Infrastructure project planning

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Abstract: This article analyzes problems arising when implementing large infrastructure projects whose number is increasing due to the transition of companies to project management. The study focuses on significant budget overruns and longtime delays in project implementation. The authors developed an approach that allows for effective project stratum decisions. The works of foreign scientists who studied experience of large infrastructure project implementation were analyzed. The analysis helped identify main causes of cost overruns and construction delays (lack of high-quality analysis of data used for project budgeting and scheduling).

1. Introduction

The current stage of economic development characterized by enhanced competition, high risks and uncertainty makes it imperative for companies to implement new building technologies and apply effective methods of corporate and project management. Companies implementing large construction projects are currently moving from the extensive development path based on the use of additional production factors to the intensive development path based on investments in large construction projects, scientific and technological achievements and innovation.

This requires a new management approach to planning of investment projects. At the planning stage, the key parameters (performance time, cost, resources) of the project are identified, and the decision on project launching is made. At this stage, it is important to analyze information. The key aspect of implementation of any
investment project is a pre-design stage which involves planning, developing schedules and budgeting. Then the decision on project launching is made. Specialists of the planning or design department of the construction company analyze information obtained by the departments involved in the project implementation process.

2. Materials and Methods
When planning the construction of large objects, in addition to the data gathered by specialists of the project department, corporate project management regulations are used as well. They contain a list of typical works and typical performance time. In budgeting, prices of similar objects or estimates used for the construction of other objects with regard to correction factors (e.g., the inflation coefficient) are used.

The data on performance time are summarized in the schedule, while the data on costs are summarized in the budget scheme. If the documents are approved, a target plan and a project budget are developed. Schedules are often developed taking into account only the launching date determined by the top management within the limits of a strictly stipulated budget. This practice of corporate management causes the need for schedule revision which reduces the performance time that lies on a critical path and limits the budget.

This approach is possible if the decision to set a deadline and allocate a strictly limited budget concerns investment projects in a field in which the company has already had successful construction experience. The approach can be justified if the company analyzes managerial decisions made before launching the project and after completing it. There is a correlation between retrospective decisions and the result. Second, there are no changes in the professional project team over the long period, or its structure changes slightly.

For a new project, the approach to the performance time and project cost should be flexible. First, probability of unaccounted expenses and events affecting the performance time is extremely high. As a result, the size of the allocated budget and available reserves will not be sufficient which can “freeze” the project. Second, the performance time and costs often become known to the public; third parties are involved in these processes, and the company strives to implement the project on time to strengthen its position in the market (to obtain the government and banking support, to cooperate with reputable contractors).

If the deadline has been violated and the cost has increased, the company has a reputational risk that could undermine trust of “stakeholders” - government authorities, creditors, potential consumers, and other organizations.

Thus, in scheduling and budgeting, it is not enough to rely only on experience of the company management and expert opinions. Errors made at the planning stage can have a significant impact on both financial and temporary effectiveness of the project.

The most common causes of failures of large construction projects are as follows.
First, the company relies on previous projects. Balancing on the “time edge” is an important principle of successful project management. The rapid flow of changes in the external and internal environment of construction organizations forces the company's management to think about a variety of time horizons. The principle “balancing on the edge of time” prevents the company from "slipping" into the past. If too much attention is paid to previous experience, the company’s strategies turn out to be enclosed in outdated competitive models. However, it is impossible to ignore previous experience. If we ignore the accumulated potential of implemented projects, it is impossible to achieve positive results. The company always starts everything from the beginning, repeating past mistakes, and the result is a slowdown of its development. Second, it is inaccurate determination of risk probability. Third, it is “rapid” solutions.

There are a lot of examples of inefficient financial planning. Table 1 presents the most famous projects in the field of large-scale infrastructure construction, with the highest excess of planned costs of construction and installation works (CIW).

Table 1. Projects with the most significant excess of costs of construction and installation works

| Project                                      | Excess of planned costs of construction and installation works, % |
|----------------------------------------------|---------------------------------------------------------------|
| Suez Canal                                   | 1900                                                          |
| Sydney Opera House (Australia)               | 1400                                                          |
| Scottish Parliament (UK)                     | 1075                                                          |
| Calcutta Metro (India)                       | 500                                                           |
| Panama Canal                                 | 200                                                           |
| Denver International Airport (USA)           | 200                                                           |
| Boston-Washington-New York Railroad (USA)    | 130                                                           |
| Brooklyn Bridge (USA)                        | 100                                                           |
| Shinkansen Railway (Japan)                   | 100                                                           |
| Washington Metropolitan (US)                 | 85                                                            |
| Mexico Metropolitan (Mexico)                 | 60                                                            |
| Baltimore Metropolitan (US)                  | 60                                                            |
| Metropolitan Tyne and Wear (UK)              | 55                                                            |

Based on [1].

In the 2000s, the expert community analyzed railway construction projects implemented in 1970-2000. In most cases, the planned number of passengers was overestimated, and the cost of projects increased by more than 50%. Despite the thirty years of experience, managerial conclusions have not been drawn. The construction of the Scottish Parliament building is a well-known example. The
planned construction costs were £ 40 million. As a result, they exceeded £430 million.

The construction of Denver International Airport is an example of inaccurate planning of the performance time. It was planned to open the airport in 1993. The decision to build the airport was made in 1988. The construction was completed on October 31, 1993, except for the automatic baggage handling system, which was on a critical path. Due to the completion of construction of the tunnels designed for servicing the automated system of remotely controlled trolleys, there were no alternative baggage handling methods (reconstruction of the tunnels would take up more time than construction of the baggage handling system). Owing to the commissioning delay, the airport was launched only in 1995. [2]

The reason for the launching delay was ignorance of the development time for a similar system (Baggage handling system “Crisbag”) at Franz Josef Strauss Airport in Munich. The developers of Munich airport spent 2.5 years developing, testing and debugging a similar system. [3] These dates were ignored by the DIA Board.

As can be seen from Table 1, errors occur in projects implemented in different countries at different time and by different companies. According to the International Association of Engineering Insurers IMIA, disruption of construction deadlines resulting in a significant increase in the project cost was y influenced by management errors, including material and equipment delivery delays (33%). Other reasons are low quality of CIW (23%) and designing errors (12%).

The study on planned and actual costs of large infrastructure projects shows that the lack of in-depth analysis of factors that may affect project costs significantly affects its budget. Overruns for railway projects amounted to 45%, tunnel and bridge construction projects – 34%, road construction projects - over 20%. [4]

Table 2 presents data on the most famous projects.

| Project                                      | Cost overruns, % |
|----------------------------------------------|------------------|
| Large Boston Tunnel (USA)                    | 196              |
| Humber Bridge (UK)                           | 175              |
| Boston-Washington-New York Railroad (USA)    | 130              |
| Railway tunnel Great Belt (Denmark)          | 110              |
| Motorway A6 (UK)                             | 100              |
| Shinkansen Railway (Japan)                   | 100              |
| Washington Metropolitan (US)                 | 85               |
| Mexico Metropolitan (Mexico)                 | 60               |
| Metropolitan Tyne and Wear (UK)              | 55               |

Based on [4].

The study on the effectiveness of large infrastructure projects conducted by the University of Aalborg in Denmark revealed deviations of actual costs from the
designed ones by 28%. The conclusions drawn from this study are as follows:
- in 9 out of 10 transport infrastructure projects, the costs were underestimated which caused the excess of costs;
- underestimation of costs and cost overruns have not decreased over the last 90 years; there are planning errors;
- underestimation of costs and cost overruns are due to planning errors and strategic distortion of data, deception [5].

The findings of these scientists are complemented by in-depth studies [6] carried out by B. Flivbjorg who believes that "the main cause of cost overruns is the lack of realism in the original estimate." He formulated the following causes of unsuccessful planning:
- a method: integrated production planning and logistics (econometric software packages). Probability of using an inappropriate model is high due to specific requirements.
  - insufficient database;
  - biased assessment: the desire to include political preferences into the forecast, experience of implementation of large infrastructure projects in the country of his origin.
- a non-permanent model of behavior and the influence of additional factors (attractiveness of stations; their location near bus stops, shops and parking facilities; consumer safety; navigation data; compliance with hygiene requirements in transport; availability of access roads; flexibility of urban development and housing policy, etc. [7]
  - unexpected changes in exogenous factors (social and political upheavals, changes in energy prices);
  - unexpected political situation: changes in government decisions on urban infrastructure, taxation, etc.
- biased assessment by the project manager: distortion of data when the manager wants to launch the project regardless of possible unaccounted over-costs. [8]

Thus, the most significant factor influencing the performance time and project costs is poor-quality data. In the conditions of shortage of time and competition, the project management is more likely to decide to launch the project.

3. Results
A conclusion drawn by D. Kahneman, the founder of modern behavioral economics and hedonistic psychology, who received the Nobel Prize for applying psychological techniques in economics, can confirm our viewpoint. In his well-known work “Think slowly, decide quickly,” he points out: “The main source of forecasting errors might be a trend to underestimate or ignore distribution information. Therefore, planners should work hard to identify the problem of forecasting and gather and analyze distribution information.” [9]

Distribution information are data on similar projects. According to Kahneman, information collection eliminates planning errors." [10]
To reduce the impact of this factor (since full elimination of the factor of uncertainty is impossible), it is necessary to use the methods which can solve this problem.

Considering the root cause of the problem of incomplete collection of initial data for making decisions on implementation of investment and innovative projects, let us analyze the theory of decision making developed by D. Kahneman and A. Tversky, according to which “optimistic distortion is an important source of risk acceptance”. This theory says that in standard rational economic models, people take risks in favorable conditions, i.e. people accept probability of losses with sufficient probability of success.

In project planning, under the influence of deceptive optimism, the developers overestimate project benefits and underestimate project costs analyzing successful scenarios and skipping tricky places where you can make errors. It causes budget overruns, temporary delays, non-return of funds, etc. [11]

Having eliminated the planning error, one can increase probability of a right decision. Any investment project is implemented under high uncertainty and risks, and elimination of planning miscalculations enhances project certainty.

To reduce planning errors, the methods presented in Table 3 can be applied.

| Method       | SWOT-analysis                           | Network Planning Analysis                        | Critical Path Method                                                                 |
|--------------|-----------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------|
| Essene       | Description of advantages, weaknesses, opportunities and threats of the project | Assessment and analysis of the project, performance time, labor and other resources | Identification of the critical path of the project, i.e. a temporary shift in one of the works which increases or decreases the construction period |
| Advantages   | Analysis of advantages and disadvantages of the organization which allows for general assessment of the company capabilities and limitations regarding the construction of the facility | Applicable for large construction projects. The method takes into account uncertainty of the project through simulation of three project development options: pessimistic, optimistic and simple. | Simplicity. The method identifies works that are on the critical path |
The analysis of the methods presented in Table 3 shows that the use of one of them is not enough for effective planning; the company will need to take additional measures to eliminate planning shortcomings.

For leveling planning deficiencies, it was proposed to use an extended approach, which is similar to the method for eliminating a priori probability ignorance errors developed by Kahneman (see Table 4). It consists of three successive planning stages.

| Stage | Description | Example |
|-------|-------------|---------|
| Identification of the source category | Identification of the object for which source data should be gathered | Railway construction |
| Data capturing | It is necessary to gather all data on previous projects carried out by the company, as well as on similar objects. | The cost of the railroad track construction depending on the season |
| Using specific information to improve the baseline forecast | Each object of the internal and external environment, which can affect the project is analyzed. Expert organizations are involved to assess company capabilities, availability of conditions (internal and | For example, for a small-scale, relatively short-term facility, it is necessary to foresee the use of wooden sleepers impregnated with creosote instead of reinforced concrete. Otherwise, there may be disproportionate goals of the project: high cost of sleepers due to the |
| Stage | Description | Example |
|-------|-------------|---------|
|       | external) for the project. All data are analyzed and consolidated to make a decision on implementation / cancellation of the construction project as well as on application of information on promising projects | use of concrete and pre-tension reinforcement; - high cost of fasteners; - high cost of transportation; - difficult installation may increase the duration of project implementation |

At the first stage, it is necessary to determine the nature and “bottlenecks” of the project, and take into account its basic parameters: goal, planned deadlines, budget, etc. This information is included in the project charter. It is necessary to consolidate all the project documents: minutes, reports, meeting materials, materials of video and audio conferences, decisions.

According to experts, [12] in order to successfully plan a project and achieve target results, it is necessary to set a goal using the SMART ideology:

- Specific: a target result;
- Measurable: quantitative expression of the result (absolute or relative indicators);
- Achievable: a realistic goal (the company need to have resources);
- Relevant: checking the goal for relevance (whether the project is significant now and will be significant in the future);
- Time-bound: the goal statement contains the deadline.

After the project documents have been prepared, the second planning stage begins. After the main project parameters have been identified, the project management needs to develop a Work Breakdown Structure - this is a graphic representation of the project, i.e. a set of interrelated project elements [13]

Depending on the type of a project - a new original project, or a project similar to the previous one, different methods are used for developing the WBS:

1) the bottom-up method is used when developers lack information about the upcoming works. In practice, the method of brainstorming and grouping of works and tasks are applied. The volume of works is estimated. This grouping is carried out before elements reach the top level.

2) the top-down method assumes that developers are aware of the upcoming works. Decomposition is carried out from the topmost elements to indivisible units of work, resources, etc.

In developing the WBS, special attention should be paid to the statistical data on similar works. It is necessary to use all possible sources of information:
- Information on previous projects, if these projects have already been implemented by the company;
- Analysis of the current state of the market and forecasts for the future;
- Gathering of information from all specialists involved in the project ("experience gathering");
- Research carried out by professional organizations;
- Involvement of companies having benchmarking experience;
- Statistics, schedules and other information about similar projects implemented by other companies.

The information is accumulated and structured for further analysis.

4. Conclusion
At the final stage, specific information is used to improve the baseline forecast. All the information is analyzed by the project management. The company develops an approximate plan (Plan A). It is necessary to adjust this plan to the results of analysis of the information gathered. This is the second variant of the schedule (Plan B) which must be saved and compared with Plan A.

In addition to the standard quantitative methods, the critical chain method (CPM), the Monte Carlo and others methods used for analyzing the performance time, the authors suggest analysis of qualitative parameters (climatic conditions, possible inclusion of the land leased for the project into the sanitary protection zone, companies operating in the area, attitude of local people to facilities constructed on their land, etc.).

It is necessary to take into account all factors influencing the project. Based on the in-depth analysis, plan B is adjusted and plan C is developed. The latter reflects real performance time and project costs.

When "bottlenecks" are identified, it is easier to develop appropriate measures to minimize or eliminate project uncertainty. The final stage is comparison of plans. As a rule, at this stage, the project team has already had an idea of the upcoming works, their challenges and opportunities. The comparison makes it possible to identify differences in the superficial "optimistic" planning and in-depth preliminary project analysis. After the comparison has been carried out, a final document is developed. It is presented to the top managers. Based on this report, the management makes a decision on the project.

Thus, in order to make a balanced decision on the project, it is necessary to eliminate planning errors which entail too optimistic forecasts of the project costs and performance time. To eliminate planning errors, it is necessary to carry out in-depth and high-quality gathering and analysis of data on the project.

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