pipelines, and radio relay communications lines). Regarding possible actions, the following options are used:

- The need to build a new infrastructure in its absence (f = n);
- The need for reconstruction, for example, to expand the capacity of the infrastructure (f = r); and
- The absence of the need for any action, for example, if the existing infrastructure fully meets specified needs (f = 0).

A basic scenario for infrastructure corridor development can be created with this technique. For example:

- Snrd describes a scenario involving the construction of a new road along the infrastructure corridor;
- Srrw describes a scenario involving the reconstruction of an existing railway along the infrastructure corridor; and
- S0it describes a scenario requiring no action on the fibre-optic communications line along the infrastructure corridor because it already exists and fully meets all existing and future needs.

In another example, the designation { Srrd , S0rw , S0eg , Snit } describes a scenario involving the reconstruction of the road and the laying of a new fibre-optic communications line along the infrastructure corridor. The scenario also indicates that no action is needed on the railway and power line either because they fully satisfy existing and future demands, or they are not needed.

Table 6 describes a method for determining the development scenario for an existing infrastructure. The method is based on a true or false analysis of three statements that examine the state of the infrastructure, its fulfilment of the economic and technological needs (e.g., whether the capacity of an existing road can meet the potential increase in freight traffic), and the presence or absence of an alternative infrastructure to meet needs. For example, the transportation of goods can be provided by both road and rail. Therefore, an economic assessment may be required to compare the scenarios for improving an existing infrastructure and constructing a new one along the infrastructure corridor.

Table 6 shows eight different situations. In three situations, it is assumed that the infrastructure needs to be reconstructed (Sr), in two situations, no action is needed (S0), and in three situations, an alternative infrastructure should be considered (Sr|S0). If a sub-scenario is included for the construction of a new railway to fully meet the needs of passenger and freight traffic, it is advisable to also include a sub-scenario that requires no action for the road, even if this road in its current state cannot cope with passenger and freight flows.

### Table 6: Example of determining the development scenario for an existing infrastructure

| Option | Characteristics of the infrastructure | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| The infrastructure needs improvement due to the unsatisfactory condition of its segments | + | + | + | + | – | – | – | – |
| The infrastructure meets economic and technological needs | + | + | – | – | + | + | – | – |
| A new infrastructure is the only way to meet economic and technological needs | + | – | + | – | + | – | + | – |
| **Scenario** | $S^r$ | $S^r \mid S^0$ | $S^r$ | $S^r \mid S^0$ | $S^0$ | $S^0$ | $S^r$ | $S^r \mid S^0$ |

Notes: + = true statement; – = false statement.

Table 7 describes a method for determining the development scenario for a new infrastructure. Similar to Table 6, the method is based on a true or false analysis of two statements related to demand and the presence or absence of alternative options to meet demands.

### Table 7: Example of determining the development scenario for a new infrastructure

| Option | Characteristics of the infrastructure | | | |
|---|---|---|---|---|
| The intensity of economic and technological flows demonstrates the need to build a new infrastructure | + | + | – | – |
| A new infrastructure is the only way to meet economic and technological needs | + | – | + | – |
| **Scenario** | $S^n$ | $S^n \mid S^0$ | $S^0$ | $S^0$ |

Notes: + = true statement; – = false statement.

Table 7 shows four different situations. In one situation, it is assumed that a new infrastructure is needed (Sn), in two situations, no action is needed (S0), and in another situation, further assessment may be required (Sn│S0). If the analysis shows that either a new road or a new railway is needed to cope with passenger and freight traffic, then only one of the two sub-scenarios will be included. But for other scenarios, an alternative sub-scenario may be needed. This approach allows comparison from an economic and technological point of view to assess which scenario best meets current and future needs.

Using the method suggested in Tables 6 and 7, a set of N basic scenarios for infrastructure corridor development can be formed, each of which defines four sub-scenarios (one for each type of infrastructure) for the construction of a new infrastructure, improvement or reconstruction of an existing one, or no action is required. The number of scenarios will depend on the number of infrastructures under consideration and possible alternative scenarios for their development. Generally, there will be about 15 scenarios based on the formula: t2 – 1, where t is the number of infrastructure types, which is four in this case (road, railway, power line and fibre-optic cables).

Subsequently, M additional scenarios can be added to the N basic scenarios for infrastructure corridor development to include the co-deployment of transport and energy infrastructures with the ICT infrastructure. Based on the four infrastructure types, there will generally be a maximum of 11 additional scenarios, and the total number of possible scenarios does not exceed 26. The scenarios for developing new infrastructures based on the principles of co-deployment can be denoted as Snrd+it , Snrw+it and Sneg+it to represent the co-deployment of the ICT infrastructure with roads, railways and power lines, respectively.

To further elaborate on the methodology for determining scenarios for infrastructure corridor development, additional examples are presented in Tables 8 and 9. Table 8 provides an example of assessing the state of infrastructures along the corridor, and Table 9 provides an example of the results of comparing the characteristics of economic and technological flows with the existing capacity of the infrastructures along the corridor.

Table 8: Example of assessing the state of infrastructures along the infrastructure corridors

| Example no. | Condition of infrastructure | | | |
|---|---|---|---|---|
| | Road | Railway | Power line | Fibre-optic communications line |
| I | +/– | + | + | + |
| II | + | – | +/– | – |
| III | – | – | – | – |

Notes: – = No infrastructure of this type; + = This infrastructure type exists and does not require reconstruction; and +/– = This infrastructure type exists, but requires reconstruction due to its unsatisfactory condition.

Table 9: Example of economic and technological flows along the infrastructure corridors

| Example no. | Information on economic and technological flows | | | |
|---|---|---|---|---|
| | Passenger flow | Freight flow | Electric flow | Data flow |
| I | + | +/– | + | + |
| II | + | + | + | + |
| III | + | – | – | + |

Notes: – = No flow or the value of its intensity is insignificant; + = Flow is present and its intensity can be fully satisfied only by an infrastructure in a satisfactory state or a new infrastructure; and +/– = Flow is present, but its intensity is such that even an infrastructure in an unsatisfactory state can cope.

Using information from Tables 8 and 9 and the methods explained in Table 6 and 7, a set of development scenarios for the three examples above can be presented (Table 10).

Table 10: Example of a set of basic scenarios for the development of three infrastructure corridors

| Scenario no. | Infrastructure corridor | | |
|---|---|---|---|
| | Example I | Example II | Example III |
| 1 | $\{ S^{r}_{rd} , S^{0}_{rw} , S^{0}_{eg} , S^{0}_{it} \}$ | $\{ S^{0}_{rd} , S^{n}_{rw} , S^{r}_{eg} , S^{n}_{it} \}$ | $\{ S^{0}_{rd} , S^{n}_{rw} , S^{0}_{eg} , S^{n}_{it} \}$ |
| 2 | $\{ S^{0}_{rd} , S^{r}_{rw} , S^{0}_{eg} , S^{0}_{it} \}$ | $\{ S^{r}_{rd} , S^{0}_{rw} , S^{r}_{eg} , S^{n}_{it} \}$ | $\{ S^{n}_{rd} , S^{0}_{rw} , S^{0}_{eg} , S^{n}_{it} \}$ |
| 3 | $\{ S^{r}_{rd} , S^{r}_{rw} , S^{0}_{eg} , S^{0}_{it} \}$ | $\{ S^{r}_{rd} , S^{n}_{rw} , S^{r}_{eg} , S^{n}_{it} \}$ | $\{ S^{n}_{rd} , S^{n}_{rw} , S^{0}_{eg} , S^{n}_{it} \}$ |
| 4 | $\{ S^{0}_{rd} , S^{0}_{rw} , S^{0}_{eg} , S^{0}_{it} \}$ | – | – |

In Example I, it is assumed that there are four basic scenarios for the development of the infrastructure corridor, each of which does not require any action on the power line and fibre-optic communications line, since their conditions are satisfactory and fully meet corresponding demands. Alternative scenarios are generated using a combination of sub-scenarios for reconstruction of only a road, only a railway, and both at the same time. The fourth scenario does not involve any action with any infrastructure. Such a scenario is valid only if the analysis shows that existing roads and railways are able to meet demands for passenger and freight traffic.

In Example II, it is assumed that there are three basic scenarios, each of which requires the construction of a new fibre-optic communications line due to its absence and the presence of data flow, and reconstruction of the power line due to its unsatisfactory condition and the presence of an increasing energy flow. Alternative scenarios are generated using a combination of sub-scenarios for construction of a new railway, reconstruction of an existing road, and the co-deployment of these two sub-scenarios.

In Example III, it is assumed that there are three basic scenarios, each of which requires the construction of a new fibre-optic communications line due to its absence and the presence of data flow, and the absence of the need to build a power line due to the absence of demand for electricity flow in this direction. Alternative scenarios are generated using a combination of sub-scenarios for construction of a new road, construction of a new railway, and the co-deployment of these two sub-scenarios.

It should be noted that in the above examples, Example I does not have additional scenarios, since there are no opportunities for co-deployment. In Examples II and III, however, opportunities for co-deployment of the transport infrastructure with the ICT infrastructure are present. In Example II, there are two additional scenarios, namely: {S0rd , Snrw+it , Sreg} and {Srrd , Snrw+it , Sreg}, and in Example III, there are four additional scenarios, namely: {S0rd , Snrw+it , S0eg }, {Snrd+it , S0rw , S0eg}, {Snrd+it , Snrw , S0eg} and {Snrd, Snrw+it , S0eg}. Thus, the total number of scenarios to consider for Example I is four, Example II is five and Example III is seven.

## 2.4 Determination of the Economic Efficiency of Scenario Implementation

The scenarios for infrastructure corridor development are likely to differ in the amount of investments required. The i-th scenario can require significant capital and operating expenses in comparison with other scenarios and a long payback period, thereby reducing the overall efficiency of the scenario and its attractiveness, in terms of forming partnerships for its implementation.

Due to the differences in the scenarios, it is advisable to analyse each scenario as a set of actions, each with its own characteristics (e.g., state of infrastructure, terrain topology, participating country). These characteristics affect the capital and operating investments required. Section 2.4.1 provides a methodology for determining the capital and operating expenses, and Section 2.4.2 provides a methodology for determining the efficiency of the scenarios.

### 2.4.1 Determining the Capital Investment for Deployment and Recurring Maintenance Costs

This methodology determines the capital investment required for deploying each i-th scenario (Ki), the recurring maintenance costs (ESi), the labour intensity of technological processes (LIi), and the cost of all consumables (QMi) for each infrastructure by taking into account the actions that must be performed for each scenario.

In order to determine the labour intensity for each infrastructure component, it is necessary to form a list of its technological processes. Each technological process, in turn, contains a set of technological elements. These elements can be divided into scalable and non-trivial elements. Scalable technological elements have in place standards for calculating labour intensity, while non-trivial technological elements do not have standardized technological processes and the corresponding labour intensity standards.

For scalable technological elements, it is possible to determine the cost of deploying and operating a unit of infrastructure by direct calculation (e.g., laying and maintaining 1km of road or 1 channel-kilometre of fibre-optic communications line on flat terrain).

For non-trivial technological elements without known economic and technological characteristics (e.g., constructing a mountain pass and laying a tunnel underwater), the calculations for capital and operating costs are based on the labour intensity of each technological element or on the standards and norms of labour costs for the most similar technological processes. This can be based on the standards or norms of labour costs for a certain type of work, on working time or on expert assessments that are averaged out for the entire length of the infrastructure.

The complexity of the processes can be adjusted using coefficients, taking into account various factors, namely:

- Кcc – Coefficient of accounting for the complexity of processes (e.g., complex topography of the area, and natural and climatic conditions), $1.01 < Кcc < 1.25$; and
- Кrd – Coefficient of the possibility of using standard technical solutions (e.g., use of ready-made software modules or technical designs), $0.85 < Кrd < 0.95$.

The processes for determining capital investments and recurring maintenance costs for the technological elements are summarized in Figures 4-8.

Figure 4: Processes for determining capital investment and recurring maintenance costs

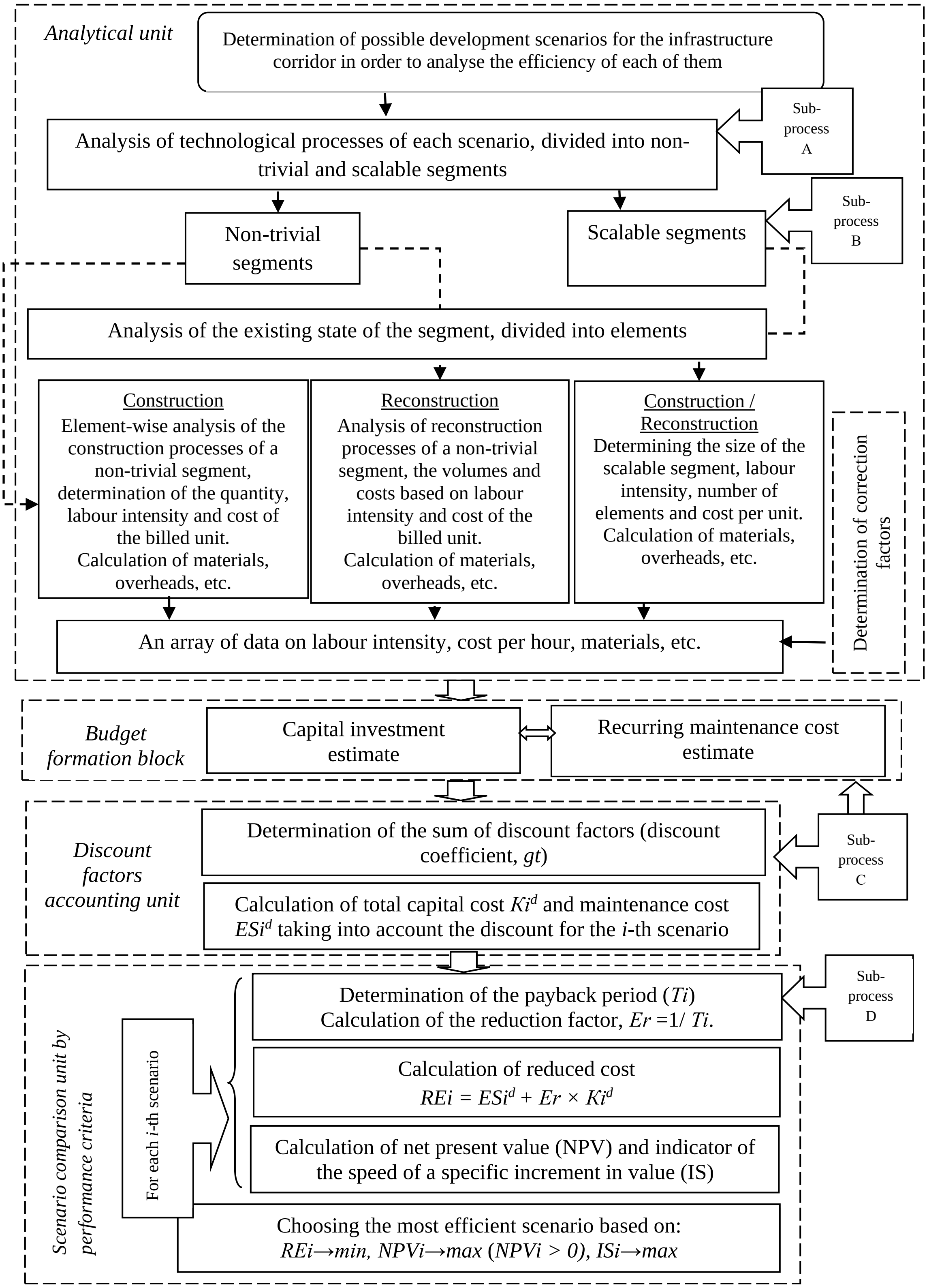


Figure 5: Sub-process A – Analysis of technological processes

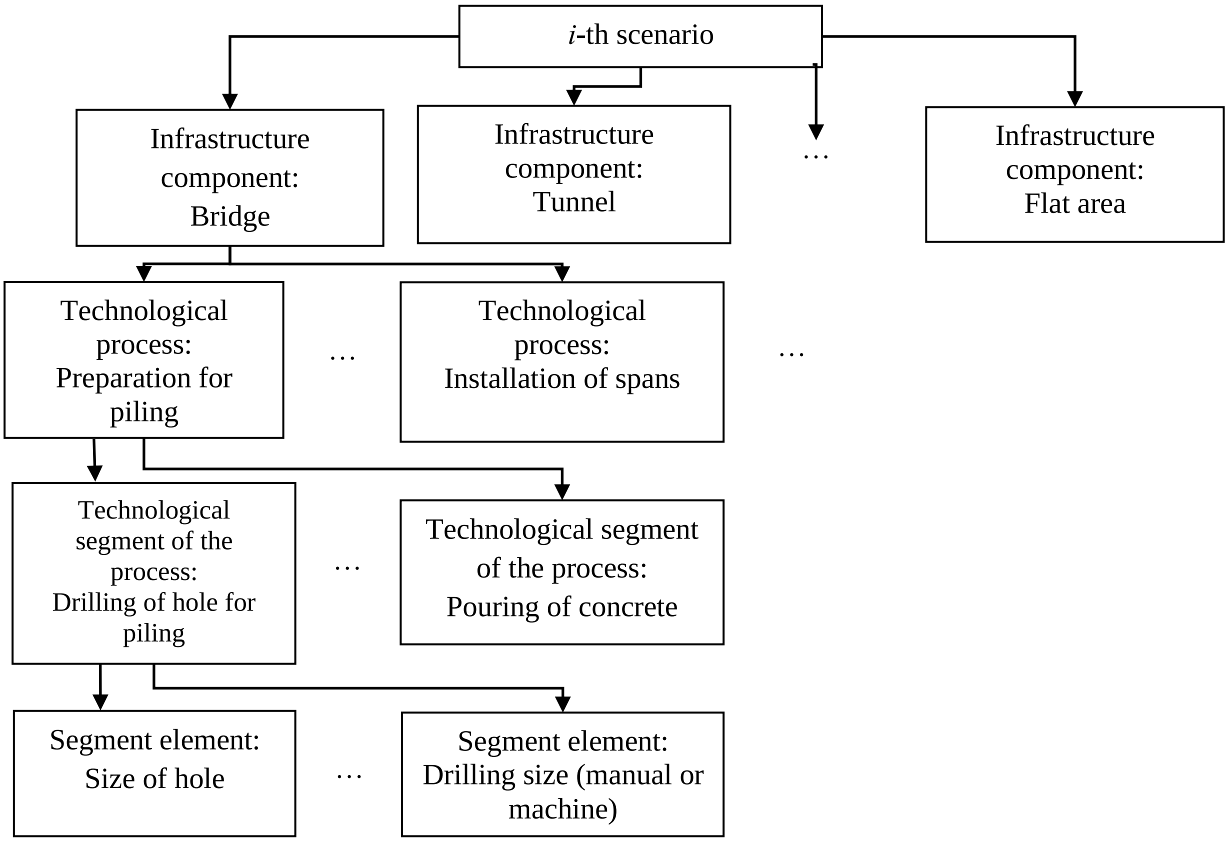


**Figure 6**: **Sub-process B – Analysis of technological elements by triviality or scalability**

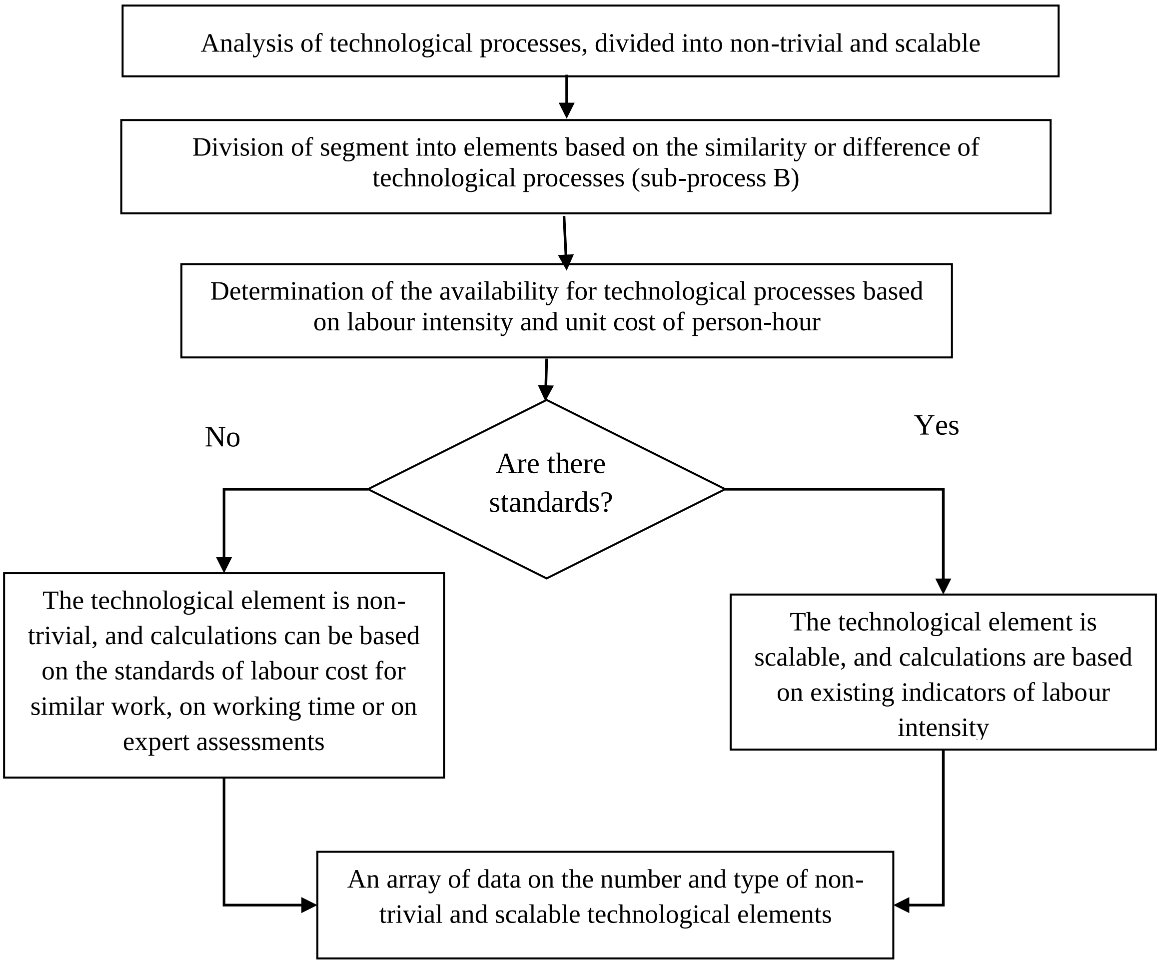


Figure 7: Sub-process C – Determination of discount factors

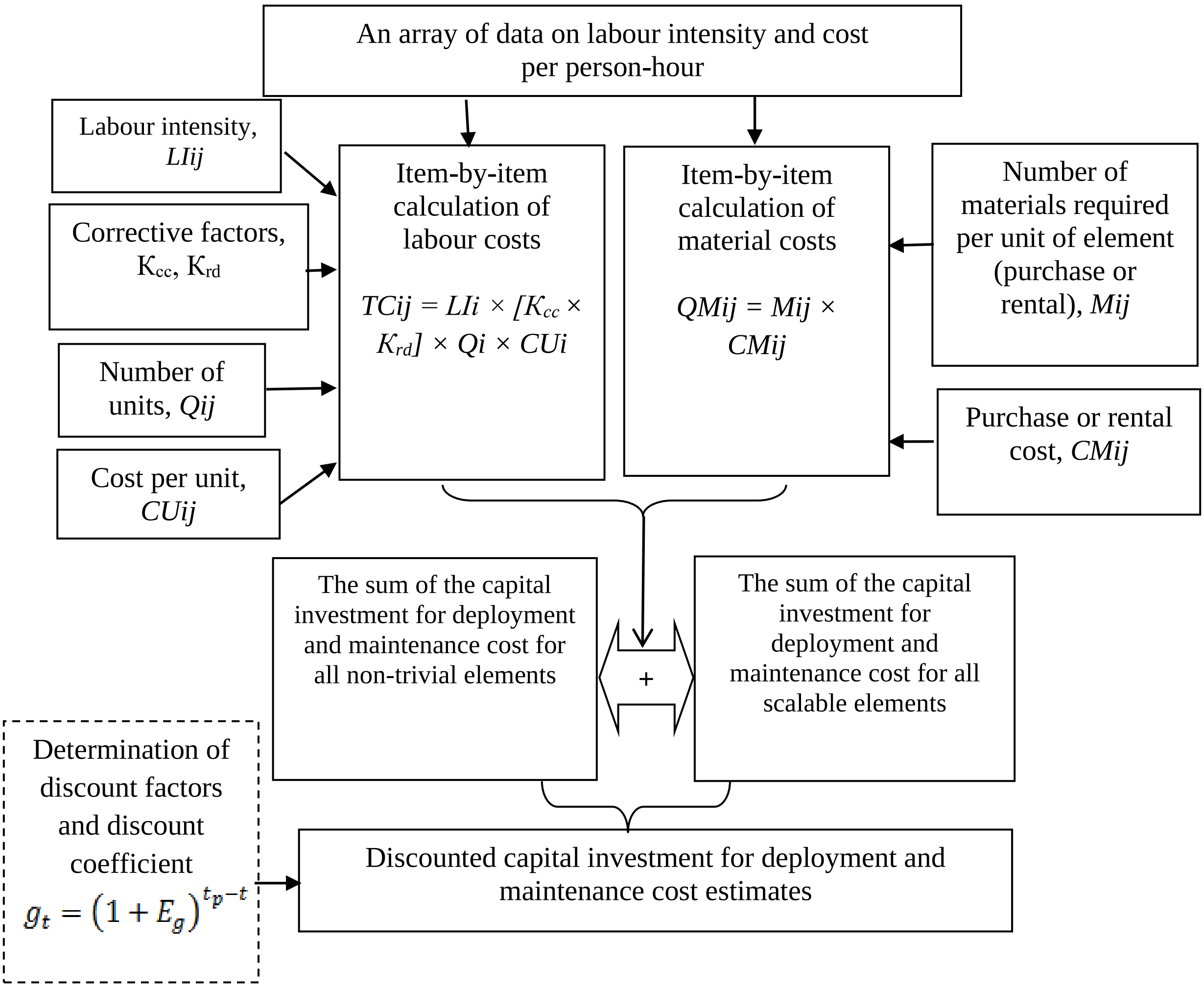
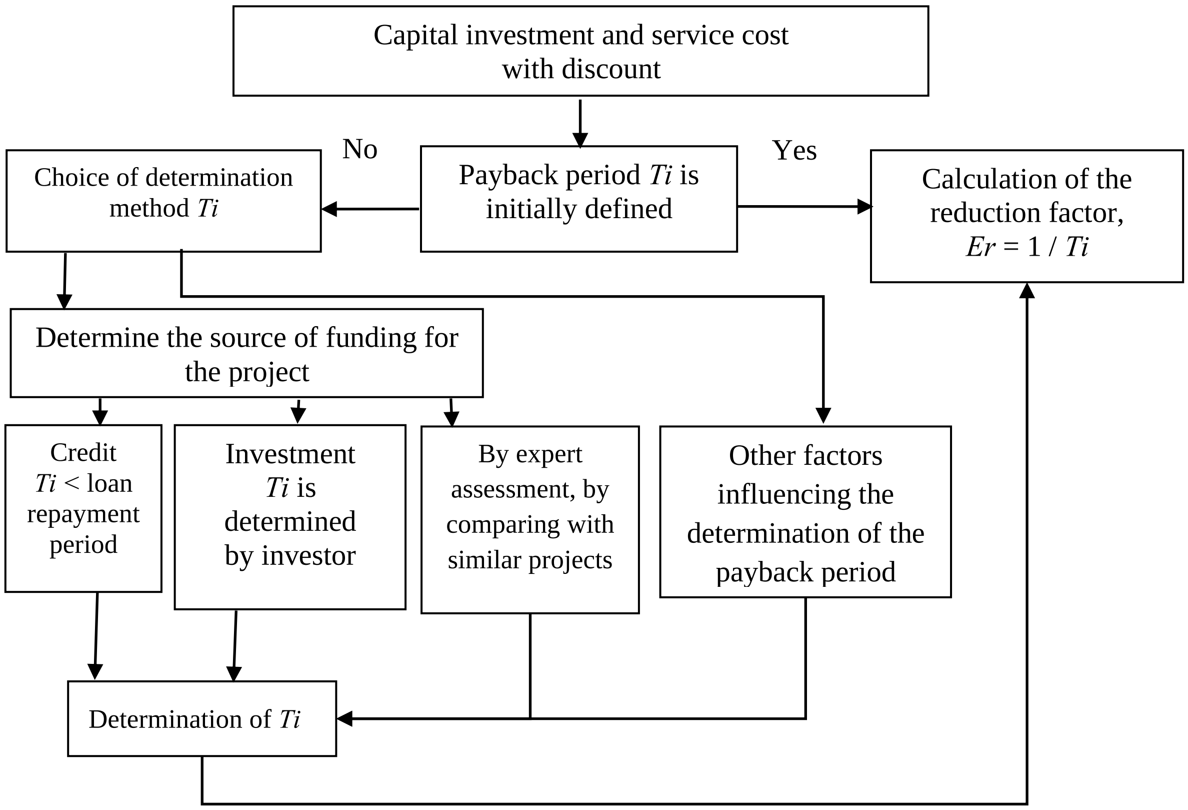


Figure 8: Sub-process D – Determination of the payback period



The described processes in Figure 4-8 are reflected in Tables 11 and 12.

Table 11: Cost of deploying and maintaining non-trivial segments

| ***J*-th element** | **Labour intensity (number of person-hours per unit), *LIij*** | **Value of the correction coefficients (if any), $К_{cc}$, $К_{rd}$** | **Number of units, *Qij*** | **Unit cost, USD or national currency, *CUij*** | **Therefore for *j*-th element of *i*-th segment, $TCij = LIi \times [K_{cc} \times K_{rd}] \times Qi \times CUi$** |
|---|---|---|---|---|---|
| **Deployment of a segment (Drilling of hole for piling)** | | | | | |
| Method A (determining size of hole) | | | | | |
| Method A.1 (measurements) | | | | | |
| Method A.2 (check against plan) | | | | | |
| Method A.n | | | | | |
| Method B (machine drilling) | | | | | |
| Method B.1 (machine installation) | | | | | |
| Method B.2 (drilling process) | | | | | |
| Method B.m | | | | | |
| … | | | | | |
| Total labour cost | | | | | $TCX = \Sigma TCij$ |
| **Service** | | | | | |
| ***L*-th service unit** | **Labour intensity (number of person-hours per unit), *LIil*** | **Value of the correction coefficients (if any), $К_{cc}$, $К_{rd}$** | **Number of units, *Qil*** | **Unit cost, USD or national currency, *CUil*** | **Total for the *l*-th element, $TCil = LIi \times [K_{cc} \times K_{rd}] \times Qi \times CUi$** |
| Method C (regular check) | | | | | |
| Method C.1 (field visit) | | | | | |
| Method C.2 (verification) | | | | | |
| Method C.n | | | | | |
| Method D (defect detection) | | | | | |
| Method D.1 (flaw detector analysis) | | | | | |
| Method D.2 | | | | | |
| Method D.m | | | | | |
| … | | | | | |
| Total maintenance labour | | | | | $TCS = \Sigma TCil$ |

**Item-by-item estimate of materials**

| | **Amount of materials required, *Mij*** | **Purchase or rental cost (including transportation and other costs), USD or national currency, *CMij*** | **Total for the *j*-th element** |
|---|---|---|---|
| Materials for | | | $A = Mij \times CMij$ |

| | | | |
|---|---|---|---|
| deployment A, detailed | | | |
| Service materials B, detailed | | | *B = Mij × CMij* |
| … | | | |
| Total materials | | | *ME = A + B* |
| **Grand total** | | | *ENTE = TCS+TCX+ME* |

**Table 12: Cost of deploying and maintaining scalable segments**

| ***J*-th element** | **Labour cost per billed unit, *Mij*** | **Person-hour cost, *CMij*** | **Number of person-hours, *Vij*** | **Total, *QMij = Mij×CMij×Vij*** |
|---|---|---|---|---|
| **Deployment of a segment** | | | | |
| Method E | | | | |
| Method E.1 | | | | |
| Method E.2 | | | | |
| Method E.n | | | | |
| Method F | | | | |
| Method F.1 | | | | |
| Method F.2 | | | | |
| Method F.m | | | | |
| … | | | | |
| Total | | | | *QMX = Σ QMij* |
| **Segment service** | | | | |
| ***L*-th service process** | **Labour cost per billed unit, *Mil*** | **Person-hour cost, *CMil*** | **Number of person-hours, *Vil*** | **Total, *QMil = Mil×CMil×Vil*** |
| Method G | | | | |
| Method G.1 | | | | |
| Method G.2 | | | | |
| Method G.n | | | | |
| Method H | | | | |
| Method H.1 | | | | |
| Method H.2 | | | | |
| Method H.m | | | | |
| … | | | | |
| Total Service | | | | *QMS = Σ QMil* |

| **Item-by-item estimate of materials** | | | |
|---|---|---|---|
| | **The amount of materials, equipment, etc. required per unit (purchase or lease), *Mij*** | **Purchase or rental cost (including transportation and other costs), USD or national currency, *CMij*** | **Total** |
| Deployment materials C, detailed | | | *C = Mij × CMij* |
| Service materials D, detailed | | | *D = Mij × CMij* |
| … | | | |
| Total materials | | | *QM = C + D* |
| **Grand total** | | | *ESE=QMX+QMS+QM* |

The total capital investment for a deployment is the sum of similar indicators for scalable and trivial elements:

$$Ki = TCX + A + QMX + C$$

The total maintenance cost is the sum of similar indicators for scalable and trivial elements:

$$ESi = TCS + B + QMS + D$$

It is necessary to take into account the discounting processes by determining the sum of the discount factors (gt) that have the greatest impact on each i-th scenario of the infrastructure corridor. The most significant factors include the dynamics of inflation (DI), the refinancing rate of the national bank of the country or international financial institutions (RR) (in the case of attracting credit funds for deployment of the infrastructure corridor), and the level of risk (RL).

These factors can be different for different scenarios, especially the risk factor. Thus, the numerical value of the discount factors can be determined separately for each scenario based on the statistical indicators for each factor (in fractions or percentages). As a result, the sum of the discount factors is:

$$Eg = DI + RR + RL$$

The discount factor is determined by the formula:

$$gt = (1 + Eg)tp-t$$

- t – Year under research; and
- tp – Point in time at which value indicators lead.

The discount coefficient may be less than one in the event of deflation, a decrease in refinancing rates of national banking institutions, a reduction in risks and other circumstances.

Then, the total capital investment for deployment, taking into account discounting is:

$$Kid = Ki \times gt$$

The total maintenance cost, taking into account discounting is:

$$ESid = ESi \times gt$$

The total sum of these indicators for each i-th scenario makes it possible to compare the efficiency of the various infrastructure corridor development scenarios.

### 2.4.2 Determining the Economic Efficiency of Infrastructure Corridor Development Scenarios

Due to significant differences between the scenarios for infrastructure corridor development, the selection of the most promising scenario for implementation should not be based solely on the least cost option. A six-stage methodology is detailed below to determine the economic efficiency of infrastructure corridor development scenarios.

**Stage 1: Formation of indicators of capital investments and maintenance costs for each i-th scenario**

The methodology for determining these indicators is described in Section 2.4.1.

**Stage 2: Determination of the payback period (Ti) for each i-th scenario**

The payback period can be determined in various ways:

- At the discretion of the investor;
- Based on the interests of potential project partners;
- Based on the terms of the loan allocated for the project;
- Based on average payback stock (for a given class of projects); and
- Expert assessments.

### Stage 3: Calculation of the reduced costs for each i-th scenario

Reduced costs (REi) are calculated using the formula:

$$REi = ESid + Er \times Kid$$

- ESid – Total service cost, discounted;
- Kid – Total capital investment for deployment, discounted; and
- Er – Efficiency ratio of the i-th scenario, which shows the capital investment that should be recovered in one year. Hence,

$$Er = \frac{1}{Ti}$$

### Stage 4: Calculation of net cash flow for each i-th scenario

The net present value (NPV) is calculated using the formula:

$$NPV = CFdisc - Kid$$

- CFdisc – Discounted cash flow for the entire period, CFdisc = ΣCF × gt

The cash flow (CF) is defined as the net profit (NP) under the i-th scenario plus depreciation (D):

$$CF = NP + D$$

Net profit (NP) is defined as the difference between profit (P) and income tax (InTax, translated into unit shares), in the country of deployment of the i-th scenario or in accordance with an intercountry agreement (in the case when the infrastructure corridor affects the interests of different countries):

$$NP = P \times (1 - InTax)$$

Depreciation (D) is defined as the product of the initial cost of each type of production asset and the depreciation rate for the corresponding type of asset. The depreciation rate is selected based on the current legal framework or by direct calculation using straight-line or cumulative method.

The calculation of the annual profit is based on the expected traffic (for all infrastructure types), which is described in Section 2.2. Traffic in monetary terms (Ti,j) is taken to be equal to the expected income (EI).

Note that the greater the flows in a given scenario (e.g., passenger transportation, freight transportation, etc.) and the greater the interflow between them (as described in Section 2.2), the greater the expected income from each flow and, as a consequence, the greater the expected total profit. The formula for calculating profit is:

$$P = EI - VAT - ESid$$

- EI – Expected income;
- VAT – Valued-added tax; and
- ESid – Maintenance costs in the current year described in Section 2.4.1.

### Stage 5: Calculation of growth rate index

The indicator of the speed of a specific increment in value (IS) is calculated using the formula:

$$IS = \frac{NPV}{Ti \times ESi^{d}}$$

- Ti – Estimated payback period determined at stage 2.

### Stage 6: Determination of the most efficient scenario from an economic point of view

The most efficient scenario is one that meets the following conditions:

REi → minimum, NPVi → maximum (for all NPVi > 0), Isi → maximum

Table 13 shows an example of the calculations for determining the most efficient scenario. The example finds that Scenario 3 is the most efficient from an economic point of view (provided that the discount factor is the same for all scenarios), since REi = 123.0 (minimum), NPV = 70 (maximum), and Isi = 0.048 (maximum).

In addition to economic efficiency, determined by capital investments and maintenance costs, other factors can be taken into consideration, including:

- Social and geopolitical factors associated with conditions for providing households and/or businesses with services along the infrastructure corridor; and
- Ecological factors associated with an assessment of environmental impacts during infrastructure corridor development and its subsequent operation.

Table 13: Calculations to determine the most promising scenario for infrastructure corridor development

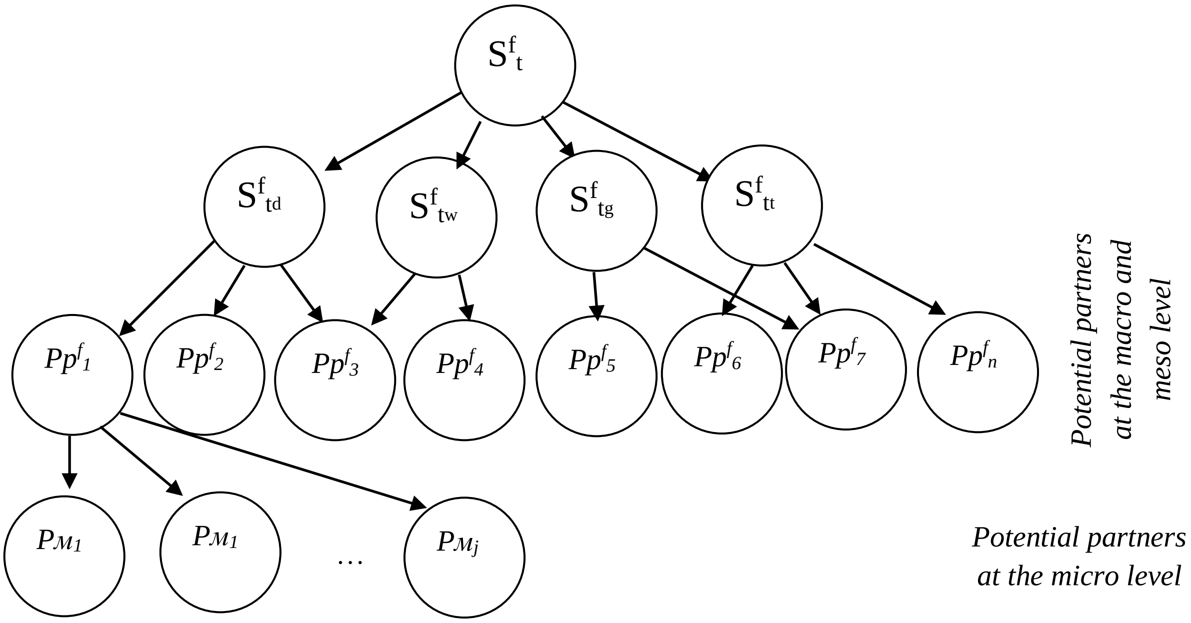
| **Scenario** | **Total sum of capital investment, million c.u., $Ki^d$** | **Total service cost, million c.u., $ESi^d$** | **Payback period, *Ti*** | **Efficiency ratio, $Er = \frac{1}{Ti}$** | **Reduced cost, $REi = ESi^d + Er \times Ki^d$** | **Net cash flow, *NPVi*, million c.u.** | **Specific value growth rate index, *ISi*** |
|---|---|---|---|---|---|---|---|
| Scenario 1 | 350 | 55 | 4 | $\frac{1}{4} = 0.25$ | 55 + 0.25 × 350 = 142.5 | 64 | 0.3 |
| Scenario 2 | 480 | 150 | 8 | $\frac{1}{8} = 0.125$ | 150 + 0.12 × 480 = 207.6 | 11 | 0.0008 |
| Scenario 3 | 240 | 75 | 5 | $\frac{1}{5} = 0.2$ | 75 + 0.2 × 240 =123.0 | 70 | 0.048 |
| Scenario 4 | 365 | 80 | 3 | $\frac{1}{3} = 0.33$ | 80 + 0.33 × 365 = 200.45 | 25 | 0.004 |

## 2.5 Identification of the Optimal Form of Partnership for Scenario Implementation

The application of the graph theory can be used to identify the optimal combination of potential partners for the implementation of a promising scenario. In this approach, a hierarchical graph is formed that does not contain loops (Figure 9).

The first level (Sft scenario) is divided into sub-scenarios (Sftd, Sftw, Sftg, Sftt) that form the second level. In turn, each sub-scenario is further divided to form a third level that comprises of a list or group of partners (Ppfi) discussed in part one (Section 6) of this Infrastructure Corridor Development Series.

Figure 9: Model graph for selecting forms of partnership for scenario implementation (simplified form)



In this model, it is necessary to assess the feasibility and benefits of various forms of partnership for the different sub-scenarios (Sftd, Sftw, Sftg, Sftt). The forms of partnership (pij) can be assessed by experts using the following formula:

$$\sum_{j=1}^{N} pij = 1 \ (i = \overline{1,N})$$

As a result, the distribution of choices for one of the scenarios (Sftd, Sftw, Sftg, Sftt) and the distribution of choices for the optimal partner or group of partners can be obtained. Next, the numerical value of the total estimates for each path is determined as the product of the obtained pij. This gives an array of numerical assessments and the optimal form of partnership is where Pij = maximum.

As an example, an assessment for choosing the optimal form of partnership for the development of the Almaty–Cholpon-Ata infrastructure corridor, based on the model graph in Figure 9 is presented in Table 14.

Table 14: Choosing the optimal form of partnership for the development of the Almaty–Cholpon-Ata infrastructure corridor

| **Basic scenario for the development of the Almaty–Cholpon-Ata infrastructure corridor** | | | |
|---|---|---|---|
| **Sub-scenario $S^f_{td}$ (reconstruction of road)** | **Sub-scenario $S^f_{tw}$ (reconstruction and/or laying of railway)** | **Sub-scenario $S^f_{tg}$ (reconstruction of power lines)** | **Sub-scenario $S^f_{tt}$ (reconstruction and/or laying of fibre-optic communications line)** |
| *Expert assessment of the feasibility of choosing this scenario – 0.4* | *Expert assessment of the feasibility of choosing this scenario – 0.1* | *Expert assessment of the feasibility of choosing this scenario – 0.2* | *Expert assessment of the feasibility of choosing this scenario – 0.3* |
| *Expert assessment of the feasibility of choosing a form of partnership (at the macro and meso levels)* | | | |
| Forms of partnership: $Pp^f_1$ – public-private partnerships; $Pp^f_2$ – interstate agreements; $Pp^f_3$ – network structures; $Pp^f_4$ – holdings; $Pp^f_5$ – alliances; $Pp^f_6$ – financial and industrial groups; $Pp^f_7$ – outsourcing; and $Pp^f_n$ – other forms | | | |
| $S^f_{td}$ - $Pp^f_1$ – 0.05 | $S^f_{tw}$ - $Pp^f_1$ – 0.4 | $S^f_{tg}$ - $Pp^f_1$ – 0.05 | $S^f_{tt}$ - $Pp^f_1$ – 0.15 |
| $S^f_{td}$ - $Pp^f_2$ – 0.2 | $S^f_{tw}$ - $Pp^f_2$ – 0.25 | $S^f_{tg}$ - $Pp^f_2$ – 0.05 | $S^f_{tt}$ - $Pp^f_2$ – 0.05 |
| $S^f_{td}$ - $Pp^f_3$ – 0.05 | $S^f_{tw}$ - $Pp^f_3$ – 0.05 | $S^f_{tg}$ - $Pp^f_3$ – 0.05 | $S^f_{tt}$ - $Pp^f_3$ – 0 |
| $S^f_{td}$ - $Pp^f_4$ – 0.1 | $S^f_{tw}$ - $Pp^f_4$ – 0.05 | $S^f_{tg}$ - $Pp^f_4$ – 0.3 | $S^f_{tt}$ - $Pp^f_4$ – 0.3 |
| $S^f_{td}$ - $Pp^f_5$ – 0.3 | $S^f_{tw}$ - $Pp^f_5$ – 0 | $S^f_{tg}$ - $Pp^f_5$ – 0.35 | $S^f_{tt}$ - $Pp^f_5$ – 0.25 |
| $S^f_{td}$ - $Pp^f_6$ – 0.05 | $S^f_{tw}$ - $Pp^f_6$ – 0.05 | $S^f_{tg}$ - $Pp^f_6$ – 0 | $S^f_{tt}$ - $Pp^f_6$ – 0.05 |
| $S^f_{td}$ - $Pp^f_7$ – 0.2 | $S^f_{tw}$ - $Pp^f_7$ – 0.15 | $S^f_{tg}$ - $Pp^f_7$ – 0.05 | $S^f_{tt}$ - $Pp^f_7$ – 0.1 |
| $S^f_{td}$ - $Pp^f_n$ – 0.05 | $S^f_{tw}$ - $Pp^f_n$ – 0.05 | $S^f_{tg}$ - $Pp^f_n$ – 0.15 | $S^f_{tt}$ - $Pp^f_n$ – 0.1 |
| *Total scores for each path* | | | |
| $S^f_{td}$ - $Pp^f_1$ – *0.05×0.4=0.02* | **$S^f_{tw}$ - $Pp^f_1$ – *0.4×0.1=0.04*** | $S^f_{tg}$ - $Pp^f_1$ – *0.05×0.2=0.01* | $S^f_{tt}$ - $Pp^f_1$ – *0.15×0.3=0.045* |
| $S^f_{td}$ - $Pp^f_2$ – *0.2×0.4=0.08* | $S^f_{tw}$ - $Pp^f_2$ – *0.25×0.1=0.025* | $S^f_{tg}$ - $Pp^f_2$ – *0.05×0.2=0.01* | $S^f_{tt}$ - $Pp^f_2$ – *0.05×0.3=0.015* |
| $S^f_{td}$ - $Pp^f_3$ – *0.05×0.4=0.02* | $S^f_{tw}$ - $Pp^f_3$ – *0.05×0.1=0.005* | $S^f_{tg}$ - $Pp^f_3$ – *0.05×0.2=0.01* | $S^f_{tt}$ - $Pp^f_3$ – *0×0.3=0* |
| $S^f_{td}$ - $Pp^f_4$ – *0.1×0.4=0.04* | $S^f_{tw}$ - $Pp^f_4$ – *0.05×0.1=0.005* | $S^f_{tg}$ - $Pp^f_4$ – *0.3×0.2=0.06* | **$S^f_{tt}$ - $Pp^f_4$ – *0.3×0.3=0.09*** |
| **$S^f_{td}$ - $Pp^f_5$ – *0.3×0.4=0.12*** | $S^f_{tw}$ - $Pp^f_5$ – *0×0.1=0* | **$S^f_{tg}$ - $Pp^f_5$ – *0.35×0.2=0.07*** | $S^f_{tt}$ - $Pp^f_5$ – *0.25×0.3=0.075* |
| $S^f_{td}$ - $Pp^f_6$ – *0.05×0.4=0.02* | $S^f_{tw}$ - $Pp^f_6$ – *0.05×0.1=0.005* | $S^f_{tg}$ - $Pp^f_6$ – *0×0.2=0* | $S^f_{tt}$ - $Pp^f_6$ – *0.05×0.3=0.015* |
| $S^f_{td}$ - $Pp^f_7$ – *0.2×0.4=0.08* | $S^f_{tw}$ - $Pp^f_7$ – *0.15×0.1=0.015* | $S^f_{tg}$ - $Pp^f_7$ – *0.05×0.2=0.01* | $S^f_{tt}$ - $Pp^f_7$ – *0.1×0.3=0.03* |
| $S^f_{td}$ - $Pp^f_n$ – *0.05×0.4=0.02* | $S^f_{tw}$ - $Pp^f_n$ – *0.05×0.1=0.005* | $S^f_{tg}$ - $Pp^f_n$ – *0.15×0.2=0.03* | $S^f_{tt}$ - $Pp^f_n$ – *0.1×0.3=0.03* |
| For this sub-scenario, the optimal form of partnership is $Pp^f_5$ (alliances) | For this sub-scenario, the optimal form of partnership is $Pp^f_1$ (public-private partnerships) | For this sub-scenario, the optimal form of partnership is $Pp^f_5$ (alliances) | For this sub-scenario, the optimal form of partnership is $Pp^f_4$ (holdings) |

According to the example in Table 14 for the development of the Almaty–Cholpon-Ata infrastructure corridor, the implementation of sub-scenario Sftd (road reconstruction) is optimal by forming alliances with various stakeholders, according to expert assessments at the macro and meso levels. An example of a successful alliance is the East Transport Alliance.

A similar assessment can be carried out for the micro level. Table 15 provides an example of an assessment for choosing the optimal form of partnership at the micro level for sub-scenario Sftd for the development of the Almaty–Cholpon-Ata infrastructure corridor.

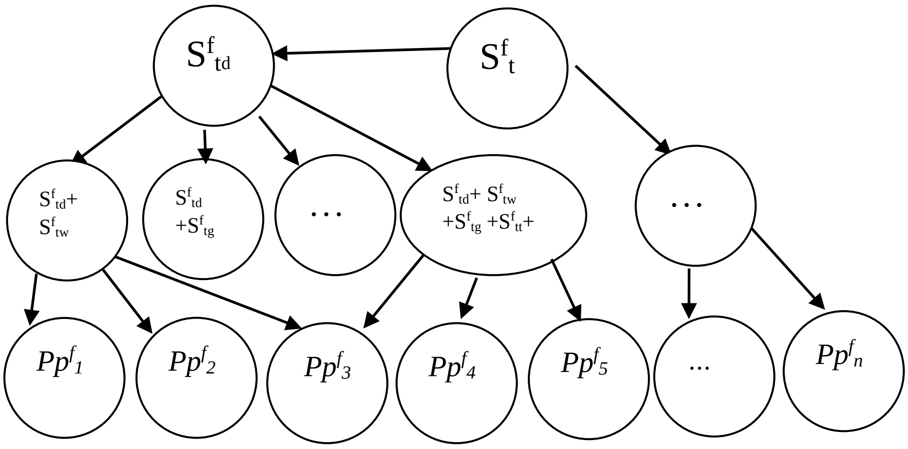
### Table 15: Choosing the optimal form of partnership at the micro level for sub-scenario Sftd for the development of the Almaty–Cholpon-Ata infrastructure corridor

| Sub-scenario $S^f_{td}$ for the development of the Almaty–Cholpon-Ata infrastructure corridor | | | | | | |
|---|---|---|---|---|---|---|
| Forms of partnership: FIG – financial and industrial groups; NS – network structures; and DLC – direct labour contracts | | | | | | |
| FIG | NS | DLC | FIG + NS + DLC | FIG + NS | NS + DLC | FIG + DLC |
| *Expert assessment of the feasibility of choosing a form of partnership at the micro level* | | | | | | |
| *0.15* | *0.15* | *0.1* | *0.2* | *0.1* | *0.05* | *0.25* |

According to the example in Table 15, the optimal form of partnership for implementing sub-scenario Sftd at the micro level is through a financial and industrial group, which can provide financial resources, the necessary equipment and other components, and through direct labour contracts with employees and/or contractors.

In the event that the decision to deploy the infrastructure corridor is implemented based on a combination of several scenarios and/or sub-scenarios (Sft), it is necessary to form a complex graph with many direct and complex (integrated) paths (Figure 10). However, the methodology remains unchanged.

### Figure 10: Example of a model graph for selecting forms of partnership for scenario and/or sub-scenario implementation

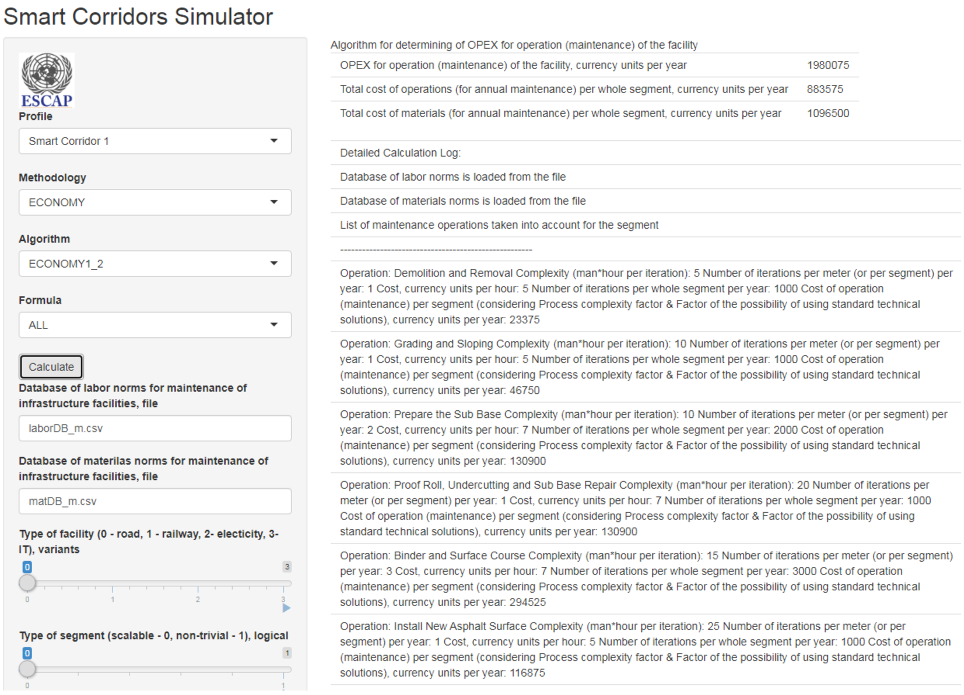


# 3. Web-based Simulation Model for Determining the Most Promising Scenario for Infrastructure Corridor Development

In order to automate the process of determining the most promising model for infrastructure corridor development, a web-based simulation model was developed using indicators of economic efficiency based on capital investments and maintenance costs required in the construction or reconstruction of infrastructures along the infrastructure corridor.

The simulation model is implemented by R programming language in the RStudio environment using the Shiny library package. The working version of the model is published in the shinyapps.io cloud service and available at: https://broadband.shinyapps.io/SmartCorridorsSimulator/. Figure 11 shows a screenshot of the simulator.

Figure 11: Screenshot of the simulator



Profile: Smart Corridor 1
Methodology: ECONOMY
Algorithm: ECONOMY1_2
Formula: ALL
Database of labor norms for maintenance of infrastructure facilities, file: laborDB_m.csv
Database of materilas norms for maintenance of infrastructure facilities, file: matDB_m.csv
Type of facility (0 - road, 1 - railway, 2- electicity, 3- IT), variants: 0
Type of segment (scalable - 0, non-trivial - 1), logical: 0

Algorithm for determining of OPEX for operation (maintenance) of the facility

| | |
|---|---|
| OPEX for operation (maintenance) of the facility, currency units per year | 1980075 |
| Total cost of operations (for annual maintenance) per whole segment, currency units per year | 883575 |
| Total cost of materials (for annual maintenance) per whole segment, currency units per year | 1096500 |

```
Detailed Calculation Log:
Database of labor norms is loaded from the file
Database of materials norms is loaded from the file
List of maintenance operations taken into account for the segment
--------------------------------------------------------
Operation: Demolition and Removal Complexity (man*hour per iteration): 5 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 23375
Operation: Grading and Sloping Complexity (man*hour per iteration): 10 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 46750
Operation: Prepare the Sub Base Complexity (man*hour per iteration): 10 Number of iterations per meter (or per segment) per year: 2 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 2000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 130900
Operation: Proof Roll, Undercutting and Sub Base Repair Complexity (man*hour per iteration): 20 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 130900
Operation: Binder and Surface Course Complexity (man*hour per iteration): 15 Number of iterations per meter (or per segment) per year: 3 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 3000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 294525
Operation: Install New Asphalt Surface Complexity (man*hour per iteration): 25 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 116875
```

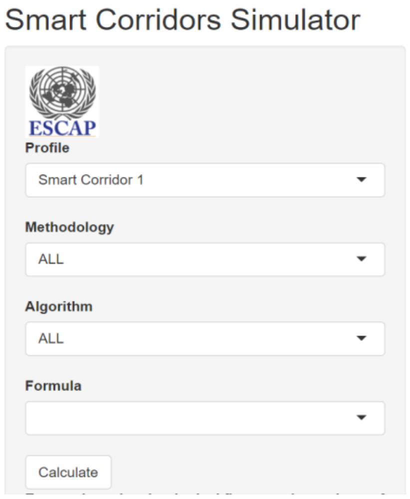
The simulator has four main components:

1. Drop-down menu for selecting the investigated (modelled) elements of the methodology (upper left corner);
2. Box for modelling results (upper right corner);
3. Box for input of special parameters (lower left corner);
4. Box for operation log output (lower right corner).

## 3.1 Drop-Down Menu for Selecting the Investigated Elements

The drop-down menu allows users to select the infrastructure corridor profile, methodology, algorithm and formula to generate the calculations (Figure 12).

Figure 12: Drop-down menu for selecting the investigated element


Smart Corridors Simulator

Profile: Smart Corridor 1

Methodology: ALL

Algorithm: ALL

Formula:

The profiles of the infrastructure corridors are loaded automatically from a file named "profiles.csv" located in the root directory of the simulation model. Each entry in this file contains two columns: profile display name and profile configuration file name. The three profiles in the simulator are: Almaty (Kazakhstan) – Cholpon-Ata (Kyrgyzstan); Semey (Kazakhstan) – Rubtsovsk (Russia); and Urzhar (Kazakhstan) – Chuguchak (China).

The methodologies are automatically loaded from the configuration files in the selected profile and contain five entries:

1. All – Methodology for determining the most promising model for infrastructure corridor development;
2. Flows – Methodology for determining economic and technological flows;
3. Scenarios – Methodology for determining the development scenarios of new infrastructure corridors;
4. Economy – Methodology for assessing the economic efficiency of implementing the development scenarios of new infrastructure corridors; and
5. Partnership – Methodology for selecting the most promising partnership models for infrastructure corridor development.

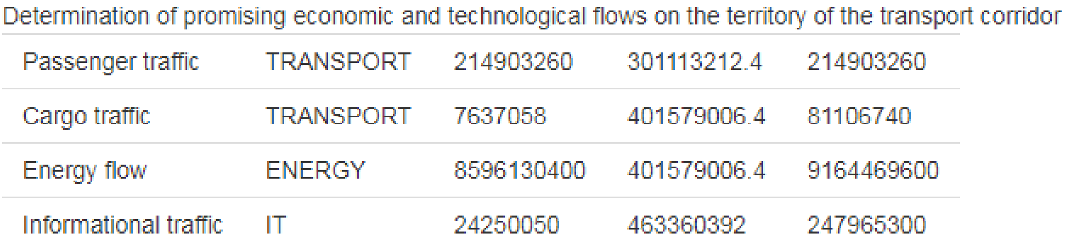
The algorithms are automatically loaded from the configuration files in the selected profile and contain a list of algorithms. Similarly, the formulae are automatically loaded from the configuration files in the selected profile and contain a list of formulae that are part of the selected algorithm.

Finally, users can click on the "Calculate" button to activate the simulation model.

### 3.2 Box for Modelling Results

This box for modelling results displays the sub-elements of the model (e.g., a list of algorithms included in the calculation method) and the results of calculations.

Figure 13: Example showing box for modelling results



Determination of promising economic and technological flows on the territory of the transport corridor

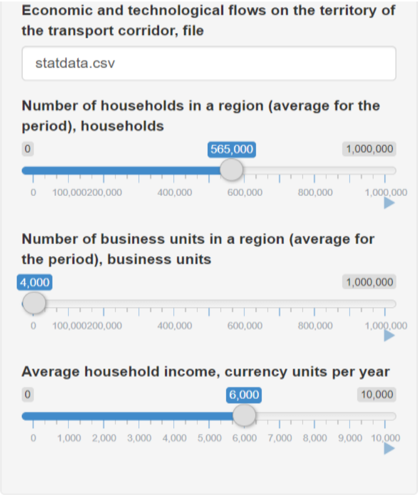
| | | | | |
|---|---|---|---|---|
| Passenger traffic | TRANSPORT | 214903260 | 301113212.4 | 214903260 |
| Cargo traffic | TRANSPORT | 7637058 | 401579006.4 | 81106740 |
| Energy flow | ENERGY | 8596130400 | 401579006.4 | 9164469600 |
| Informational traffic | IT | 24250050 | 463360392 | 247965300 |

In the process of selecting the components from the drop-down menu, the name and description of the investigated element and sub-elements are displayed here. Upon clicking the "Calculate" button, the corresponding name and description are replaced with the results of the calculations, which include the key results and their numerical and/or string values.

## 3.3 Box for Input of Special Parameters

This box is formed dynamically, depending on the components selected from the drop-down menu, and allows users to change the conditions of modelling.

Figure 14: Example showing box for input of special parameters



Economic and technological flows on the territory of the transport corridor, file

statdata.csv

Number of households in a region (average for the period), households

0 — 565,000 — 1,000,000

Number of business units in a region (average for the period), business units

4,000 — 1,000,000

Average household income, currency units per year

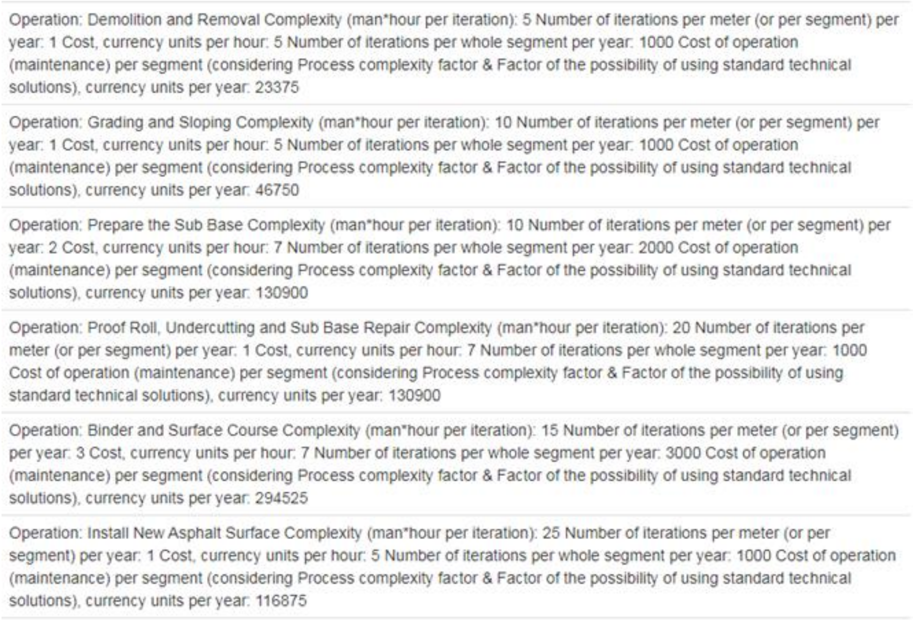
0 — 6,000 — 10,000

The parameters displayed in the box are based on the profile, methodology and algorithm selected, with options for adjusting the text field (e.g., for entering a file name) and the numeric field using the slider to adjust the variables.

## 3.4 Box for Operation Log Output

This box displays the intermediate results of simulation modelling in the form of log records, which allows users to study the modelling process in a step-by-step mode in the context of separated components (e.g., segments of an infrastructure).

Figure 15: Example showing box for operation log output



Operation: Demolition and Removal Complexity (man*hour per iteration): 5 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 23375

Operation: Grading and Sloping Complexity (man*hour per iteration): 10 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 46750

Operation: Prepare the Sub Base Complexity (man*hour per iteration): 10 Number of iterations per meter (or per segment) per year: 2 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 2000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 130900

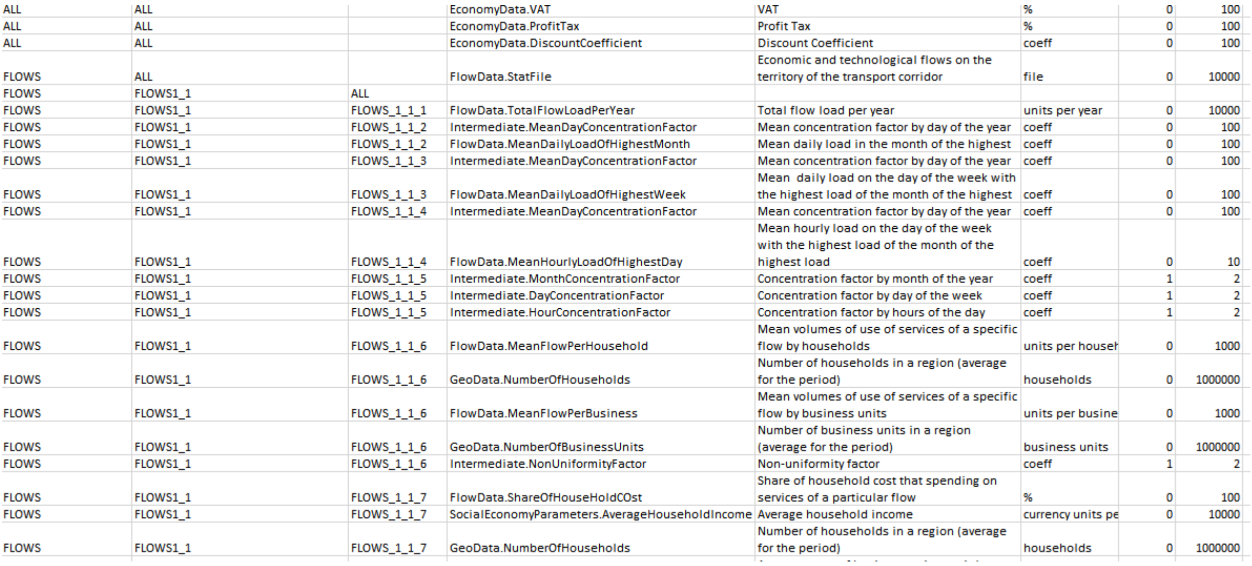
Operation: Proof Roll, Undercutting and Sub Base Repair Complexity (man*hour per iteration): 20 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 130900

Operation: Binder and Surface Course Complexity (man*hour per iteration): 15 Number of iterations per meter (or per segment) per year: 3 Cost, currency units per hour: 7 Number of iterations per whole segment per year: 3000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 294525

Operation: Install New Asphalt Surface Complexity (man*hour per iteration): 25 Number of iterations per meter (or per segment) per year: 1 Cost, currency units per hour: 5 Number of iterations per whole segment per year: 1000 Cost of operation (maintenance) per segment (considering Process complexity factor & Factor of the possibility of using standard technical solutions), currency units per year: 116875

Figure 16 shows an example of a configuration file for an infrastructure corridor profile.

Figure 16: Example of a configuration file for an infrastructure corridor profile



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ALL | ALL | | EconomyData.VAT | VAT | % | 0 | 100 |
| ALL | ALL | | EconomyData.ProfitTax | Profit Tax | % | 0 | 100 |
| ALL | ALL | | EconomyData.DiscountCoefficient | Discount Coefficient | coeff | 0 | 100 |
| FLOWS | ALL | | FlowData.StatFile | Economic and technological flows on the territory of the transport corridor | file | 0 | 10000 |
| FLOWS | FLOWS1_1 | ALL | | | | | |
| FLOWS | FLOWS1_1 | FLOWS_1_1_1 | FlowData.TotalFlowLoadPerYear | Total flow load per year | units per year | 0 | 10000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_2 | Intermediate.MeanDayConcentrationFactor | Mean concentration factor by day of the year | coeff | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_2 | FlowData.MeanDailyLoadOfHighestMonth | Mean daily load in the month of the highest | coeff | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_3 | Intermediate.MeanDayConcentrationFactor | Mean concentration factor by day of the year | coeff | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_3 | FlowData.MeanDailyLoadOfHighestWeek | Mean daily load on the day of the week with the highest load of the month of the highest | coeff | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_4 | Intermediate.MeanDayConcentrationFactor | Mean concentration factor by day of the year | coeff | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_4 | FlowData.MeanHourlyLoadOfHighestDay | Mean hourly load on the day of the week with the highest load of the month of the highest load | coeff | 0 | 10 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_5 | Intermediate.MonthConcentrationFactor | Concentration factor by month of the year | coeff | 1 | 2 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_5 | Intermediate.DayConcentrationFactor | Concentration factor by day of the week | coeff | 1 | 2 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_5 | Intermediate.HourConcentrationFactor | Concentration factor by hours of the day | coeff | 1 | 2 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_6 | FlowData.MeanFlowPerHousehold | Mean volumes of use of services of a specific flow by households | units per househ | 0 | 1000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_6 | GeoData.NumberOfHouseholds | Number of households in a region (average for the period) | households | 0 | 1000000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_6 | FlowData.MeanFlowPerBusiness | Mean volumes of use of services of a specific flow by business units | units per busine | 0 | 1000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_6 | GeoData.NumberOfBusinessUnits | Number of business units in a region (average for the period) | business units | 0 | 1000000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_6 | Intermediate.NonUniformityFactor | Non-uniformity factor | coeff | 1 | 2 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_7 | FlowData.ShareOfHouseHoldCOst | Share of household cost that spending on services of a particular flow | % | 0 | 100 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_7 | SocialEconomyParameters.AverageHouseholdIncome | Average household income | currency units pe | 0 | 10000 |
| FLOWS | FLOWS1_1 | FLOWS_1_1_7 | GeoData.NumberOfHouseholds | Number of households in a region (average for the period) | households | 0 | 1000000 |

Structurally, the configuration file is a csv file that contains the following columns:

- Name of the methodology to which the record belongs;
- Name of the algorithm to which the record belongs;
- Name of the formula to which the record belongs;
- Name of the variable (this value cannot be changed);

- Variable description;
- Variable units;
- Minimum value of the variable (for slider controls);
- Maximum value of the variable (for slider controls);
- Step value of the variable (for slider controls);
- Default value of the variable; and
- Service fields displayed in the box for input of special parameters.

The parameters include not only numerical values, but also files containing sets of initial data that the simulation model operates on. Like the configuration file, all these files are in csv format and can be easily created or edited in Microsoft Excel. The complete list of files used by the simulation model, as well as a description of their structure is given in Table. 16.

Table 16: List of files used by the simulation model

| № | File description (application) | Module, algorithm, expression | File name by default | Structure description |
|---|---|---|---|---|
| 1 | Statistical data to determine the characteristics of economic and technological flows along the infrastructure corridor | All flows | statdata.csv | 1. Flow name<br>2. Flow type<br>3. Volume of consumption by households (units per year)<br>4. Volume of consumption by businesses (units per year)<br>5. Share of expenditure on services flow in the total volume of household expenditures (per cent)<br>6. Volume of expenditure on services flow by one business unit (USD per year)<br>7. Rate of services flow for households (USD per unit)<br>8. Rate of services flow for businesses (USD per unit)<br>9. Coefficient of uneven flow by month<br>10. Flow non-uniformity factor by days of the week<br>11. Flow non-uniformity factor by hours<br>12. Influenced rating of the external loop<br>13. Influenced rating of the inner loop |
| 2 | Existing and planned infrastructures along the infrastructure corridor | All scenarios | facilities.csv | 1. Name of infrastructure<br>2. Type of flow to which the infrastructure belongs (TRANSPORT – transport, ENERGY – energy; IT – informational)<br>3. Type of infrastructure (RD – road; RW – railway; EG – electrical grid; IT – fibre-optic communications line)<br>4. Capacity of infrastructure in flow units<br>5. Capacity of infrastructure in monetary terms<br>6. State of infrastructure (EXISTING – existing infrastructure; PLANNED – planned infrastructure)<br>7. State of infrastructure development (1 – |

| | | | | |
|---|---|---|---|---|
| | | | | reconstruction; 2 – new or planned infrastructure)<br>8. Name of file with detailed segment information on the infrastructure |
| 3 | Database of labour norms for construction of new infrastructure | All economies | laborDB_b.csv | 1. Type of infrastructure (RD – road; RW – railway; EG – electrical grid; IT – fibre-optic communications line; RD + IT, RW + IT, EG + IT – co-deployment of IT with other types of infrastructure)<br>2. Type of segment (SCALABLE – scalable; UNTRIVIAL – non-trivial)<br>3. Subtype of non-trivial segment<br>4. Name of operation (type of work)<br>5. Complexity of operation in person-hours<br>6. Number of operations per metre of infrastructure (for scalable segments) or for the entire infrastructure (for non-trivial segments)<br>7. Cost of an hour for this type of work in USD (or national currency) for one person-hour |
| 4 | Database of labour norms for reconstruction of existing infrastructure | All economies | laborDB_r.csv | |
| 5 | Database of norms on materials consumption for construction of new infrastructure | All economies | matDB_b.csv | 1. Type of infrastructure (see above)<br>2. Type of segment (see above)<br>3. Subtype of non-trivial segment<br>4. Name of material type<br>5. Amount of material in conventional unit of measurement per metre of infrastructure (for scalable segments) or for the entire infrastructure (for non-trivial segments)<br>6. Cost of a conventional unit of material measurement |
| 6 | Database of norms on materials consumption for reconstruction of existing infrastructure | All economies | matDB_r.csv | |
| 7 | Database of labour norms for maintenance of existing infrastructure | All economies | laborDB_m.csv | 1. Type of infrastructure (see above)<br>2. Type of segment (see above)<br>3. Subtype of non-trivial segment<br>4. Name of operation (type of work)<br>5. Complexity of operation in person-hours<br>6. Number of operations per metre of infrastructure (for scalable segments) or for the entire infrastructure (for non-trivial segments) per year<br>7. Cost of an hour for this type of work in USD (or national currency) for one person-hour |
| 8 | Database of norms on materials | All economies | matDB_m.csv | 1. Type of infrastructure (see above)<br>2. Type of segment (see above)<br>3. Subtype of non-trivial segment |

| | | | | |
|---|---|---|---|---|
| | consumption for maintenance of existing infrastructure | | | 4. Name of material type<br>5. Amount of material in conventional unit of measurement per metre of infrastructure (for scalable segments) or for the entire infrastructure (for non-trivial segments) per year<br>6. Cost of a conventional unit of material measurement |
| 9 | Matrix with an expert assessment of potential partner models for the implementation of promising scenarios for infrastructure corridor development | All partnerships | partnership.csv | 1. Type of partnership or name of a specific partner<br>2. Expert assessment of potential participation of partner or model of partnership for the implementation of a scenario for infrastructure corridor development |
| 10 | Economic and technological flows along the infrastructure corridor (the file is intended specifically for the study of one of the model modules) | All scenarios | flows.csv | 1. Name of economic and technological flow<br>2. Flow type (TRANSPORT – transport; ENERGY – energy; IT – informational)<br>3. Flow rate in conventional units<br>4. Intensity of flow in monetary terms (USD or national currency), calculated using the method of estimating the share of expenses<br>5. Intensity of flow in monetary terms (USD or national currency), calculated using the method of assessing historical demand and existing rates |
| 11 | Basic scenarios for the development of infrastructure corridor (the file is intended specifically for the study of one of the model modules) | All scenarios | bscenarios.csv | 1. Contributing scenario of road infrastructure development (S0 – no action, Sr – reconstruction, Sn – construction of new infrastructure)<br>2. Contributing scenario of railway infrastructure development<br>3. Contributing scenario of energy infrastructure development<br>4. Contributing scenario of ICT infrastructure development |
| 12 | A database of segments of infrastructures (when calculating the full cycle, the file contained in item no. 8 of file no. 2 of this list | All economies | roadsegments.csv<br>rwsegments.csv<br>egsegments.csv<br>itsegments.csv | 1. Segment identifier<br>2. Segment length in metres (for scalable segments)<br>3. Type of segment (SCALABLE – scalable; UNTRIVIAL – non-trivial)<br>4. Subtype of non-trivial segment<br>5. Type of required operation (RECONSTRUCTION – reconstruction; BUILDING – |

|  |  |  |  |  |
|---|---|---|---|---|
|  | is used) |  |  | construction)<br>6. 6 – Complexity factor of processes (e.g., complex topography of the area, natural and climatic conditions), from 1.01 to 1.25<br>7. Factor of the possibility of using standard technical solutions (e.g., the usage of ready-made software modules or technical structures), from 0.85 to 1 |
| 13 | A complete list of scenarios for the development of the infrastructure corridor (the file is intended specifically for studying one of the model modules) | All partnerships | allscenarios.csv | 1. Contributing scenario of road infrastructure development (S0 – no action, Sr – reconstruction, Sn – construction of new infrastructure, Scd+it – co-deployment of ICT infrastructure with another infrastructure)<br>2. Contributing scenario of railway infrastructure development<br>3. Contributing scenario of energy infrastructure development<br>4. Contributing scenario of ICT infrastructure development |