

Improving the Methodology for Evaluating the Efficiency of Investment in Digital Projects in the Railway Industry

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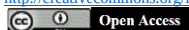
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ABSTRACT

Railway networks have a cost structure dominated by fixed and semi-fixed expenses, which means that when traffic volumes fall, costs cannot be reduced proportionally. This paper identifies such cost rigidity as the economic rationale for investment in digitalisation. Using the operating statistics of Uzbekistan Railways JSC, it shows that in 2019–2020 traffic measured in train-kilometres decreased by 13.9%, while total costs increased by 16.5%, giving a negative cost elasticity with respect to volume of -1.19 . Under such conditions, the main way to raise efficiency is to perform the same volume of work with fewer resources, which is precisely what digital solutions offer. However, the standard discounted cash flow (DCF) apparatus distorts the value of digital projects. The study identifies three systematic limitations of the standard approach: benefits in the form of avoided losses from improved safety and reliability are not reflected in cash flows; software components have a much shorter service life than hardware; and observed changes are attributed entirely to the project. Corresponding adjustments are proposed: an attribution coefficient for the avoided-loss component, a reinvestment stream for short-lived components, and a discount rate weighted by the actual financing structure of the investment portfolio. An analysis of that structure for 2020–2021 shows that it is stable (Ryabtsev index 0.0458) and that market-based sources account for less than 3%, which makes a purely market discount rate unjustified. Finally, a binomial expansion option model is applied to value staged implementation; under illustrative parameters, flexibility adds 45% to the static net present value. The proposed methodology shifts appraisal results in a conservative direction and provides a basis for starting digital projects with a pilot stage.

Introduction

A large part of the costs on the railway network is fixed in nature. According to the statistics of Uzbekistan Railways JSC, in 2019–2020 the volume of work measured in train-kilometres decreased by 13.9%, while total costs increased by 16.5%; the elasticity of costs with respect to volume therefore took a negative value of -1.19 [2]. With such a structure, the ability to reduce costs in line with falling volume is limited, and the main way to increase efficiency is to perform the volume with fewer resources. It is precisely this task that digitalisation is expected to solve: automated train control, predictive maintenance, digital asset management and electronic document flow reduce the resource intensity of each unit of work.

The economic literature on information technology confirms that the returns on digital investment depend on complementary organisational changes and are often realised with a lag and in forms that are not directly visible in accounting cash flows [13]. As a result, digital projects are poorly served by the standard appraisal toolkit: when they are evaluated by the conventional net present value (NPV) method, their value is distorted, sometimes upwards and sometimes downwards.

The relevance of the problem for Uzbekistan is determined by the scale of planned investment. The "Digital Uzbekistan – 2030" Strategy envisages the large-scale digital transformation of

infrastructure sectors, including transport [18], and Uzbekistan Railways JSC implements a multi-year investment programme financed from several sources with very different costs [3]. Errors in appraisal methodology under these conditions translate directly into misallocation of public and borrowed funds.

The aim of the study is to identify the sources of these distortions and to propose an appraisal methodology adapted to the railway network. The objectives are: (1) to substantiate the economic rationale for digital investment through cost rigidity; (2) to identify systematic limitations of the standard DCF approach in relation to digital projects; (3) to propose formal adjustments; (4) to determine the discount rate on the basis of the actual financing structure; and (5) to assess the value of staged implementation using real options.

Literature review

The assessment of investment projects based on discounted cash flows is considered the main tool of financial analysis [9; 17]. At the same time, the limitations of this approach under uncertainty have been widely discussed in the economic literature. S. Myers first put forward the idea of viewing a firm's future investment opportunities as options and showed that traditional calculations do not adequately reflect their value [5]. A. Dixit and R. Pindyck provided the theoretical foundation for the proposition that, for irreversible investments, the opportunity to wait and to proceed step by step has an independent economic value [7]. L. Trigeorgis systematised the types of real options – to defer, stage, expand, contract, abandon and switch – and showed how they interact within a single project [10]. T. Copeland and V. Antikarov adapted these ideas to corporate practice [11].

For the practical calculation of option value, the discrete binomial model developed by J. Cox, S. Ross and M. Rubinstein is widely used [6]; it approximates the continuous-time framework of F. Black and M. Scholes [12]. Its advantage is the ability to work with a small number of numerical parameters, which is important under the conditions of a network where information is limited. In the field of information technology, M. Benaroch and R. Kauffman were among the first to show empirically that real options analysis changes investment decisions on IT projects [14], and E. Schwartz and C. Zozaya-Gorostiza developed models specifically for IT acquisition and development projects [15].

In the practice of appraising transport projects, the need to take into account results that are not directly reflected in cash flows – increases in safety and reliability – is a separate issue. The European Commission's guide to cost-benefit analysis prescribes the monetisation of accident reduction and time savings as economic benefits [16]. National literature also notes the need to take these effects into account when evaluating digital solutions [8]. However, in existing works the observed change is usually attributed to the project as a whole, and the influence of other factors is not separated. The same approach was used in the author's earlier work [1]. Finally, research on large infrastructure projects shows a systematic tendency to underestimate costs and overestimate benefits [19], which supports the case for conservative adjustments in appraisal.

Materials and methods

Data

The study uses the operating and financial statistics of Uzbekistan Railways JSC for 2017–2020 [2] and data on its investment projects for 2017, 2020 and 2021, including the structure of financing sources [3]. Foreign practice is represented by the German federal investment framework plan for transport infrastructure for 2025–2029 [4].

Limitations of the standard approach

The standard approach has three systematic limitations. The first concerns the composition of benefits: part of the benefit – increased safety and reliability – is not recorded in the accounting system as a cash flow and is therefore omitted. The second concerns the service life: the software component of a digital project becomes obsolete much faster than the hardware, so a single service life overstates the

duration of benefits per unit of investment. The third concerns attribution: the observed change in performance is attributed entirely to the project. The first limitation reduces the estimated result, while the third increases it; therefore, they must be corrected simultaneously, otherwise one correction will only amplify the opposite distortion.

Adjustment 1: avoided losses with an attribution coefficient

Expected avoided losses in year t are calculated with an attribution coefficient:

$$E_{av,t} = \sum_j (N_{0j} - N_{1j,t}) \cdot C_j \cdot k_j$$

where N_{0j} is the baseline frequency of events of type j (accidents, failures, delays), $N_{1j,t}$ is their frequency after implementation, C_j is the average loss per event, and k_j is the share of the reduction in events attributable to the project. The coefficient k_j is determined using a comparison group (sections of the network where the solution has not yet been introduced) or control variables; when these are not available, it is conservatively set at a small value.

Adjustment 2: reinvestment stream for short-lived components

The net present value, taking into account the reinvestment stream R_t required to renew the software component during the project horizon, is:

$$NPV = \sum_t (CF_t + E_{av,t} - R_t) / (1 + r)^t - I_0$$

where CF_t is the direct cash flow, I_0 is the initial investment, and r is the discount rate.

Adjustment 3: discount rate based on the actual financing structure

The discount rate is determined as the weighted cost of the financing sources:

$$r = \sum_i w_i \cdot r_i$$

where w_i is the share of source i in the company's investment portfolio [3] and r_i is its cost. This approach follows the logic of the weighted average cost of capital [9; 20], but uses the actual structure of a portfolio dominated by own funds, state-guaranteed loans and budget allocations rather than a hypothetical market capital structure. The stability of the structure is assessed using the Ryabtsev index of structural differences.

Valuing staged implementation

The possibility of extending a project step by step after a successful pilot is evaluated as an expansion option using the one-period binomial model [6]:

$$C = e^{(-rT)} \cdot [q \cdot \max(V \cdot u - I_e, 0) + (1 - q) \cdot \max(V \cdot d - I_e, 0)]$$

where V is the present value of the expansion's benefits, I_e is the cost of expansion, u and d are the up and down factors determined by volatility, q is the risk-neutral probability, and T is the time horizon. The value of flexibility is the difference between the value of the staged strategy and the static NPV of implementing the project in full at once. Where the model is extended to simulation, the required number of iterations is determined by the condition $n \geq z^2 p(1-p)/e^2$, where z is the quantile of the normal distribution, p is the expected probability of the event of interest, and e is the required accuracy [21; 22].

Results

Structure of investment financing

Table 1

Structure of financing of the investment portfolio, %

Source	01.01.2020	01.01.2021	Change, p.p.
Company's own funds	40.79	43.93	+3.14
Foreign loans under state guarantee	25.83	23.56	-2.27
State budget	15.29	15.47	+0.18
Fund for Reconstruction and Development	11.47	8.83	-2.64
Foreign direct investment	4.76	5.48	+0.72
Commercial bank loans	1.86	2.74	+0.88

Source: author's calculations based on [3].

The structure is stable between the two dates: the largest shift is 3.14 percentage points, and the Ryabtsev index is 0.0458, which corresponds to a very low level of structural difference. The share of market resources (commercial bank loans) is less than three percent, which makes setting the discount rate at the market level unjustified. Almost 85% of the portfolio is formed by own funds, state-guaranteed loans and budget resources, whose cost differs substantially from market rates.

The portfolio analysis yielded another result: projects related to digitalisation are not allocated separately – digital solutions are included within electrification projects and rolling-stock renewal projects. Consequently, it is currently impossible to evaluate the efficiency of digital investment as a separate category at the portfolio level.

Direction of the adjustments

Table 2

Effect of the proposed adjustments on the appraisal result

Limitation of the standard approach	Adjustment	Effect on NPV
Avoided losses (safety, reliability) are ignored	Component $E_{av,t}$ added	Increases
Observed change attributed entirely to the project	Attribution coefficient $k_j \leq 1$	Decreases
Single service life for hardware and software	Reinvestment stream R_t	Decreases
Market or arbitrary discount rate	Rate weighted by actual financing structure	Depends on structure

Source: developed by the author.

Value of staged implementation

The staged model was tested with conditional parameters: the expected value of the expansion is 20% above its cost, volatility is 40%, and the horizon is one year. The value of the staged option is 2.90, while the static result of implementing the project in one step is 2.00; the value of flexibility is therefore 0.90, or 45% of the static NPV. These values are not empirical results but a demonstration of the model's logic.

For simulation-based evaluation, with $z = 1.96$ and $p = 0.3$, accuracy of two percentage points requires approximately 2,017 iterations, and accuracy of one percentage point requires 8,068 iterations.

Discussion

Conservative direction of the adjustments

The proposed adjustments move the result in a conservative direction: the attribution coefficient reduces the benefit, and the reinvestment stream increases the cost. This direction was chosen deliberately, because in investment decisions an overestimation error is more costly than an underestimation error: an overvalued project consumes resources irreversibly, while an undervalued one can be reconsidered at the next stage. This choice is consistent with evidence of systematic optimism in infrastructure appraisal [19]. In the author's earlier version [1], the observed change was attributed entirely to the project; the present methodology corrects this.

Real options and institutional uncertainty

The results of the staged model are consistent with the theoretical conclusions in the literature: the higher the uncertainty, the greater the value of the opportunity to wait and proceed step by step [7; 10]. Under network conditions this rule has a specific content. The institutional gap is high, i.e. target indicators deviate noticeably from actual results, which means high uncertainty regarding project outcomes. Under such conditions, starting with a pilot stage is not merely a risk-reduction measure but an economically justified decision. This links the investment methodology to institutional analysis: the

larger the gap between plans and outcomes, the greater the value of flexibility. Empirical studies of IT investments likewise show that explicitly valuing staging options changes the optimal decision from immediate full deployment to a sequential one [14; 15].

Level of appraisal

The fact that digital projects are not separated in the portfolio determines the level of assessment: efficiency should be calculated not at the level of the network but at the level of a separate project. A similar situation is observed in Germany, where digitalisation in the federal investment plan is given as part of infrastructure modernisation [4]. It is therefore recommended that the company introduce a separate classification code for digital components within investment projects, which would allow their costs and effects to be monitored.

Limitations

The attribution coefficient requires a comparison group or reliable control variables, which are not always available; in their absence the conservative default value may underestimate effective projects. The cost of each financing source (r_i) was not available in public data, so the discount rate formula is presented without a numerical estimate. The option model is one-period and uses illustrative parameters; a multi-period lattice calibrated on project data is a direction for further research.

Conclusion

The cost structure of the network determines the economic rationale for digital investment: when costs do not fall with volume, efficiency can be increased only by reducing the resource intensity of work. The standard appraisal apparatus requires adaptation in three directions: the composition of benefits, the time horizon of components, and the attribution of results to the project. Setting the discount rate according to the actual financing structure and evaluating staged implementation as an option increase the validity of investment decisions on digital projects. It is recommended (1) to include avoided losses with an attribution coefficient in the appraisal of digital projects; (2) to separate the software component and its reinvestment cycle; (3) to determine the discount rate from the actual financing structure; (4) to begin projects with high uncertainty from a pilot stage; and (5) to allocate digital components as a separate category in the company's investment portfolio.

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