Economic efficiency of strategies that change multimodal transportation network shape and capacity

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Abstract. The methodology developed by the authors for designing a stage-by-stage change the shape and capacity of a multimodal transportation network allows, on the basis of the initial set of strategies, forming the area of effective strategies. This area is used to make an optimal design decision. The article discusses the efficiency of the strategy that stage-by-stage changes shape and capacity of the multimodal transportation network. In this study the strategy efficiency is the strategy compliance with the set goals and interests of potential participants of the investment project for its implementation. At the same time, the use of only economic indicators does not always determine the optimal strategy. For this purpose, in the multimodal transportation network designing methodology a set of interrelated balanced indicators is applied: economic, social, technical, operational, environmental, etc. The article provides recommendations for determining the indicators of economic efficiency: social, national (federal), regional and industry efficiencies included in the Balanced scorecard. These indicators allow estimating possible outcomes of strategies implementation of multimodal transport network development in economic and social spheres for society as a whole, economy of the country, transport industry, and also investment appeal of strategy for potential participants of the project on its realization.

1. Introduction

The task of effective development of transport infrastructure for multimodal transport is complex and urgent. So, project decisions concerning changes in the shape and capacity of such complex transportation systems as the multimodal transportation network (MTN) should have a scientific substantiation. Therefore, the main research of the authors is devoted to the development of a multimodal transportation network designing methodology. MTN is a set of multimodal transportation corridors (MTC) consisting of multimodal transportation hubs (nodes) (MTH) and transportation links (TL) of various modes of transport [1]. In [1] the fundamentals of this methodology are defined. In the many existing transport researches the various models, methods and techniques for the solution of separate problems of functioning and development of complex transportation systems, transportation corridors were considered [2-8 and other].

The taken decision to choose the variant of changing the shape and capacity of the multimodal transportation network should be scientifically sound and effective compared to other variants. This requires to create a tool provided an assessment of MTN development strategies taking into account
external and internal factors that impact on forming of the MTN shape, MTN functioning and development.

Using only economic indicators does not always determine the optimal variant. For this purpose, the MTN designing methodology uses a set of interconnected balanced indicators [9] to determine the effectiveness of strategies changed multimodal transportation network shape and capacity. It will allow to evaluate possible outcome of each strategy implementation in economic and social sectors for society as a whole, the economy, the transport industry and the project investment attractiveness to their potential participants [1, 10].

This article provides recommendations for the definition of economic efficiency indicators included in the Balanced scorecard [10].

These indicators:
- take into account the socio-economic consequences of the implementation of the MTN development strategy for the society as a whole, assessing the economic, environmental, social and foreign economic effects;
- determine the feasibility and attractiveness of the investment project for its potential participants.

2. Materials and Methods
The strategy adopted for implementation, which implements a stage-by-stage change in the MTN shape and capacity, is the basis for the development of an investment project. Its definition is given in [11].

In [12] economic tasks of investment designing, assessment of project efficiency at different stages, project selection are considered. As stated in [12] the project efficiency includes economic, social, environmental, defense and other types of efficiency in general.

In this study, the strategy effectiveness is the correspondence this strategy to the specified goals and interests of the participants who implement it.

According to [11] the implementation of effective strategy that changes multimodal transportation network shape and capacity will increase GDP. On the basis of incomes and costs of the society, the government and the transport industry, the efficiency types are determined in accordance with [11]. In [10] the Balanced scorecard uses social efficiency, national efficiency and transport industry efficiency for the economic evaluation of MTN development strategies.

3. Results
The social efficiency of MTN development strategy ($E_{social}$) reflects its performance from the point of view of society assuming that society will get all outcomes and will bear all costs associated with the project implementation. Also, the social efficiency allows to estimate the reasonability of resource expenditure (which is limited in the economy) on this project implementation [12].

According to [12], social efficiency takes into account the measurable consequences, including costs and outcomes in related areas. Social efficiency can be assessed on the basis of taking into account the impact of the consequences from the implementation of the adopted MTN development strategy. It means the impact on social and environmental conditions of society, demographic effect, transport accessibility and mobility, the number of new jobs, etc.

Projects implementing measures (actions) that change MTN’s objects shape and capacity can be classified as large-scale projects. These projects have a direct impact on the economy not only of the regions, but also the whole country, as well as on the quality of population’s life. Therefore, the definition of social efficiency is mandatory, especially if state support is planned for this project.

Indicators of national economic (federal) efficiency ($E_{national}$) of MTN development strategy reflect economic efficiency from the point of view of the country as a whole. Herewith it takes into account the impact of the strategy implementation on the country's enterprises, social and environmental situation in the country, revenues and expenditures of the country's budget. If the task of MTN development is considered within one region (RMTN), these indicators are called regional efficiency indicators ($E_{region}$). Indicators $E_{region}$ reflect the financial effect of the strategy implementation, which
takes into account its impact on the efficiency of the organizations and enterprises of the studied region, its budget items, as well as the environment and social conditions [11]. Indicators reflect the financial effect of the strategy, which takes into account its impact on the organizations functioning efficiency in studied region, on its budget items, as well as on the environment and social conditions [11]. If the Russian Federation acts as a region, then $E_{\text{region}}$ is called national economic (federal) efficiency $E_{\text{national}}$ for this case.

Indicators of industry efficiency ($E_{\text{industry}}$) of MTN development strategy reflect the financial efficiency from the point of view of the transport industry. It means the impact of the strategy implementation on costs and outcomes. According to [12], in general, when these indicators are calculated, the impact of the project implementation on the other enterprises activities in this industry (indirect sectoral financial results of the project) is taken into account.

This study uses the integral discounted effect ($E_f$) or, in other words, net present value as the main indicator of calculating the economic efficiency of the strategy that change the MTN shape and capacity ($E_{\text{social}}$, $E_{\text{national}}$ and $E_{\text{industry}}$). $E_f$ evaluates the strategy taking into account the time difference, discounting costs and outcomes for $T_p$:

$$E_f = \sum_{t=0}^{T_p} (R_t - EX_t) \left(1 + \text{Dis}\right)^{-t},$$  \hspace{1cm} (1)

where $R_t$ – projected outcomes (income) achieved to the t-year if the assessed MTN development strategy is possible implemented; $EX_t$ – projected expenditures (investments $K_t$ and operating expenses $C_t$), incurred in the year $t$ with the possible implementation of the assessed MTN development strategy; Dis – discount rate.

$E_{f,\text{social}}$ is calculated using the public (social) discount rate ($\text{Dis}_{\text{social}}$). The profitable part ($R_t$) of the integrated discounted effect includes the results of production – the predicted result of the functioning system, which is based on the product of the tariff on the volume of transported cargo mass in the domestic and foreign markets. The costly part ($EX_t$) – includes the cost of necessary resources (material, financial, labor, intellectual).

In revenues and costs of $E_{f,\text{social}}$, it is necessary to take into account the results of the strategy implementation, with accounting their impact as an additional economic effect in other areas and the financial results of the project (for example, taxes, depreciation, profit).

During the determining the national economic efficiency ($E_{\text{national}}$), calculation of incomes and expenditures must be carried out by combining cash flows from various types of activities. At the same time, the accounting of credit amounts, from partially financial activities, is conducted only from the external, in relation to the country and the region [11, 12].

During the determining the transportation industry efficiency ($E_{\text{industry}}$), revenues from freight and passenger transportation can be taken as the outcome ($R_t$) from implementation of the MTN development strategy. In scientific papers [13, 14] it is proposed to determine this outcome depending on the tariff (on rail transport) or the accord rate (on sea transport), and the volume of cargo work for the current year $t$ from the calculation period $T_p$.

In accordance with the recommendations in scientific papers [13-15], mentioned above, investments $K_t$ for each evaluated strategy are defined as the amount of following:
- investments for all measures (actions) which are part of this strategy and are implemented in appropriate MTN objects;
- investments for purchase of the necessary vehicles to ensure the required traffic volumes by years of the calculation period.

For this purpose, data of specific projects, projects-analogs or the enlarged indicators of construction cost for various types of transport can be used.
Operating expenses $C_t$ are calculated as the amount of following:
- expenses which are proportional to the movement of vehicles;
- expenses for the maintenance of constant structures of MTN objects by years of the calculation period.

Operating expenses $C_t$ are determined, as recommended in [16], by direct calculation or by the calculated rates on the measurers. The calculated rates include: labor costs, including tax and social needs, diesel fuel cost and electricity cost, depreciation, water and heat costs, maintenance and repair of all technical systems of MTN, administrative overhead costs, etc.

Investments $K_t$ and operating expenses $C_t$ are calculated for MTN objects and then this results are aggregated in accordance with the four-level decomposition of MTN.

$R_t$ and $EX_t$ calculated for social efficiency $E_{social}$, national efficiency $E_{national}$ and industry efficiency $E_{industry}$ define according to recommendations [11-13, 16 and other]. $E_{social}$, $E_{national}$ and $E_{industry}$ efficiencies are used to work the decision maker with the area of effective strategies that change multimodal transportation network shape and capacity.

Discounted construction and operating expenses are used in comparison of strategies within the estimated case $i_{rs}$ [17]. Discounted construction and operating expenses are defined according to the proposed four-level decomposition of MTN [1]:

$$EX_{mtn}(t,G^m_{p(l)}(t), f : str^{mtn}(t) \rightarrow Em^{mtn}(t)) =$$

$$= \sum_{mtn \in MTK} EX_{mtn}(t,G^m_{p(l)}(t), f : str^{mtn}(t) \rightarrow Em^{mtn}(t)),$$  \hspace{1cm} (2)

$$Z_{mk}(t,G^m_{p(l)}(t), f : str^{mtn}(t) \rightarrow Em^{mtn}(t)) =$$

$$= \sum_{zv \in ZV} EX_{zv}(t,G^v_{p(l)}(t), f : str^v(t) \rightarrow Em^v(t)) +$$

$$+ \sum_{mty \in MTY} EX_{mty}(t,G^m_{p(l)}(t), f : str^{mty}(t) \rightarrow Em^{mty}(t)),$$  \hspace{1cm} (3)

$$EX_{zv}(t,G^v_{p(l)}(t), f : str^v(t) \rightarrow Em^v(t)) =$$

$$= \sum_{g^v \in \{p_{mty} \times h_{zv} \}} EX_{g^v}(t,G^v_{p(l)}(t), f : str^{g^v}(t) \rightarrow Em^{g^v}(t)),$$  \hspace{1cm} (4)

$$EX_{mty}(t,G^m_{p(l)}(t), f : str^{mty}(t) \rightarrow Em^{mty}(t)) =$$

$$= \sum_{g^{mty} \in \{p_{mty} \}} EX_{g^{mty}}(t,G^m_{p(l)}(t), f : str^{g^{mty}}(t) \rightarrow Em^{g^{mty}}(t)),$$  \hspace{1cm} (5)

$$EX_{g^{zv}}(t,G^{g^{zv}}_{p(l)}(t), f : str^{g^{zv}}(t) \rightarrow Em^{g^{zv}}(t)) =$$

$$= \sum_{t=0}^{T_{ex}} \left( K(t,Em_{g^{zv}}^{g^{t}}(t)) \left( 1 + Dis^{t} \right) + \frac{K_{p}(t,G^{g^{zv}}_{p(l)}(t),str^{g^{zv}}_{zv}(t))}{\left( 1 + Dis^{t} \right)^{t}} \right) +$$

$$+ \sum_{t=1}^{T_{ex}} \frac{C(t,G^{g^{zv}}_{p(l)}(t),str^{g^{zv}}_{zv}(t))}{\left( 1 + Dis^{t} \right)^{t}},$$  \hspace{1cm} (6)
where $EX_{mn}^g, EX_{mtk}^g, EX_{ztv}^g, EX_{my}^g, EX_{my}^z$ – discounted construction and operating expenses for strategies that change shape and capacity of MTN, MTC, TL, MTH and their objects; $G_{p(l)}^g, G_{p(l)}^{mtk}, G_{p(l)}^{ztv}, G_{p(l)}^{my}, G_{p(l)}^{my}$ – required traffic volumes accordingly for MTN, MTC, TL, MTH and their objects for the estimated case $i_{rs}$; $st_{mn}^g, Em_{mn}^g, st_{mtk}^g, Em_{mtk}^g, st_{ztv}^g, Em_{ztv}^g, st_{my}^g, Em_{my}^g, st_{my}^z, Em_{my}^z, st_{my}^{n}, Em_{my}^{n}$ – development strategies and their measures (actions) to change shape and capacity of MTN, MTC, TL, MTH and their objects; $K(t, Em_{ztv}^g(t))$ – investments for measures (actions) implementation $Em_{ztv}^g(t)$ to change shape and capacity object of TL (ztv) in year $t$ of the calculation period; $K(t, Em_{my}^g(t))$ – investments for measures (actions) implementation $Em_{my}^g(t)$ to change shape and capacity object of MTH (mtv) in year $t$ of the calculation period; $K_{ps}(t, G_{p(l)}^{ztv}(t), st_{ztv}^g(t))$ – investments for purchase of the necessary vehicles to ensure the required traffic volumes $G_{p(l)}^{ztv}(t)$ during the implementation of the development strategy ($st_{ztv}^g(t)$) of the TL object (ztv) in the year $t$ of the calculation period; $K_{ps}(t, G_{p(l)}^{my}(t), st_{my}^g(t))$ – investments for purchase of the necessary vehicles to ensure the required traffic volumes $G_{p(l)}^{my}(t)$ during the implementation of the development strategy ($st_{my}^g(t)$) of the MTH object (mtv) in the year $t$ of the calculation period; $C(t, G_{p(l)}^{ztv}(t), st_{my}^g(t))$ – operating expenses to ensure the required traffic volumes $G_{p(l)}^{ztv}(t)$ during the implementation of the development strategy ($st_{my}^g(t)$) of the TL object (ztv) in the year $t$ of the calculation period; $C(t, G_{p(l)}^{my}(t), st_{my}^g(t))$ – operating expenses to ensure the required traffic volumes $G_{p(l)}^{my}(t)$ during the implementation of the development strategy ($st_{my}^g(t)$) of the MTH object (mtv) in the year $t$ of the calculation period.

4. Conclusions
The mathematical model of economic efficiency indicators and recommendations for their definition, proposed by the authors, are used in the multimodal transportation network designing methodology to form the area of effective MTN development strategies. These indicators allow estimating possible outcomes of strategies implementation in economic and social spheres for society as a whole, economy of the country, transport industry. And also these indicators allow estimating investment appeal of strategies for potential participants of the project on their implementation. Thus investments and operational expenses for calculation of the discounted construction and operational expenses by
strategies of objects development are accepted as initial data. They should be established in accordance with the approved methods for different modes of transport, according to analogous projects or enlarged indicators of the cost of transport objects construction.

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