Criterion of comparative efficiency in planning of the transport network

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Abstract. Currently, there is a significant number of strategic documents that directly or indirectly postulate the priorities for the development of the railroad transport network. This drives the problem of document matching which should result in actual development trajectory. But this requires a thorough per network pre-project research in order to establish the full extent of transport and non-transport effects that are potentially caused by the network project. The paper focuses on formulating the conditions that allow simplifying pre-project evaluation and states that one of the correct ways to simplify evaluation is to use the criterion of comparative efficiency. The hypothesis of this research is that there is a more nuanced way to present capital investments in infrastructure through the aspects of infrastructure operational efficiency. Standard method of time-linear discounting of money flow is insufficient in transport network development projects. A suggested method is illustrated with a real calculation providing rationale for an option that provides powerful after-action for a rationalized project of a new strategic railroad line.

1. Introduction

Nowadays, some Federal program-strategic documents have been enforced in Russia. They specify the state priorities for transport network at international, national and regional levels. The main documents are: Transport Strategy of Russian Federation till 2030 [1], Development Strategy of Railroad Transport in Russian Federation till 2030 and Plan of its implementation [2], General Scheme of Railroad Development in RF till 2030 with the perspective till 2035[3], most recently approved Strategy of Spatial development of Russian Federation till 2025 [4], state program of Russian Federation “Development of Transport System” [5].

A big number of existing state strategies result in the aggravated problem of matching goals, methods, priorities and determined by them directions in development. Thus, (1) majorly focuses on reducing transport pressure on economy and society, (4) determines the leading aim of transport policy as infrastructure development to increase population mobility, (5) with the amendments of 2019 reinforces the lag of transport network development for the period till 2024, stating the priority projects as those focused mainly on transit and export of resources. This program pays diminished attention to the development of transport network in mid regions; current importance projects, meeting different strategic goals, obviously compete for limited development resources.

Projects of transport network development can be complementary or competing. Even in case of total complementarity projects are accepted according to their priority due to severe resource
limitations. In theory while approving projects for the programs they can be ranked by absolute economic efficiency criteria. Despite the necessity of this criteria adaptation for the industry, evaluation of projects for transport network aspects is based on existing overall economic method. However, in practice consideration of only this criterion leads to aggravated unbalance in network development which means that its development is tuned to serve the determined social-economic priorities and relations damaging modernization strategy of productive forces and, therefore, to facilitate the accelerated scenario of development. In the author’s opinion, methodic premise to such unfavorable effect of the absolute economic efficiency criteria lies in its reduced practice of application with the assessment of mainly the direct cost indicators without proper analysis of the indirect ones, namely, linked non-transport effects, firstly, inter product multiplicative effects. Though the theoretical basis for the calculations has been well developed by the national science, high labor input and specific features of such complex technical and economic research require participation of specialized institutes both in the pre-investment phase and in the process of designing the key network elements.

This paper describes an alternative method of technical and economic feasibility for the projects of transport network development which is based on the criteria of comparative economic efficiency.

2. Goal setting, methods

Transport network development programs are a result of competition of investment projects. It is quite common that such a competition doesn’t correlate with project’s efficiency, but with particular strength of project stakeholders. Territories of location of network projects compete for development resources and economic environment. However, a balanced approach to development of transport networks on wide polygons, including nation-wide polygons, is required. In that case a real evaluation and ranging of project efficiency is difficult to perform. Most evaluations are accurate enough only for construction and operation costs of network elements.

That is why a possible approach may be in ranging of project goals and not the projects themselves. Common goals correlate with aforementioned strategic goal setting and decompose to transport-economical tasks. Finally, the program should include the projects that solve transportation and operation tasks of capacity development, in particular, projects that eliminate passthrough and management limits of transport flow in the network section.

For example, following transport network development tasks are determined for a particular middle region of Russian Federation:
- development of transit capacities in the region
- development of regional transport infrastructure to support the growth of transport availability of the territories as well as support of locally resolved transport flow
- participation of the region in formation of new strategic directions that are already rationalized by transport-strategic high-level documents but require the formation of new large interregional projects

These tasks underline the segmentation of projects, in particular the projects that regions propose during planning of execution of Spatial development strategy. Despite the strategy’s focus on multidimensional socially oriented development that optimizes the use of country’s natural resource potential, some 20% to 50% of all projects that regions propose are of transport and logistics topics, network aspects in particular.

It is important to develop a mechanism for limitation of uncontrolled switching of unified development resources that may harm the tasks determined in tasks implementation documents. It is proposed to strategically range and evaluate tolerable ranges for proportional management of single (internetwork) development resource.

Let us take an example where such ranges are set: 50% should be devoted to capacity increase of the current growing transport flow; 30% should be devoted economical development of the territory to support the network growth with new flows, including the switch from automotive to railroad transport; 20% should be devoted to strategic long lead projects connected with network structure...
evolution. And in the simplest case there already is a set of first-priority network segments that correlate with each of the categories. That allows us to determine the groups of mutually alternative project solutions that in fact are devoted to the same task.

Identification of alternate (interchangeable) projects allows using criterion of comparative efficiency to choose the most efficient option.

It is methodically important to forecast the conditions for the equality of effects of time-bound values of transport flow volume and structure, which in our case are independent from fluctuations of transport costs. On of the ways to establish conditions for equality of effects is determined using dynamical volume values, structural and spatial dislocation of regional production.

When the conditions for the equality of effects are set it is possible to solve specifically the task of comparing the efficiency of resource usage in the transport system. Its main goal is to find rational trajectory and resource pull required for the sustain of equality of effects. This is a development task because it requires to compare alternate plans of capital and current resources.

Development tasks in a large system are characterized by their long lead time. This is due to the necessity of evaluation of long optimization period determined by high transportation costs and systematic nature of transport network. Calculation horizon reflects consequence effect: preventive costs are beared to sustain the future requirements of the development of the system.

Due to the long lead time temporal factor gains significance as an economic criterion. It is important for the registry of resource value change in time. The technique for temporal factor evaluation concentrates on time-interval basis of costs and results.

Calculation of temporal factor in optimization tasks may be resolved with expert based evaluation of resource values used in system development optimization methods. Optimal values in dynamic systems determine the resource value based on the temporal factors, including projected system resource use time forecasts.

The hypothesis of this research is that there is a more nuanced way to present capital investments in infrastructure through the aspects of infrastructure operational efficiency. Standard method of time-linear discounting of money flow is insufficient in transport network development projects because money flows for construction and operation of the network lie in different, and sometimes totally unconnected, measurement systems. Construction investment may come from federal budget; operational costs may be covered by corporate budgets that a completely beared by the customers.

That stipulates the attempt to differentiate the coefficients of intertemporal reduction of capital and operation costs.

All of the available resources of the regional transport system may be presented by two collections – investment in temporal function – \( K(t) \) and production costs in temporal function and investment – \( C(t, K(t)) \). We set reginal economical results, total regional internal revenue as an example, as a target function so let’s set it as a function of \( K \) and \( C \) of regional transport network:

\[
D(t) = D(K(t), C(K(t), t), t)
\]  

Maximizing the target function

\[
\max \varphi = \sum_{t=0}^{T} D_t \text{, we have: } d\varphi = d \sum_{t=0}^{T} D_t = 0 | \varphi = \max
\]  

In order to provide the economic evaluation of a specific program of actions or a decision that requires some form of investment in a specific part of the network we analyze the increase of associated investment and the response of the function in a form of its full differential:
\[
d\varphi = \left[ \frac{\partial}{\partial K_{ip}} \sum_{t=p+1}^{T} D_t + \sum_{j=p}^{T-1} \frac{\partial}{\partial C_{j}} \sum_{t=j+1}^{T} D_t \frac{\partial C_{j}}{\partial K_{ip}} \right] \cdot dK_{ip} = 0
\]

Let's introduce these values:

\[
h_{ip} = \frac{\partial}{\partial K_{ip}} \sum_{t=p+1}^{T} D_t ; \quad g_{j} = \frac{\partial}{\partial C_{j}} \sum_{t=j+1}^{T} D_t ; \quad E_{ipj} = \frac{\partial C_{j}}{\partial K_{ip}}.
\]

(3)

where \( h \) – influence of investment on \( i \) object (or \( i \) program) on target function, it’s maximal influence on total regional profit. Similarly, \( g_{j} \) - is the maximal influence of future operational required costs \( C_{j} \) on total regional revenue, where \( C_{j} \) is generally influenced by \( K_{ip} \).

In a general case this correlation is systematic: overall operational cost resource of the system depends on investment decision and not only on costs of the object of investment as part of the system. As an example, development of a part of the system influences overall system costs, specifically by affecting flow distribution.

Thus, the response speed of the target function (cumulative revenue) to additional capital and operational costs is principally different. Specifically, coefficients \( h \) and \( g \) are set as the coefficients of separate discounting of capital and operation costs which led to a relative increase in capital costs value.

This approach may lower the required conditions for equality of effects when there is certainty that proposed options can exceedingly sustain the production capabilities of the network (flow capacity, for example) in the planned time frame. If there is no such certainty than it is correct to include marginal costs into the weaker option. Discussion of the marginal cost category is out of scope of this article.

3. Research results

Authors used the method of comparative efficiency to evaluate project initiatives on development of backbone railroad transport network in Ural macro region. Projects devoted to solution of different tasks were coupled for the evaluation. First pair of the projects dwells on the development of flow capabilities of the network in the direction West Siberian oil and gas complex – European part of Russia to the west of Ekaterinburg. The second pair of projects are two promising projects to be integrated into meridional lines system that carries trans Russian transit and foreign flows in the North - South direction. Project 2A is supposed to strengthen the west Ural passage (Bogdanovich – Chelyabinsk – Orsk) with planned extension to the south through Kazakhstan to Kandagach station. Project 2B should connect the south of Permksiy region (Chernushka) and Ufa and the further south, through Orenburg to Kazakhstan. So, this is a pair of options of a line along South Ural on the either side of the mountain range. The authors note that both projects demonstrate significant after actions in nontransport effects which should be studied, but the study is quite expensive.

The results of the analysis of project 1A and project 1B are given here. Project 1A is a construction of a complete third line in the interval Tyumen – Bogdanovich to increase the flow capacity up to 27 train pairs in the area with an additional development of Tyumenskiy junction. Project 1B is a construction of single line electric powered rail line Bolsheselskiy – Tavda with a follow up reconstruction of an existing line Egorshtino – Tavda. The projected flow capacity of the new section is 30 train pairs a day. Projected load is 20-22 tons in the uneven direction and 10-11 tons in the even
direction. Such load, considering the empty flow and partial-packed transportation schedules with projected station parameters, corresponds to 9-10 train pairs a day. Investment and operation costs are in current prices without VAT.

Table 1. The calculation result of comparative efficiency for Project 1A and 1B.

|                | Total investment, mln. Rub. | Annual operation cost increase, mln. Rub. | Discount investment, mln. Rub. (0.07 – 0.13) | Discount annual operation cost increase, mln. Rub. | Reduced cost, mln. Rub. |
|----------------|-----------------------------|-------------------------------------------|----------------------------------------------|--------------------------------------------------|------------------------|
| Project 1A     | 67553.86                    | 4060.0 – 4902.0                           | 58764.1 – 59674.4                            | 3898.9 – 4667.85                                 | 46876.5 – 57654.6      |
| Project 1B     | 47766.78                    | 6812.2 – 78841.1                          | 41357.6 – 41087.6                            | 6634.3 – 7598.9                                  | 41987.5 – 50432.4      |

It is clear that Project 1B significantly wins in comparative reduced costs. This means that two competing projects are express evaluated in their costs with a significant headroom of production capabilities. In this case the more efficient project is the one that will construct a new line that opens further development possibilities; thus, the choice of this project is rational. Inclusion of additional parameters into the comparison will only strengthen the rationale. As an example, the project will open approximately 500 high-skilled job vacancies. The calculations account for that factor with an increase in operation costs, but new vacancies also provide social benefit that is collateral for a technic-economic analysis.

The variance in values is driven by the range of increase in operation costs due to uncertainty of the initial data. Moreover, the range of discount investment and discount operation costs forms during the analysis of project sensitivity to macro economical conditions during project implementation phase through ranges of discount coefficients. Coefficient $h$ is set at 3% - 5%. Coefficient $g$ – at 7% - 12%. $E = 0.1$.

4. Discussion of results

Given calculations perform a bigger discount for investment costs which is dictated by the chosen method. It is illustrated that in the current project pair that fact didn’t play a significant role due to short investment term, low volume of the investment and an insignificant (less than 40%) variance in investment. In that situation the balance between investment resources and planned investments should influence the importance of discounting.

Additionally, the insignificant role of higher discount of investment has no effect on the results reliability, because higher discounting doesn’t affect the studied comparative effects.

Project 1B “Tavda-Tobolsk” differs because of the local and overall preconditions. This line will be well supported by transport flows which guarantees its direct transport effect. Moreover, the line is interesting for network graph development causing non transport effect in line with regional and interregional criterion.

The most common project prerequisite that supports the principle of system development continuity is its large diagonal connecting manufacture heavy Ural and oil and gas region of West Siberia, which was noted in several works [9,10]. The line’s internetwork value is in mobilization of geoeconomic potential of Ural as a middle-country macro region that will gradually increase the transport communication network to maximize its integration and transition roles. In general perspective such a project will lead to a formation of new transport line to the east of Ural-North Siberian flows that will take the excessive load from Trans Siberian line simultaneously reducing the transport arm of the locally generated flows. Additionally, the line should be seen as a head-line part of the new Middle-Ural cross-meridional line that will allow an additional transfer through Urals in direction of Nijniy Tagil – Perm when other cross-transfer lines will be depleted. Meanwhile, on the first phase of formation of the new corridor, the suggested Tavda – Tobolsk line will serve as a secondary line to the main ones. Such lines will eventually close the transport network by forming a celled macroregional transport network. A closed celled structure of the network is better suited to the
needs of transport availability than a more common tree-like structure of peripheral networks. Additionally, any element of the network or any graph line is adequately evaluated within the macroregional system even outside of the separate region of RF.

Project “Tavda - Tobolsk” creates investment and infrastructure stimuli for the development of the heavily wood manufacturing western province. The project will contribute to the transport availability of the western part of the region, as well as job creation, reduction in transport stress on the economy of the region, etc. Similar effects arise for Tyumenskaya oblast with even a more pronounced decrease in costs for Tyumenskaya oblast than for Sverdloskaya oblast because of the major direction of supply of petrochemicals from the Tobolskiy junction. The main difference of our approach compared to the desired corporate position of JSC “RZD” of further development of the main railroad line is in support of regional interests in social and economic development through the increase in transport connection between Tyumenskaya oblast and Sverdlovskaya oblast.

Even if we use only the comparative criterion for project approval that minimizes the complex of costs of transport system the choice of adequate initial cost calculation system is very important. For most of the project initiatives this is specifically an over-regional calculation system that suggest a comparison of dynamic situation throughout project implementation. The inclusion of nontransport effects in the comparison will broaden the scope of possible solutions and will provide the rationale for Tavda – Tobolsk line. A correct choice of an investment scheme of the project is required to sustain both corporate and regional interests.

Such projects illustrate the interests of different stakeholders of the transport system: owners of the infrastructure (network itself), transport service providers, load producers and finally social-economic regional actors. This is the main reason for formation of pulls of investment projects for government-private and regional partnerships.

The evidence shows that project success lies in fine-tuning of administrative and economic mechanism of interaction between project team and its stakeholders. There is a significant benefit in allocating project resources to that particular task. Pre project evaluation that involves both actual and comparative efficiency criterions significantly enriches methodical toolbox of the project activity.

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