

Integrated Methodology for Efficient Sizing of Investments In Transport Infrastructure*

Frantz Daniel FISTUNG, Cornelia NEAGU,
Marius BULEARCĂ and Cristian SIMA

Centre for Industry and Services' Economics, Romanian Academy,
Bucharest, Romania

Correspondence should be addressed to: Frantz Daniel FISTUNG, dfistung@yahoo.com

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Abstract

The purpose of this paper is to present an integrated analysis methodology that is more appropriate in most cases where a decision must be made regarding the correct and profitable sizing of investments in transport infrastructure. The methodology analysed proposes three distinct stages, namely: Sizing investments for the current year; Evaluating replacement (renewal) costs; Sizing operational and maintenance expenses. Based on the proposed methodology, the specific elements for calculating infrastructure investments are presented in detail for each mode of transport. The final part of the paper presents examples of calculating the investment needs for transport infrastructure, currently adopted in several European countries.

Keywords: Transport infrastructure, investment policy, investment efficiency methodology

Introduction

The modernization and expansion of infrastructure, the increase in the number of jobs, and the increase in lab or productivity are desirable developments that are only possible through a judicious investment policy based on modern management methods, tools, and techniques that allow for the preparation and substantiation of highly objective decisions the selection of the best investment project options and the optimal solutions for their implementation.

It is generally accepted that investments in transport infrastructure must be guided by a sector development strategy.

There are several factors that influence the quality of a transport infrastructure development strategy. Thus, a transport infrastructure development strategy must be stable over time, appropriate to needs, financially sustainable, acceptable from an environmental impact perspective, and balanced from a territorial accessibility perspective.

Literature Review

Changes are made to the scope of a project, sometimes after decision makers have approved it, without any assessment of the incremental costs and benefits of this change. More recent studies (Eliasson and Fosgerau, 2013, Rose and Hensher, 2013, and Makovšek, 2014) also suggest that the systematic errors in forecasting traffic and estimating costs may, at least in part, be the inherent result of the characteristics of the methods applied. Project costs are often underestimated (Flyvbjerg, 2004 and Flyvbjerg, Holm and Buhl, 2005). Transport investment policy has been frequently analysed and combined with other complementary segments as part of general transport policy. Kalotay (2008) analysed the level of foreign direct investment in the two neighbouring countries that joined the EU in 2007, Romania and Bulgaria. Islam et al. (2015) assess forecasts for rail freight demand for the next three decades and the impact of the European Union's White Paper on transport. Adamopoulos (2011) measures transport costs in relation to income differences between countries. Köhler, Jin, and Barker (2008) develop an integrated model of European Union transport policy that is . More directly focused, Rodrigue (2024) clearly defines investment policy in the transport sector, starting from the general notion of investment policy launched by Masse (1959), and at national level by several researchers, including Constantinescu (1974), Ciomoş (2004) and Fistung and Popescu (2020).

Theoretical clarifications

Expenditures for infrastructure with the same functionality may differ from one country to another, i.e., from one infrastructure manager to another. The main factors determining such differences are as follows:

- Construction standards (legal safety requirements, degree of technical progress applied to infrastructure construction, special standards for mountainous areas or environmentally sensitive areas)
- Type of infrastructure: construction and maintenance (motorways/others, high-speed railways/others, tunnels/bridges, underground/above-ground systems, canals)
- Wage and price levels by country
- Expected traffic flow and occupancy rate
- Weather and climate
- Population density (land costs)
- Assessment of the percentage of a project (or category of expenditure) that should be considered investment, renewal, and maintenance.

Infrastructure expenditure can be classified according to how it improves the functionality and/or lifespan of the infrastructure (asset-based approach). According to this classification, we define the following types of expenditure:

- Investment expenditure: expenditure related to a) new infrastructure with specified functionality and lifespan, or b) the extension of existing infrastructure in terms of functionality and/or lifespan.
- Renewal expenditure: expenditure on replacing existing infrastructure, extending its lifespan without adding new functionality.
- Maintenance expenditure: expenditure to maintain the functionality of existing infrastructure during its initial lifetime.
- Operating expenses: expenses not related to improving or maintaining the lifespan and/or functionality of the infrastructure.

Infrastructure expenditures can also be classified according to how they are influenced by infrastructure use, namely transport volume. According to this classification, we define the following types of expenditures:

- Variable expenses: expenses that vary depending on transport volume, while the functionality of the infrastructure remains unchanged.
- Fixed expenditures: expenditures that do not vary with transport volume, while the functionality of the infrastructure remains unchanged, or expenditures that increase the functionality or lifespan of the infrastructure.

The distinction between fixed and variable costs is relevant because it allows for an efficient allocation of infrastructure costs.

There are two formal methods for differentiation between fixed and variable costs:

- The econometric approach – in which total expenditure is considered to be the dependent variable (to be ‘explained’) and transport outcomes (e.g. train-kilometres) are among the independent variables. Based on cross-sectional data and/or time series, econometric analysis can be used to determine and estimate a total expenditure function from which variable expenditures can be derived.
- Engineering approach - where total expenditure is disaggregated into subcategories, and for each of these categories, separate analysis provides the share of variable expenditure within each category.

Both the econometric and engineering methods are affected by requirements for large data volumes, which often cannot be met by available statistics. Most, if not all, studies using one of these methods are case studies on relatively small segments of an infrastructure. The results of these studies are then extrapolated to larger parts of the infrastructure.

Due to the shortcomings of both the econometric and engineering methods, a third method can be used to differentiate between fixed and variable costs. This method uses practical experience, simple calculations, and/or expert opinions to determine the variability of each category of expenditure in the available statistics. We will refer to this method as the cost allocation approach.

The cost allocation approach, by its nature, does not have formal procedures like the other two approaches. Consequently, it does not produce objective or reproducible results. This is a major disadvantage. However, the data requirements for the cost allocation approach are much easier to meet than the data requirements of either of the other two methods.

Current situation regarding methods for sizing investment needs for transport infrastructure in several European countries

Investments in road infrastructure

Most European countries can distinguish between investment and maintenance expenditure, at least for the main road network. In addition, many countries are also able to distinguish between operating and administrative expenditure.

Under Regulation (EEC) No 1108/70, Member States should keep detailed records of investment expenditure (new construction, extensions, reconstruction, and renewal), current expenditure (maintenance, operation), traffic police expenditure, and general expenditure.

However, there was no evidence that road expenditure is recorded in this detailed manner in the selected countries. In general, investment and maintenance expenditures are distinguished and subsequently divided into subcategories in some countries. The definitions applied differ considerably between the selected countries (see the following section for more details).

Most countries distinguish between capital costs (investment, depreciation, and interest) and operating costs. In Estonia, the only investment or capital costs available are the costs for new investments and replacements, as well as interest and depreciation for new investments and replacements.

In addition, Regulation 1108/70 stipulates that expenditure should be classified by "type" of road and therefore the road network must be divided into several categories. However, road categories differ from one country to another.

In the Netherlands, investment expenditure refers to all expenditure related to the expansion of road infrastructure capacity. This refers not only to new roads, but also to the widening of existing roads (e.g., from 2 to 3 lanes in each direction). All other expenditures are maintenance expenditures.

Fixed maintenance is also known as 'annual' maintenance and refers to relatively minor maintenance work. Variable maintenance is also known as "non-annual" maintenance and refers to large-scale maintenance. Fixed and variable maintenance costs are divided into 5 subcategories:

1. Road surfaces;
2. Road operation (expenses for buildings, sites, energy, research, etc.);
3. Traffic forecasting expenses for signalling, special events, etc.);
4. Environment (expenditure on minimizing negative effects, waste management).

Austria separates expenditures for construction, structural maintenance, and operational maintenance:

- Construction refers to expenditure on new construction and the expansion of existing infrastructure capacity
- Structural maintenance refers to measures to improve and maintain existing infrastructure, such as roads, tunnels, and bridges.
- Operational maintenance refers to actions aimed at keeping networks operational and efficient at all times. Importance is given to the continuous improvement of safety and comfort in use. Operational maintenance consists, for example, of winter maintenance, road installations, tunnel operation, grass maintenance, emergency services, and repairs.

In the UK, the Highways Agency divides road expenditure into five main categories (subprograms). These are:

- (1) Maintenance,
- (2) Minor improvements (programs costing less than £5 million),
- (3) Technological improvements,
- (4) Traffic management, and
- (5) Major improvements (programs with expenditures greater than £5 million).

Expenditures are subsequently considered to be capital expenditures (investments) or resource expenditures.

Capital refers to improving the asset and therefore increasing its value. Resource expenditure refers to maintaining the value and keeping it safe and available for use.

In short, the five programs cover:

(1) The maintenance program aims to keep the network in a safe and functional state at minimal cost over its lifetime and with minimal interruptions.

(2) The minor improvements program consists mainly of:

- Local network management systems: schemes aimed at reducing accidents, improving the environment, reducing congestion, etc.;
- Research & development: Research projects in the field of development (resources) starting with new materials, through safety and performance analysis, to user behaviour;
- Information technology: Development, implementation, and modernization of asset and business management systems.

(3) The technological improvement program consists of schemes primarily aimed at reducing accidents and congestion, such as queue/incident detection/warning systems, cameras, and driver information systems/equipment. Pilots testing new techniques, such as ramp metering/control and active traffic management, are also part of this program.

(4) The traffic manager services program consists of traffic officers (and their vehicles and uniforms) who assist in the operation of major roads/highways, particularly by assisting in the clearance of incidents/accidents. The operation of regional control centres, which provide the means to detect incidents/accidents and disseminate information to drivers to reduce traffic congestion, is also part of the program.

(5) The major improvements program ultimately consists of major road improvements to enhance safety, reduce traffic congestion, and improve the environment. This program also includes the acquisition of land for the improvement/operation of main roads/motorways and the sale of surplus land purchased for/released through the improvement/operation of main roads/motorways.

In Sweden, road infrastructure expenditure is divided into investment and operating expenditure. Operating expenditure is classified into routine maintenance and periodic maintenance and is further divided into sub-groups:

Routine maintenance (effects lasting less than one year) refers to the following subgroups:

- Surface road: rapid action to deal with problems that arise suddenly on surface roads (e.g., cracks and bumps, surface abrasion, street cleaning).
- Gravel road: rapid actions to manage sudden problems on gravel roads (e.g., grading, dust reduction, street cleaning).
- Bridge and tunnel: actions to maintain the accessibility of tunnels and bridges. Some traffic safety actions are also included.
- Road equipment: management of traffic information systems, road infrastructure, lighting, service areas, etc.
- Winter: Road maintenance aims to keep roads safe and available at a set level.
- Ferries: transport of vehicles, people, and goods across rivers, small lakes, to islands in archipelagos, etc. to maintain a continuous road. In Sweden, these ferries are free of charge and considered part of the road.

Periodic maintenance refers to the following subgroups:

- Road surface: maintenance of the road surface, substructures, superstructures, and drainage system
- Paved road: maintenance of the road surface, substructures, superstructures, and drainage system
- Structures: maintenance of bridges, tunnels, ferry quays;
- Road equipment: maintenance of road equipment

Investment expenditure refers to expenditure on new construction and the expansion of existing infrastructure capacity.

In Spain, the road network is divided into different networks, depending on their area of responsibility. The state road network, Red de Carreteras del Estado, covers 24,105 km and is managed by the Dirección General de Carreteras (direction). The state is responsible for managing and financing the network through the general budget or the company to which the concession has been awarded. The rest of the roads are the responsibility of the Autonomous Communities (Autonomous Network), the Provincial Councils (Provincial Network) and the Island Councils (Canary Islands Road Network). The classification of investments and maintenance procedures are more or less identical at each of these three levels.

Normally, investments are organized through two independent programs:

- Program for new construction works. This refers to the construction of new roads, bypasses, and cross streets in urban centres and the improvement of any roads.
- Road maintenance and operation program. This program deals with maintaining surface drainage conditions, improving road safety conditions, and conserving and improving the road surface, bypasses, and roads through comprehensive contracted management.

The maintenance and operation program includes routine maintenance, special maintenance, and safety improvements.

Routine maintenance activities are those that delay any deterioration that occurs on roads due to use and time. This includes any negative impact that the surroundings may have had on the roadway and that prevents its proper use, although these impacts may not have caused any deterioration. Routine maintenance activities are:

- Inspection and maintenance of the road surface and roadside;
- Inspection and maintenance of drainage systems (ditches, pipes, curbs, gutters, etc.);
- Inspection and maintenance of road shoulders, central reservations, and slopes;
- Inspection and maintenance of road signs and equipment, lighting and ventilation installations;
- Inspection and maintenance of variable message signs and safety equipment in tunnels and urban areas;
- Inspection and maintenance of factory works and other installations.

Special maintenance refers to activities aimed at improving roads that are approaching or have already reached the end of their expected lifespan. For example, in addition to periodic repairs, special interventions are planned to adapt the characteristics of the road to the increasing demand in the necessary sections.

Improving safety conditions is a third program aimed at improving safety conditions. Interventions under this program include treating or eliminating black spots caused by accidents.

In Germany, the Ministry of Transport, Building, and Housing is responsible for the main road network. The road network consists of motorways (approximately 12,000 km) and national roads (approximately 41,000 km). The rest, over 550,000 km, is managed by regional governments.

Construction and management costs are classified as follows:

1. Road management and operation
2. Road design
3. Road investments and improvements
4. Outstanding expenditure

As in many other countries, investments and large-scale investments are separated from current expenditures such as road management and road operation. With regard to road management and road operation, expenditures are separated from road infrastructure and other infrastructure elements.

With regard to road infrastructure expenditure, three types of expenditure are distinguished:

- Road lane infrastructure, such as lines, guardrails, and rail guards
- Structures such as bridges, tunnels, and noise barriers
- "Outstanding" expenses for plantations, foundations, traffic management systems, etc.

In France, with regard to the national road network, there are two types of roads:

- The national toll-free road network, approximately 13,000 kilometres long, consisting of toll-free motorways and major national roads. These roads are managed by the French road authorities.
- Toll motorways, approximately 8,000 kilometres long, which are managed by commercial companies under concession contracts.

The classification of road infrastructure also depends on whether or not the network is tolled (operated by toll motorway concessionaires).

Classification of road expenditure France is breaking with the tradition of expenditure-oriented budgets by developing program-oriented budgets based on public policy objectives. The new budgetary process began in 2005, came into effect at the beginning of 2006, and was accompanied by new government accounting standards (close to those of the French general accounting plan for companies and international accounting standards).

With regard to the free national road network, there are three types of expenditure:

- Capacity investments: These infrastructure development expenditures relate to the construction of new infrastructure and the expansion of existing infrastructure capacity.
- Maintenance and operating expenditure. There are five types of expenditure:
 - Rehabilitation and preventive maintenance
 - Engineering works, divided into:
 - Maintenance and refurbishment costs;

Tunnel safety expenses

- Safety provisions
- Expenses incurred by "local offices" and settlement of accounts during winter:
- Expenses for plantings, foundations, traffic management systems, signage, etc.
- Expenses for winter settlement
- Other expenses for building maintenance and operation, material upgrades, building relocation, etc.
- Other expenses related to personnel, taxes, general expenses, general surveys, etc.

Concessionaires manage toll motorways and are commercial companies that must perform general accounting. Concession contracts also require concessionaires to provide more detailed accounts to describe the particularities of their activities (such as financing plans). These contracts lead to functional accounts that show the following aggregate expenses:

- Investments:
 - New investments: preliminary work (e.g., studies, land acquisition, etc.), construction work
 - Investments in operational networks: widening of motorways, improvement of standards, new rest areas, etc.
- Renewal of fixed assets: e.g., road toll equipment
- Major repairs: renewal of roadways and bridge and tunnel structures, mainly through periodic maintenance
 - Routine maintenance and operating expenses: local repairs, informing users about traffic conditions, winter maintenance, cleaning rest areas, etc.
 - Personnel expenses
 - General expenses
 - Taxes, duties, income tax
 - Financing costs
 - Profit margin

From the examples given of road infrastructure-specific costs and expenditures, we can conclude that all countries are able to distinguish between investment and maintenance expenditures. Many countries are also able to divide maintenance expenditure into several types of "regular" and "irregular" maintenance, although all countries apply different definitions. In the Netherlands, the terms "fixed maintenance" and "variable maintenance" are used, "structural maintenance" and "operational maintenance" in Austria, "routine maintenance" and "periodic maintenance" in Sweden, and "routine maintenance" and "special maintenance" in Spain.

A division into investments, "normal" and "abnormal" maintenance could form the basis for an approximate framework, but it is clear that much more consistency is needed in the definitions currently used in different countries. This issue and the availability of data are probably the most difficult topics for achieving a harmonized EU-wide framework for monitoring road infrastructure expenditure.

Investments in rail infrastructure

In this transport sector, expenditure is defined according to its purpose, with expenditure on investment, renewal, maintenance, and operational costs.

Consistency in classification improves the transparency and comparability of cost calculations. It can be seen, for example, whether similar depreciation rates are used in different countries. This obviously influences the result of the asset value calculation and, therefore, indirectly, the capital costs. This classification is also useful because the proportion of fixed and variable expenses differs from one expense category to another. Investments, for example, may relate to the track itself, superstructures, but also software and office furniture.

Operating expenses consist of operating costs and, depending on accounting principles, a certain share of maintenance costs. Capital costs relate to investments, renewals, and a share of maintenance costs.

Both capitalized expenses and operating expenses are sometimes divided into subcategories, such as buildings, superstructure, and engineering works for capitalized expenses. The subcategories applied for operating expenses are, for example, traffic control management, train traffic schedules, and operating expense safety. Capitalized expenses are not generally classified according to investments, renewals, and maintenance in the company's accounts. However, such a breakdown is important in order to determine the proportion of fixed and variable expenses. While investments are entirely fixed, maintenance and also renewal expenses may be partly variable.

In practice, it is not always easy to distinguish between renewal and investment. Renewal will often involve some added functionality due to technical progress. Large investment projects may also include, for example, some renewal of existing lines. British and Dutch infrastructure managers have indicated that, in such cases, they classify part of the project as renewal and part as investment expenditure.

Investments relate to the reinforcement or improvement of existing infrastructure or to completely new infrastructure elements. Renewals replace existing infrastructure and do not add new functionality, but extend its life expectancy. Maintenance is intended to effectively achieve the life expectancy for which the infrastructure was designed. Operating expenses relate to traffic management, train schedules, research, and the like. Note that in some cases, expenditure on low-value assets (e.g., up to €400 in Austria and €640 in Estonia) is accounted for as incurred in the reporting period, regardless of their normal useful life (ECORYS, 2005).

Investments are often subject to a more detailed classification. This classification usually consists of around 5-10 different categories, but infrastructure managers use an even more detailed classification internally.

For France, the 11 categories presented in the commercial account are in fact based on 77 categories used internally. In the Netherlands, 125 categories are distinguished internally. In Sweden, there are over 60 categories of assets and over 30 categories of operating expenses. The published categories are not fully consistent between different infrastructure managers. Each infrastructure manager uses its own terminology, and therefore direct comparisons cannot easily be made. However, it is clear that there are significant overlaps in the classification of use.

Some of the most commonly used subcategories:

- Buildings/stations
- Civil engineering works / Structural works (e.g., tunnels and bridges)
- Superstructure (e.g., rail and sleepers)
- New construction in progress
- Transmission lines
- Signalling equipment
- Telecommunications equipment
- Safety installations
- Vehicles/rolling stock for maintenance
- Installations and machinery
- Office equipment, computers and other equipment, tools

In some countries, several categories are combined and/or renamed. For example, in Estonia, transmission lines and railways have been combined and there is no separate category for structural works such as tunnels and bridges. Similarly, in Austria, safety and telecommunications installations are presented together and, first of all, it is unclear which category signalling equipment falls under. Only in the Netherlands are they classified separately; in other countries, there is a category for "Buildings." In the United Kingdom, " " includes the railway stations themselves, but the space in them used for retail is reported separately under the category "real estate investments."

At the same time, some countries have categories that do not appear in any other country. For example, Sweden has a category called 'Improvements to other people's property', and France is the only country that classifies 'Level crossings' and 'Land development' separately. Importantly, however, none of the countries cited make a distinction between fixed and variable costs.

However, it is clear that this issue has been attracting increasing interest from infrastructure managers since the introduction of Directive 2001/14/EC (EC, 2001). Many countries adhere to the principle that only marginal (or variable) costs can be passed on to infrastructure users through infrastructure charges. A notable exception is Germany, where a total cost approach is applied and no distinction is made between variable and fixed costs. Since infrastructure charging is based on a full cost recovery approach, German administrators consider that information on the share of variable costs is not necessary.

In the Netherlands, the proportions of fixed and variable costs for different categories of expenditure are determined by internal experts, which is a subjective and unsound method. In the United Kingdom, infrastructure charges are regulated by the Office of Rail Regulation. For heavy traffic loads, the share of variable costs increases. In Sweden, the infrastructure manager does not distinguish between fixed and variable costs.

Investments in inland waterway infrastructure

In France, the definitions used to distinguish between investment and maintenance expenditure for inland waterways are:

- Investment expenditure: Expenditure on new construction and the extension of existing infrastructure, including reconstruction, renewal, and major repairs.
- Maintenance expenditure: Expenditure on keeping infrastructure in working order. This includes surface maintenance, accidental (emergency) repairs, and routine repairs.

In the Netherlands, maintenance expenditure refers to periodic renewals and improvement works related to the operation of waterways (e.g., remote control of bridges). Compared to the glossary for transport statistics, this definition of maintenance expenditure is broader, as improvement works are classified as investment in the glossary. Expenditure on replacing bridges and locks at the end of their life cycle is financed in the Netherlands from different budgets. The same accounts when a waterway is "modernized" (expanded to accommodate larger vessels), this is considered an investment expenditure.

In inland waterway statistics, no distinction is made between fixed and variable expenditure. There is no distinction between expenditure that can be attributed to ships and expenditure for other functions of waterways (i.e., drinking water, water quality and quantity, recreation, dykes to prevent flooding of land, etc.) or "mode of crossing." For example, bridges cannot be attributed entirely to inland navigation, as they are at least partly related to road traffic.

The Netherlands and Germany define the costs for inland waterways and inland ports separately, while France does not.

Investments in maritime transport infrastructure

The management and ownership of infrastructure in ports varies from almost all ports being privately owned (United Kingdom) to all ports being under government control (France and Spain).

In Sweden (Gothenburg), expenditure on improving the performance of an asset above its initial level is considered an investment. Expenditure on repairs and maintenance is presented as costs.

Thus, there are the following categories of expenditure:

- Investment expenses:
 - Ships
 - Other constructions
 - Vehicles
- Operating expenses (Intermediate consumption)
- Other expenses (taxes, labour costs, interest)

In the UK (associated British ports), all tangible assets are reported as costs, except for operational land. In Germany, the annual results of the port authorities in Hamburg and Bremen (Germany's largest ports) are included in the annual reports of the respective city-state. Therefore, information on port infrastructure alone is difficult to obtain.

France uses the following definitions for maritime transport statistics:

- Investment expenditure is expenditure on new construction and the extension of existing infrastructure, including reconstruction, renewal, and major repairs.
- Maintenance expenditure is expenditure on keeping infrastructure in working order.

For the Netherlands and Spain, as for the United Kingdom, the definitions of the business reports of the port authorities are used, which are established by the national accounting principles of the respective countries.

For Spain, the central government organization responsible for all state-owned ports uses a breakdown for investment expenditure for all these ports, namely:

- Quays and mooring
- Maritime access and signals, shelter
- Land
- Access to land
- The city's port
- Minor investments
- Other investments

For Estonia, investment expenditure includes new construction, renovations, and acquisitions. Operating costs include maintenance, operating, and administrative/overhead costs. The breakdown of infrastructure operating costs in this country is related to:

- Coastal waterways
- Ferry ports for domestic transport

The data analysed shows that none of the countries investigated distinguishes between fixed and variable expenditure in its statistics on maritime transport infrastructure expenditure.

As a specific conclusion, there are major shortcomings in the availability of data for the analysis of specific maritime transport infrastructure expenditure. The minimum requirements that are not met by all countries are:

- infrastructure expenditure available for all seaports;
- a breakdown between fixed and variable costs/expenditures;
- inconsistency in accounting principles relevant to the assessment of capital costs.

Investments in air transport infrastructure

An important aspect of this area is that not all infrastructure expenditure by airport operators is related to air transport itself. A large proportion is accounted for by non-flight-related activities, such as retail or real estate management. Airport operators differ in how they account for their activities.

However, most airport operators in the countries analysed distinguish between investments and operating expenses. There are, however, a few observations:

- In most company accounts, air traffic control expenses are not included. This activity is often carried out by separate (public) air traffic control organizations.
- Maintenance, being one of the current expenses, is not always presented separately in the published accounts, but can, in principle, be isolated.

- Not all operators use identical definitions and criteria to distinguish between an operating expense and an investment or renewal that will be capitalized. In cases where such a distinction is made, the rule is that all such expenditures are capitalized, leading to increased capacity, productivity, or extended useful life of assets.
- All maintenance expenditures are considered operating expenditures.

Another important element is that none of the commercial accounts published by the infrastructure managers of Schiphol, Frankfurt, and Vienna airports made a distinction between fixed and variable costs.

Defining elements of an integrated methodology for calculating transport infrastructure costs

The multitude of existing methods for evaluating the efficiency of investments allocated to transport infrastructure is a problem in the decision-making process, as it is not very clear which of the options would be more useful, more accurate, or clearer.

For these reasons, we present below a methodology which, in our opinion, can better correspond in most cases where a decision must be made regarding the correct and profitable sizing of investments in transport infrastructure.

The methodology analysed proposes three distinct stages, namely:

1. Sizing investments for the current year
2. Assessment of replacement (renewal) costs
3. Sizing operational and maintenance expenses

Within Stage 1, there are several steps that must be taken, namely:

- a. Sizing investments for the current year
- b. Evaluating investments from previous years

a. To determine the total investment costs, it is not the investment expenditures that should be taken into account, but rather the capital costs of these investments. All expenditures related to the investment should be capitalized, including expenditures for:

- land acquisition;
- the acquisition, construction, or replacement of buildings and other structures;
- purchase, installation, or replacement of mobile or fixed installations, machinery, vehicles, and vessels.

To determine the capital costs of investments, you must:

- Estimate the useful life of the investment. The estimated number of years that an asset can be used for the purpose for which it was designed/built is represented, in this situation, by breaking down the infrastructure components and determining the life of each infrastructure component before it is replaced.
- Estimate the capital costs. Annual capital costs can be calculated based on the value of the asset, the useful life of the asset, and the interest rate, using a discount formula with equal payment series, i.e., a linear depreciation or geometric amortization function (ECORYS, 2005):

$$CC = V \times [D / (1 - (1 + D)^{-V})] \quad /1/$$

Where:

- CC = annual capital costs
- V = asset value
- D = interest rate

At this stage, it is very important to decide whether the capital costs of transport infrastructure are calculated on the basis of historical cost prices or replacement values. When replacement values are used, capital costs represent future expenditure for reinvestment, whereas when historical values are used, capital costs represent expenditure

for investments made in the past. As a review of national practices seems to show that most countries use the historical cost approach, it is recommended that capital costs be calculated on the basis of historical costs.

b. In order to evaluate investments made in recent years, long time series of investment expenditures (30-40 years) are needed for each mode of transport. Annual investments should, however, be grouped according to their life expectancy. In a next step, capital costs can be calculated using function /1/.

Unfortunately, the level of detail for estimating capital costs in transport infrastructure currently differs from country to country in various respects.

Some countries use detailed investment series for single categories of infrastructure (road, rail, etc.), while other countries only have aggregate series. Very few countries are able to break down public infrastructure assets into their components (e.g., embankments, foundations, surface layers, etc.).

However, summarizing the methods used, three main groups emerge:

I. The theoretical method. In this case, the different components of roads (earth, surface layer, etc.) are highlighted. Different lifespans and associated utility functions (the expiration date of infrastructure operation) are used for each component. In this method, the life of individual components may remain constant, while an average life calculated for each year's capital stock would increase or decrease depending on the composition of new investments.

II. Annual breakdown of investments method. Infrastructure is identified for each mode (road, rail, etc.), but no distinction is made between components. A weighted average life of components is used for each year's capital stock. The life of new capital stock is periodically modified to be consistent with the (estimated) composition of the capital stock by component. For example, as the main expansion of the road network is completed, the life of new capital stocks is gradually reduced to reflect a higher share of components with shorter lives in the new capital stocks.

III. Simplified method. Asset categories for infrastructure are not distinguished. Composition effects are ignored. A single average life is used and kept constant over long periods of time. Based on a sensitivity analysis carried out by Eurostat with data for German motorways, it is concluded that, in the context of a very large expansion of infrastructure networks, method I produces the most realistic results (ECORYS, 2005).

However, it is also recognised that in practice it may not even be possible to estimate separate lifetimes for each year's social capital, as mentioned in Method II.

In Stage II, the assessment of renewal expenditure, defined as the expenditure on replacing existing infrastructure, extending its lifetime without adding new functionality, implies that renewal expenditure can be characterized as expenditure that leads to an extension of the lifetime of the assets.

If a component of the infrastructure asset is replaced or restored, the expenditure should be capitalized because the expected useful life will be more than one year, using the formula:

$$CCR = R \times [D / (1 - (1 + D)^{-VR})] \quad /2/$$

Where:

CCR = Annual capital costs of renewal expenditure
R = Renewal expenditure
D = Interest rate
VR = useful life of the renewal

Stage III of the dimensioning of operating and maintenance expenditure takes into account the costs of keeping the infrastructure in working order and does not lead to an extension of the useful life of parts of the infrastructure.

These costs include items such as salaries, road surface maintenance, repair and operating repairs, police, traffic management, etc. With regard to police costs, it should be noted that, during the review of national practices, it became clear that these costs are not known for almost all modes of transport.

Operating and maintenance expenses with a life expectancy of more than one year should be capitalized; if the life expectancy is less than or equal to one year, the expenses should only be taken into account for the specific year in which the expenses were incurred without capitalization.

The capitalization of operating and maintenance expenses is done using the formula:

$$CCOI = I \times [D / (1-(1+D))^{(-VS)}] \quad /3/$$

Where:

CCOI = Annual capital costs of operating and maintenance expenses

I = Maintenance expenses

D = Interest rate

VS = useful life of the service (operation or maintenance)

Given the above, the sum of all (capitalized) renewal, operating, and maintenance expenses and the capital costs of (previous) investments for the year represents the total infrastructure costs (TIC), i.e.:

$$CTINF = CC + CCR + CCOI \quad /4/$$

Based on the methodology presented above, specific elements for calculating investments arise for each mode of transport.

Specification of infrastructure investment sizing according to the structure of expenditure for different modes of transport

Road - As mentioned above, in the case of road infrastructure, investment expenditures refer to expenditures for the construction of new roads and the expansion of existing road infrastructure capacity. Operating expenditures refer, for example, to personnel costs, general expenses, and building costs.

For maintenance and renewal costs, many European countries distinguish between "regular" and "irregular" costs. In this situation, we consider it better to regard "irregular" costs as renewal expenditure, extending the life span without adding new functionality, and "periodic costs" as maintenance expenditure, to maintain the functionality of the existing infrastructure during its initial life span.

From this perspective, we can classify all investment and operating expenses as fixed costs of road infrastructure. Therefore, variable infrastructure costs will include renewal and maintenance expenses (Table 1).

Table 1 – Structure of fixed and variable expenses specific to road infrastructure

Expense category	Fixed costs	Variable costs
Investments	100	
Renewal		100
Maintenance		100
Operational	100	

The structure presented in Table 1 is extremely general, and therefore more detailed planning is required regarding the type of infrastructure expenditure and their shares as fixed and/or variable parts (Table 2).

Table 2 – Detailed structure of road infrastructure-specific expenditures

Category	Investment expenditures		Current expenditure		Total
	Investments	Renewal	Maintenance	Operational (Operation)	
	Capital costs		Operating costs		
	Fixed or variable expense ratio				
Road surface area	100%/0	Various fixed and variable ratios			
Superstructures / Drainage works					
Weather conditions, signage					
Grass surfaces, Road edges					
Road installations					
Winter authorization					
Interest					
Total					

Table 2 shows that the proposed methodology indicates a fixed rate of 100% only for the category of investment expenses. Otherwise, all types of expenditure may have fixed and variable rates, resulting, as stated above, in some renewal and/or maintenance expenditure having a variable rate of 100%.

Railway - Obviously, there are many types of railways, from lines dedicated to freight transport to high-speed lines for passengers. Therefore, a distinction must be made between the different types of lines and the expenses must be reported separately. The reason is that such different types of lines cannot be easily compared because the quality of the infrastructure differs. Therefore, they have very different cost structures. This substantially influences the share of variable and fixed expenses.

For the sake of simplicity of the methodology applied, the division must be made for:

- Dedicated freight lines.
- High-speed passenger lines.
- Mixed networks.

Based on the above, a matrix structure is proposed, where, on the horizontal axis, expenditures are classified into investment, renewal, maintenance, and operational expenditures (Table 3).

In this classification: investments are expenditures aimed at new infrastructure or improving the quality or functionality of existing infrastructure beyond its original functionality; renewals are expenditures aimed at replacing existing infrastructure that has reached the end of its designated useful life, extending its life expectancy; maintenance expenditure relates to infrastructure that is actually reaching the end of its designed useful life. A second classification of costs relating to different areas of infrastructure is applied on the vertical axis.

Table 3 – Detailed structure of railway infrastructure-specific expenditures

Category	Investment expenditure		Current expenditures		Total
	Investments	Renewal	Maintenance	Operational (Operation)	
	Capital costs		Operating costs		
	Fixed or variable expense ratio				
Buildings / Railway stations	100%/0%	Various fixed and variable shares			
Civil engineering works					
Superstructure					
New constructions in progress					
Transmission lines					
Signalling equipment					
Telecommunications equipment					
Safety installations					
Vehicles/rolling stock					
Installations and machinery					
Other fixed assets					
Interest					
Total					

The proposed framework provides a method for benchmarking the expenditure of different infrastructure managers and different types of infrastructure (e.g., high-speed lines versus dedicated freight lines).

It should be noted that the share of variable costs may differ from one Member State to another and from one infrastructure manager to another. There are several reasons for this.

Firstly, the use of the infrastructure largely determines the share of variable costs.

Secondly, other influences, such as climatic conditions, may affect the proportion of variable costs.

Thirdly, the share of variable costs is likely to differ depending on the quality of the infrastructure.

Inland waterways - In order to correctly size the expenditure in this sector, the proposed method only addresses values specific to inland waterways without taking inland ports into account.

One reason for this is that information on inland ports and inland waterways is not recorded in the same places in many European countries. Combining the costs of inland ports and waterways would require contacting a much larger number of authorities.

Another reason why it is not appropriate to combine port expenditure with that specific to inland waterways is that a large number of inland port services are already paid for through specific activities, unlike the actual use of inland waterways.

At present, there is no common breakdown of expenditure in most EU countries, let alone between countries. Based on the information available to waterway authorities, it is recommended that the classification presented in Table 4 be used.

The assessment of a long-term investment will need to be carried out only once. When investments from previous years are known and the recording of expenditure in subsequent years is carried out in accordance with the new methodology, no additional effort/only minor additional effort is required in subsequent years in terms of data collection.

Table 4 – Detailed structure of inland waterway infrastructure-specific expenditure

Category	Investment expenditure		Current expenditure		Total
	Investments	Renewal	Maintenance	Operational (Operation)	
	Capital costs		Operating costs		
	Fixed or variable expense ratio				
Sluices	100%/0%	Various fixed and variable ratios			
Bridges					
Riverbanks					
Radars, traffic guides					
Beacons, buoys					
Service vessels (e.g., patrol vessels)					
Dredgers					
Buildings (e.g., at locks)					
Total					

Maritime - Based on the available data, expenditure can be limited to seaports only. It is recommended that expenditure on lighting, buoys and navigation aids and other maritime infrastructure at sea should not be included.

The proposed model for breaking down expenditure specific to maritime transport infrastructure is highlighted in Table 5. Expenditure capitalized in investment, renewal, and (partially) maintenance forms capital costs. Operating costs consist of operational expenditure and the portion of maintenance expenditure that is not capitalized.

Superstructure expenditure is sometimes incurred by port authorities, sometimes by private operators, and sometimes by both, depending on the country and the situation.

In order to obtain comparable information between ports and countries, it is recommended that these expenses not be included.

Private operator expenditures are very difficult to obtain due to the effort required and the sensitivity of this information, which is mostly highly strategic.

It is recommended that the costs for the main port tasks should not be included. In some ports, these tasks are performed by the port authority, in others by a separate entity.

Air transport - With regard to infrastructure specific to air transport, we consider that only infrastructure related to the activity itself should be included in the analysis, namely: infrastructure serving aviation, including ground *handling* and air traffic control services.

Table 5 – Detailed structure of expenditure specific to maritime transport infrastructure

Category	Investment expenditure		Current expenditure		Total
	Investments	Renewal	Maintenance	Operational (Operation)	
	Capital costs		Operating costs		
	Fixed or variable expense ratio				
Keys & data	100%/0%	Various fixed and variable ratios			
Maritime access (road/rail, dredging, signalling)					
Land					
Superstructure (cranes, terminals, etc.)					
Access to land					
Other civil engineering works (pipelines, etc.)					
Equipment (e.g., icebreakers, service vessels, etc.)					
Interest					
Total					

The method of calculating air transport infrastructure-specific costs assumes that capitalized expenditure on investment, renewal, and (partially) maintenance constitutes capital costs. Operating costs consist of operating expenses and the portion of maintenance expenses that are not capitalized (see Table 6).

Table 6 – Detailed structure of air transport infrastructure-specific expenditure

Category	Investment expenditure		Current expenditure		Total	
	Investments	Renewal	Maintenance	Operational (Operation)		
	Capital costs		Operating costs			
	Fixed or variable expense ratio					
Land	100%/0%	Various fixed and variable ratios				
Terminal building and quay						
Other buildings, facilities						
Aerodrome				Runway surface		
				Aircraft parking		
				Taxiways and aprons		
New construction in progress						
Roads						

Installations, equipment					
Other fixed assets					
Airport control					
Interest					
Total					

Conclusions

This paper proposes an integrated methodology for sizing and streamlining transport infrastructure expenditure, as the multitude of existing methods for assessing the efficiency of transport infrastructure investments poses a problem in the decision-making process, as it is not very clear which of the options would be more useful, more accurate, or clearer.

The study also includes an important section describing the particularities applicable to the proposed methodology for streamlining investments in the specific case of each type of infrastructure (roads, railways, etc.).

More importantly, it should be noted that the need to adopt a single, integrated methodology at European level (such as the methodology proposed in this paper) in the near future is motivated by the current diversity of methods used to classify and measure investment expenditure across the European continent.

In this context, the first part of this document briefly presents some telling examples for each mode of transport.

In road transport, all countries are able to distinguish between investment and maintenance expenditure. Many countries are also able to divide maintenance expenditure into several types of "normal" and "abnormal" maintenance, although all countries apply different definitions. In the Netherlands, the terms "fixed maintenance" and "variable maintenance" are used, "structural maintenance" and "operational maintenance" in Austria, "routine maintenance" and "periodic maintenance" in Sweden, and "routine maintenance" and "special maintenance" in Spain.

A division into investments, "normal" and "abnormal" maintenance could form the basis for an approximate framework, but it is clear that much more consistency is needed in the definitions currently used in different countries. This issue and the availability of data are probably the most difficult topics for achieving a harmonized EU framework for monitoring road infrastructure expenditure.

For rail transport, operating expenditure consists of operational expenditure and, depending on the accounting principles, a certain share of maintenance expenditure. Capital costs refer to investments, renewals, and a share of maintenance costs.

Both capitalized and operating expenditures are sometimes divided into subcategories, such as buildings, superstructure, and engineering works for capitalized expenditures. The subcategories applied for operating expenses are, for example, traffic control management, train traffic schedules, and operating expense safety. Capitalized expenses are not generally classified according to investments, renewals, and maintenance in the company's accounts. However, such a breakdown is important in order to determine the share of fixed and variable expenditure. While investments are entirely fixed, maintenance and also renewal expenditure may be partly variable.

In inland waterway statistics, no distinction is made between fixed and variable expenses. There is no distinction between expenditure that can be attributed to vessels and expenditure for other functions of waterways (i.e., drinking water, water quality and quantity, recreation, dykes to prevent flooding of land, etc.) or "mode of crossing." For example, bridges cannot be attributed entirely to inland navigation, as they are at least partly related to road traffic.

In the case of maritime transport, the management and ownership of infrastructure in ports varies from almost every port being privately owned to all ports being under government control.

For airport infrastructure, not all infrastructure expenditure by airport operators is related to air transport itself. A major proportion is accounted for by non-flight-related activities, such as retail or real estate management. Airport operators differ in how they account for their activities.

The final conclusion is clear. At present, there are major differences in terms of scale, with a view to improving the efficiency of investment expenditure on transport infrastructure. In particular, the obvious differences in the structure of these transport infrastructures for each mode of transport make it almost always difficult, if not impossible, to standardize them at Community level.

Therefore, the current study proposes a proper method of integrating current practices with the hope that it will be useful for decision-makers and, at the same time, that it will be a step forward in increasing the efficiency of investments in transport infrastructure, both now and in the future, when society is facing major problems such as health and economic crises, wars, and the excessive and rapid consumption of non-renewable resources.

References

- Adamopoulos, T. (2011). Transportation Costs, Agricultural Productivity, and Cross-Country Income Differences. *International Economic Review*, 52, 489–521.
- EC (European Commission). (2001). Official Journal of the European Communities, Directive 2001/14/EC of the European Parliament and of the Council, <https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CELEX:32001L0014>
- Constantinescu N., N. (1974). *Dictionary of Political Economy*, Ed. Politica, p. 389.
- ECORYS. (2005). Guidelines for calculate infrastructure costs, https://ec.europa.eu/ten/transport/studies/doc/2005_11_30_guidelines_infrastructure_report_en.pdf
- Eliasson, J. and M. Fosgerau (2013), “Cost-overruns and demand shortfalls – deception or selection?” *Transportation Research Part B: Methodological*, vol. 57, pp. 105-113.
- Fistung F.D., Popescu T., (2020), *Transport in the Romanian Historical Space*, Ed. Economica, ISBN: 978-973-709-941-9
- Flyvbjerg, B. (2004), *Procedures for Dealing with Optimism Bias in Transport Planning*, Department for Transport, London.
- Flyvbjerg, B., M.K. Holm and S.L. Buhl (2005), “How (In)accurate Are Demand Forecasts in Public Works Projects? The case of transportation”, *Journal of American Planning Association*, Spring, Vol. 71, No. 2.
- Islam, D. M. Z., Jackson, R., Zunder, T. H., Burgess, A. (2015). Assessing the impact of the 2011 EU Transport White Paper - a rail freight demand forecast up to 2050 for the EU27. *European Transport Research Review*, 7, 22
- Kalotay, K. (2008). FDI in Bulgaria and Romania in the Wake of EU Accession. *Journal of East-West Business*, 14 (1), 5-40
- Köhler, J, Jin, Y. and Barker, T. (2008). Integrated Modelling of EU Transport Policy: Assessing Economic Growth Impacts from Social Marginal Cost Pricing and Infrastructure Investment. *Journal of Transport Economics and Policy*, 42 (1), 1-21
- Makovšek, D. (2014), “Systematic construction risk, cost estimation mechanism and unit price movements”, *Transport Policy*, vol. 35, pp. 135-145.
- Masse P., 1959, *Le choix des investissements*, Ed. Dunod, Paris, ISSN 0430-4691, p.1
- Rodrigue J.P. (2024). *The Geography of Transport Systems*, Routledge Publish, London, chapter 9.1, DOI: 10.4324/9781003343196
- Rose, J.M., and D.A. Hensher (2014), “Toll roads are only part of the overall trip: the error of our ways in past willingness-to-pay studies,” *Transportation*, vol. 41 no. 4, pp. 819–837.