Strategic planning and development of transport infrastructures based on agile methodology

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Abstract. The development of transport infrastructures is an important task for both their strategic planning and development and the provision of quality and safe domestic and international transport services. The analysis of the approaches used to determine transport demand is based on a number of well-established theoretical and practical models, such as the classic four-step transport model. On the other hand, however, the planning of transport needs is of an international affair, requiring multi-state coordination, as is the case with the development of the transport corridors on the Balkan Peninsula. The current publication applies the Agile methodology and approach to defining needs in the design and assessment of infrastructure objects, corridors, plans and strategies. The characteristic of this approach is that it is used to define more precise requirements, using shorter cycles to determine the requirements as well as constant review and evaluation. Based on this approach, a concrete example is presented illustrating the model for the region.

1. Introduction

The planning and development of transport infrastructure are a high priority task determining the level of development of a country or region and reflecting the fundamental problems of society and its development. In this sense, the management, modernization and development of transport infrastructure has a continuous cyclical process that lags behind the expansion of economic relations between different groups of people and countries, even more so that the globalization of society has been already a fact and the way backwards impossible.

In this sense, transport increasingly ensures the daily mobility of people, goods and resources and is becoming more and more important for the production and distribution of goods and services. Transport expenses are part of the cost of production and the main prerequisite for the development of transport systems is the availability of adequate infrastructure.

Transport infrastructure maintains ongoing business connections, but there must be a reserve to ensure the mobility of the economy in the future. Planning and building, transport infrastructure, must reflect fundamental societal problems and issues such as transport safety and security. Every government has problems such as insufficient and inadequate transport infrastructure, missing interconnections, lack of funds for their removal. There are infrastructure problems in all types of transport. The unresolved problems of one type of transport create additional difficulties for other kinds of transport. Infrastructure financing issues have an impact on the quality of infrastructure, with a number of examples being addressed in [1]. Strategic planning and development of transport infrastructure is a complex task related to providing an efficient, effective and sustainable transport system requiring the design and assessment...
of infrastructure, corridors, plans and strategies as well as support the balanced development of individual regions and countries [2].

In [3, 4] the long experience of a number of researchers in the world has been systematically described and the main principles, models and methods of transport traffic research and analysis are described in relation to the assessment and the need for infrastructure development.

Traditional methods for exploring and analysing models for strategic planning and development of transport infrastructures have the following directions:

- Comparative analysis of needs and requirements for strategic planning and development of transport infrastructure.
- Techno-economic, financial analysis, benefits, costs and efficiency of the transport infrastructure development projects.
- Preparation of model schemes, models and solutions for the design and development of transport infrastructures.

In figure 1 is presented the general model (The classification model is used in the Strategic Planning and Development of Transport Infrastructure, as well as in exploring the results and studies as well as in [3]) for strategic planning and development of transport infrastructure based on the classic Four Stages Transportation / Land Use Model.

![Figure 1. Four Stages Transportation / Land Use Model.](image)

The first stage deals with predictions of travel by zones based on regression analysis to determine the number of trips by zone as a function of independent variables. The second stage deals with the spatial movements and links between travel sources and destinations that are most often judged on the distribution of the journey through a gravity model or multiple regression.

The third stage is a modal split of trips by types of transport based on the source / destination preference probability. The latter stage recognizes traffic patterns and transport links, mainly by using methods to investigate operations aimed at minimizing travel costs or time on a transport network.

This procedure is repeated by looking at the minimum cost of travel for the characteristics of the existing transport network on the basis of available data from studies, assessments and forecasts.

There are lots of applied research in this area and some of them will be mentioned in this publication. The near circle of researchers alone [5-13] shows that these methods are actively used both in research studies and practice in planning the design of transport infrastructures, including building the national strategy of our country [14].

All of this is based on complex analysis and strategic planning of transport infrastructure. This analysis is permanent and necessary for updating and upgrading, as well as coordinating regional and global strategies for the development of transport infrastructure and transport services. In a number of cases, it is established that strategic infrastructure goals are delayed over time and others are not realized on a number of objective (financial) and subjective reasons. Others are transformed to a lesser or more extent, and the end infrastructure product differs from the original design, even more so that sometimes poorly planned actions exist due to the complexity of circumstances and requirements. Another major drawback is the fact that the initial hard-core requirements in the strategy are changing and their updating
is labour-intensive and practically impossible. This requires seeking a new approach to planning and managing investment projects to build transport infrastructure.

2. Agile methodology

Agile approach is increasingly being used in the modern software industry to develop sophisticated and time-based projects. Unlike the traditional Waterfall approach, which includes 5 phases (Requirements, Design, Implementation, Verification, Maintenance), Agile Methodology fundamentally differs and has the following features:

- users of the product are actively involved in its development;
- the executive team has decision-making power;
- the requirements change, but the deadlines are fixed;

In figure 2 are shown the differences between Classic and Agile project management methods (Agile approach is successfully used and developed in the software industry, https://www.aoe.com/en/agile.html). With the Classic method Scope, Time and Budget are fixed in advance, while the Agile method is fixed to Time and Budget, and Scope is flexible.

Of course, this can lead to a Scope difference in the project, but it greatly improves the runtime and gaining effective results in the overall iterative development process of the systems. Thus the main task is to get incremental results related to the initial implementation as well as subsequent improvements by building up the next product versions of the project. Fixing Time and Budget aims to close the project implementation cycle by providing the start and end of the project as well as its funding.

![Figure 2. Classical vs Agile Methods.](image)

Agile Manifesto (http://agilemanifesto.org/) allows the development of a different management strategy based on the following principles:

- interactive development, allowing review and improvement of the outcome;
- incremental development and consistency of developing versions;
- version control and tracking changes in requirements;
- controlling the team by assigning tasks with shared responsibility.

The idea [15] for evolutionary development of project requirements goes through the following three stages:

- Generic concept of activity (Explain problem, Present rules, etc.);
- Enriching semantic by subtyping (Task 1, Task 2, ..., Task n);
- Encrasing semantics by machine-readable properties (Property 1, Property 2, ..., Property m).

Evolutionary stages should be traced to the same concept, in the same modelling method, while meeting evolving requirements relating to the depth of specialization of the concepts and specifics of the object under consideration.

In a nutshell [16-18], the Agile methodology provides the flexibility to develop sophisticated systems for which traditional design, planning, and management would be dynamic and labour-intensive,
moreover, the life of the systems themselves is sometimes shorter than their design and production times. As mentioned, this approach is successfully implemented in one of the most dynamic areas, namely the software industry and the results are present. The accumulated experience on the subject can also be transferred to other dynamic areas, such as the transport sphere, and the features that characterize it would be useful for the development of the Agile approach.

3. Agile Model, Algorithm Example and Results

Combining these two seemingly contradictory approaches can contribute to the qualitative change in strategic planning by taking advantage of the Agile approach to quickly define the initial requirements, and then, with shorter steps, move towards solving the individual tasks of the principle the downstream analysis and iterative solution and construction of the different elements of the transport infrastructure. This will of course result in Infrastructure Flexible Requirements (IFR) for Fixed Time (FxT) and Fixed Budget (FxB) features.

3.1. Agile Methodology Flexible Model

As mentioned above, the basic dependence applied in an area can be represented by the interaction function of the type:

$$IFR_t \rightarrow (FxT_t, FxB_t) \rightarrow \text{Most Important IFR},$$

(1)

where \( t \) is a function of time and the matrix comprising the plurality of IFRs:

$$\text{Matrix of IFRs}(t) = \begin{pmatrix} ifr_{1,1} & \cdots & ifr_{1,n} \\ \vdots & \ddots & \vdots \\ ifr_{m,1} & \cdots & ifr_{m,n} \end{pmatrix},$$

(2)

where \( n \) is type of transport (road, railway, water, air, etc.); \( m \) – infrastructure type (pathway, track, bridge, etc.); \( ifr \) – infrastructure flexible requirement by transport and infrastructure types.

In general, it is interesting to determine the budget costs \( R_{ifr} \) for a certain period of time, which can be found in the following way:

$$R_{ifr}(t \in [start2end]) = \sum_{n=1}^{N} \sum_{m=1}^{M} ifr_{n,m} c_{n,m}, \text{money/period},$$

(3)

where \( ifr_{n,m} \) is infrastructure flexible requirements for \( n \) transport and \( m \) infrastructure object; \( c_{n,m} \) – the budget value for the design and realization of the site; \( R_{ifr} \) – budget costs; \( start2end \) – Period of time from the beginning to the end of the project management period considered; \( N \) – number of transport; \( M \) – number of infrastructures.

The summative semantic dimension of the common differences for a given period \( \nabla IFRs \) is the set of:

$$\nabla IFRs (t \in [start2end]) = \sum_{n=1}^{N} \sum_{m=1}^{M} \Delta ifr_{n,m}, \text{differences/period.}$$

(4)

where \( \nabla IFRs \) is part of a multitude of documents pertaining to a specific transport project.

In this regard, \( \nabla IFRs \) have a multi-quantitative dimension, which is measured by the amount of documents (files) containing the semantic descriptions of the Infrastructure Flexible Requirement Differences (IFRD), i.e.:

$$\nabla IFRs \in IFRD.$$

Total Flexible Scope Alternatives for \( n \) transport and \( m \) infrastructure object can be represented by the following Linear Additive Model:

$$FA(n,m) = \sum_i w_i fa(n,m)_{i,j}; w_i > 0; fa(n,m)_{i,j} \in [fa(n,m)_{i,min}, fa(n,m)_{i,max}],$$

(6)

where \( FA(n,m) \) is the total flexible scope for alternative \( j \); \( w_i \) and \( fa(n,m)_{i,j} \) are the weight and flexible scope of criterion \( i \) for alternative \( j \); \( fa(n,m)_{i,min} \) and \( fa(n,m)_{i,max} \) define the range of flexible scopes that can be awarded for the performance under criterion \( i \).
The Linear Additive Model is widely used when comparing alternatives to infrastructure projects management \[4, 13\]. It is simple and easy to use and can also be used as shown in the assessment of agile flexible alternative.

3.2. Agile Flexible Algorithm

In the management of Agile Transport Infrastructure Projects (ATIP), the following step algorithm is used:

3.2.1. Step 1. Defining a matrix of ITFPs on FxT and FxB for n mode of transport and m type infrastructure. Model of the matrix is presented in table 1.

| id(n) | Transport, n | id(m) | Infrastructure, m | FxT, time | FxB, cost |
|-------|--------------|-------|-------------------|-----------|-----------|
| 1     | road         | 1     | road (1, 1)       | FxT (1, 1)| FxB (1, 1)|
| 2     | highway      | 1     | highway (1, 2)    | FxT (1, 2)| FxB (1, 2)|
| 3     | bridge       | 1     | bridge (1, 3)     | FxT (1, 3)| FxB (1, 3)|
| 2     | rail         | 2     | railway (2, 1)    | FxT (2, 1)| FxB (2, 1)|
| 2     | station      | 2     | station (2, 2)    | FxT (2, 2)| FxB (2, 2)|
| 3     | water        | 1     | port (3, 1)       | FxT (3, 1)| FxB (3, 1)|
| 2     | port         | 2     | port (3, 2)       | FxT (3, 2)| FxB (3, 2)|
| 4     | air          | 1     | airport (4, 1)    | FxT (4, 1)| FxB (4, 1)|
| 5     | pipe         | 1     | pipeline (5, 1)   | FxT (5, 1)| FxB (5, 1)|

3.2.2. Step 2. According to the table 2, changes into IFRs and IFRD, are defined, as well as setting priorities for implementation.

| FxR min | FxR max | ΔFxR | Priority |
|---------|---------|------|----------|
| FxR (1, 1) min | FxR (1, 1) max | ΔFxR (1, 1) | low |
| FxR (1, 2) min | FxR (1, 2) max | ΔFxR (1, 2) | high |
| FxR (1, 3) min | FxR (1, 3) max | ΔFxR (1, 3) | medium |
| FxR (2, 1) min | FxR (2, 1) max | ΔFxR (2, 1) | low |
| FxR (2, 2) min | FxR (2, 2) max | ΔFxR (2, 2) | high |
| FxR (3, 1) min | FxR (3, 1) max | ΔFxR (3, 1) | low |
| FxR (3, 2) min | FxR (3, 2) max | ΔFxR (3, 2) | medium |
| FxR (4, 1) min | FxR (4, 1) max | ΔFxR (4, 1) | high |
| FxR (5, 1) min | FxR (5, 1) max | ΔFxR (5, 1) | high |

3.2.3. Step 3.
- Define weight \( w_i \) and flexible scope \( f_a(n, m)_{i,j} \) of criterion \( i \) and alternative \( j \);
- Define the range of flexible scopes \( f_a(n, m)_{i,min} \) and \( f_a(n, m)_{i,max} \) that can be awarded for the performance under criterion \( i \);
- Solve \( FA(n, m) \).

3.2.4. Step 4. In line with the priorities, an Action Plan is prepared for the phased development of infrastructure projects, taking into account and assessing the progress towards improving the functionality of the transport infrastructure.

3.2.5. Step 5. Scope (Initial, Final, and Difference) is evaluated to what extent the requirements meet the needs and then initiate a subsequent version of the same project to improve transport needs (Traffic Capacity and More Requirements).
Once all the steps have been taken, things are reversed in the starting position again, and all potential projects that have not reached the initial requirements for its scope as it is already involved if necessary in the list of upcoming projects or versions, to achieve new outcomes and priorities for development.

3.3. Results
The Agile Methodology Flexible Model and Agile Flexible Algorithm presented above is used in the analysis of part of the upcoming infrastructure projects in the country. In order to appraise the model and the algorithm, major infrastructure projects embedded in the national transport strategy [14], are chosen and presented in table 3.

| ID | Project Description                                                                 | Period, year | Cost, BGN           |
|----|-------------------------------------------------------------------------------------|--------------|---------------------|
| 1  | Construction of an intermodal terminal in Ruse                                      | 2018-2020    | 43 055 008          |
| 2  | Motorway I-1 (E-79) “Vidin-Montana-Vratsa”                                         | 2020         | 2 774 937           |
| 3  | Rehabilitation of road sections in the direction of Kostinbrod-Berkovitsa (lot 2 – road II-81 Kostinbrod-Buchin pass and lot 3 – road II-81 Buchin pass-Berkovitsa) | 2020         | 27 348 581          |
| 4  | Project “Bypass of Gabrovo” – Stage connection including tunnel under Shipka pass (through Stara Planina mountain) | 2017-2019    | 152 554 740         |
| 5  | MTWY Hemus from Yablanitsa to Belokopitovo (sections 1 to 7) (section 1 – Yablanitsa road II-35 and Belokopitovo-Shumen) | 2017-2022    | 2 658 152 061       |
| 6  | Second bridge near Ruse on Danube River                                              | 2029-2033    | 267 759 437         |
| 7  | Construction of a speed bypass of city of Burgas                                    | 2022         | 30 030 348          |
| 8  | Modernization of the railway line Karnobat-Sindel (tunnelling Lozarevo-Bat)         | 2018-2022    | 338 400 000         |
| 9  | Rehabilitation of Road II-86 Plovdiv-Asenovgrad                                      | 2020         | 25 392 217          |
| 10 | Modernization and rehabilitation of the railway section Mezdra-Gorna Oryahovitsa    | 2018-2022    | 647 663 250         |
| 11 | Construction of intermodal terminal Varna                                             | 2018-2020    | 520 000 000         |

After application of the model, the minimum and maximum requirements Range of FxR are determined and in table 4 the defined priorities for implementation of individual projects are given.

| Project ID | Transport                      | Priority |
|------------|--------------------------------|----------|
| 1          | rail and intermodal            | low      |
| 2          | road                           | high     |
| 3          | road                           | medium   |
| 4          | road                           | medium   |
| 5          | road                           | high     |
| 6          | road                           | low      |
| 7          | road                           | low      |
| 8          | rail                           | high     |
| 9          | road                           | medium   |
| 10         | rail                           | high     |
| 11         | water and intermodal           | low      |

The interactive map of figure 3 graphically illustrates the planned infrastructure projects according to their priority. The map shown dynamically changes depending on the time of the strategic goals for the implementation of current and new infrastructure projects.
4. Conclusion
Strategic planning of transport infrastructure is an important task which is the basis for the preparation and implementation of investments in applied infrastructure projects and is part of the economic development at the regional and global level [2, 11, 19]. This process has a permanent and cyclical character and is related to the development and modernization of existing and new transport sites.

As it has been presented here, this proves to be a difficult and dynamic task, especially when it comes to complicated objects, such as transport. This puts the traditional approaches to planning, construction and development of these sites in question for their effective implementation, despite the capabilities of the modern tools for data processing and analysis, and therefore their modification and development is necessary. The presented Agile approach allows for a new concept of consideration and problem solving, namely “a faster and more effective solution, than very accurate and precise but out of time”. This advantage, which is in fact a modification of the traditional approach, allows better planning and realization of infrastructure projects according to the priorities and the degree of their significance. The release of the Scope parameter while preserving Time and Budget (figure 2) reveals Agile’s main advantage over the Classical method, namely the ability to dynamically define and solve the significant problems of managing infrastructure projects in transport.

The approach is presented in a general form and shows its general concepts and results that are the outcome of the work on a scientifically applied project related to research and analysis of models for strategic planning and development of modern transport infrastructures. The presented interactive map is an exemplary model for visualization of infrastructure objects that are included in the Action Plan for Design and Development and which are classified by priority for implementation.

Finally, it can be said that when developing a regional development strategy, both the time horizon and the dynamic changes in transport needs related to general economic and social development must be taken into account. The question of the concrete implementation of the stage for the development of infrastructure projects is up to date and adequate and quick decisions and changes in their scope are of primary importance for their solution.
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