


# Automation of the Preliminary Assessment in the Design of Commercial Roads

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**Abstract:** The research article is devoted to the problem of automating the estimation of cost and labor in the road construction process, given the complexity of influencing factors such as soil type, weather conditions and resource costs. The article discusses the importance of accurately determining these parameters in the context of road design, emphasizing the high qualification of engineers. Particular attention is paid to the importance of automating preliminary assessment, identifying its key benefits: data analysis, rapid generation of estimates, decision optimization and risk management. As a result, automated systems are becoming an integral part of successful completion of road projects, minimizing financial and time costs. The paper further focuses on the description of the developed software solution aimed at automating the preliminary determination of embankment design, geomaterial strength characteristics, resources and construction cost in road construction projects.

## 1 INTRODUCTION


The estimation of cost and labor in road construction is a complex task due to numerous influencing factors. Factors such as soil type, weather conditions, material and labor costs represent only a fraction of the parameters that need to be considered for a reliable estimate. Additionally, the complexity of road design, including technical aspects such as alignment geometry and pavement stability, adds to the complexity of cost estimation.


In light of the factors described above, accurate cost and labor estimation in road construction requires consideration of many variables and possible changes in conditions, making the process difficult and highly demanding on the skills of engineers and specialists. In this context, automating the preliminary estimation of cost and labor for road construction is of paramount importance.

The importance of this process is justified by a number of key advantages of automation. First of all, automated systems have the ability to analyze vast amounts of data and parameters, increasing the accuracy of estimates. Second, they are able to generate estimates quickly based on input data, significantly reducing time costs. Third, automated systems perform cost and labor analysis at various stages of design and construction, which helps identify optimal solutions for efficient use of resources. Finally, automated systems facilitate risk management by providing the ability to identify potential problems and risks early in the project.


In this context, the automation of pre-assessment becomes an integral part of successful completion of road construction projects, resulting in minimization of financial and time costs. The following paper will describe the developed software solution aimed at automating the preliminary determination of embankment design, geomaterial


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strength characteristics, resources and construction cost in road construction projects.

## 2 MATERIALS AND METHODS

### 2.1 Requirements elicitation

There are many methods for requirements elicitation. BABOK lists nine, but there are many more methods, such as protocol analysis (Berezovik, 2024.), job application development (Khasanov, Prokofiev, Ushmaev, Gilmanov, Margarit, 2016), and the like.

It is unlikely that any one elicitation method will always work for all projects. "While some may advocate ... only one method of elicitation... it is generally recognized that a method or approach to identifying individual requirements may not be appropriate for all projects."

The structure of the organization, the political climate, the nature of the project, and your personal strengths and preferences will largely determine which methods will work best for the project. Having said that, here are five methods that analysts with almost any experience or skill level can use and that almost always yield a great return on investment.

Table 1: Basic requirements elicitation methods.

Method name	Brief description	Benefits
Observation	Capturing what already exists. As one analyst notes, "We have found that informal use cases provide the best return on invested effort in the early stages of discovery - they are easier to repeat and provide less risk of getting tangled up in the details of early thought processes." (Hidellaarachchi, Grundy, Hoda, Mueller, 2023)	The ability to accurately identify the users' position at the beginning of a project.
Brainstorming	A way to find solutions	Helps avoid potential pitfalls in

	without frameworks and constraints using collective intelligence. Multiple ideas and information provide a rich knowledge base to choose from to understand the direction of the project.	the future by enlisting others to help uncover unknown data. Allows a large amount of information to be absorbed simultaneously to help understand the direction of the project.
Interview	Individualized elicitation of requirements from a stakeholder. One author notes: "Interviews provide an efficient way to collect large amounts of data quickly." (Khan nur, Hiremath, 2023)	In-depth exploration of the stakeholder's needs. The author adds: "The results of interviews, such as the usefulness of the information gathered, can vary considerably depending on the skill of the interviewer." (Khannur, Hiremath, 2023)
Requirements workshops	A gathering of key stakeholders to elicit requirements in an open conversation. "A requirements workshop is a highly productive, focused event that brings together carefully selected key stakeholders and subject matter experts over a short intensive period." (Sehlhorst, 2012)	Rapid requirements elicitation. Possibility of attracting inventory into the project.
Prototype	Creating a visual example of a future	The ability to validate the correct vision of a future product or solution.

	solution or product. One analyst notes: "Users and business owners should not be expected to be able to visualize new software. Users usually don't know what they want until they see what they don't want." (Bochkareva, 2015)	Analysts state: "The advantage of using prototypes is that they encourage stakeholders, more specifically users, to play an active role in requirements development. this method is extremely useful when developing new systems for completely new applications."
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In order to identify requirements for a software product, it is important to have an effective interaction with interested stakeholders. Examples of typical questions asked of stakeholders are:

- 1. Functional Requirements:
  - What functions and capabilities do you expect from the software product?
  - What basic operations or tasks would you like the product to perform?
- 2. Non-Functional Requirements:
  - What performance requirements (e.g., speed of operation, responsiveness) are important to you?
  - Are there special requirements for security, reliability, or scalability of the product?
- 3. User Experience:
  - What are user expectations for the interface and usability of the product?
  - What additional features could enhance the user experience?
- 4. Integration and Compatibility:
  - Is integration with other systems or programs necessary?
  - Are there specific compatibility requirements with operating systems, browsers, and other technologies?
- 5. Data Requirements:
  - What data needs to be considered or processed within the product?
  - Are there specifics regarding data storage, processing, and protection?
- 6. Business Objectives:
  - What business goals and outcomes do you expect from using the product?
  - What key performance indicators (KPIs) should be considered?

- 7. Budget and Time Constraints:
  - What budget constraints exist for the project?
  - Are there deadlines that need to be met?
- 8. Change Management and Development:
  - What opportunities for future development or product changes might be important?
  - What change management processes do you favor?
- 9. Training and Support:
  - What are your requirements for training users or staff on how to use the solution?
  - What support do you expect from the development team once the solution is implemented?
- 10. Expected Results:
  - How will you measure the success of the product?
  - What specific results or benefits do you expect to realize?

It is important to consider that the questions should be tailored to the specific project context and stakeholder needs. In addition, active listening and open dialog are also important elements in the requirements elicitation process.

## 2.2 Calculation of Productivities

Bulldozer productivity formula:

$$P = amount * \frac{3600 * T * Q * kb}{tc}, \quad (1)$$

where P - operational productivity in m<sup>3</sup>/shift; T - shift duration in h; Q - volume of soil in dense body, moved by bulldozer, in m<sup>3</sup>; kb - time utilization factor; tc - cycle duration in sec.; amount - number of bulldozers.

The volume of soil in a dense body, moved by bulldozer is determined by the formula:

$$Q = \frac{ho^2 * I * \sin(\beta)}{2 * kr * \tan(\varphi)}, \quad (2)$$

where ho - dump height in m; β - angle of natural slope of soil in deg; I - dump length in m; kp - loosening factor; φ - angle of inclination in plan between the longitudinal axis of the bulldozer and the dump line.

$$tc = \frac{lr}{v1} + \frac{lp}{v2} + \frac{lr+lp}{v3} + tm + 2 * ts + t0, \quad (3)$$

where lr - length of cutting path in m; lp - length of soil movement in m; v1 - speed of bulldozer

movement during soil cutting in m/sec.; V2 - speed during moving in m/sec.; V3 - speed of reverse (empty) bulldozer movement in m/sec.; tm - duration of gear shifting in sec.; ts - duration of bulldozer turning in sec.; t0 - duration of blade lowering in sec.

Dump truck productivity formula:

$$P = Qp * np, \quad (4)$$

where Qp - load per trip; np - number of trips.

Formula for calculating the load per trip:

$$tc = \frac{lr}{v_1} + \frac{lp}{v_2} + \frac{lr+lp}{v_3} + tm + 2 * ts + t_0, \quad (5)$$

where Pk - verification calculation of voyage load; Yt - curb weight of the vehicle; f - specific resistance of the road; i - guiding elevation.

Formula for calculating the number of trips:

$$np = \frac{(480 - tpz) * K}{l * (T1 + T2 + T3)}, \quad (6)$$

where l - hauling distance; T1 - travel time per 1 km in both directions; T2 - loading time; T3 - unloading time; tpz - preparation and stopping time; K - time utilization factor.

Formula for verification calculation of voyage load:

$$Pk = \frac{Me * ipk * ikn * ian * Npnm}{PK}, \quad (7)$$

where Me - operating torque on the engine flywheel; ikn - number of gears in the gearbox; ipk - number of gears in the transfer gearbox; ian - number of gears of the main transmission; Npnm - efficiency factor; PK - dynamic wheel radius.

The formula for the productivity of the roller:

$$P = \frac{Vp * (B - C) * Kv}{n}, \quad (8)$$

$$Ph = T * P * hy, \quad (9)$$

where Vp - operating speed of the trailed roller; C - width of the overlapping zone; B - width of the roller; Kv - coefficient of utilization of working time; hy - thickness of the compacted layer; n - number of passes.

The formula for the thickness of the compacted layer for the cam roller is:

$$hy = 0.65 * (L + 2.5 * b - hp), \quad (10)$$

where hp - thickness of the loosened layer; L - height of the cam; b - width of the support surface of the cam.

Motor grader productivity formula:

$$P = \frac{3600 * (B - b) * L * kb}{m * \left(\frac{L}{v} + t\right)}, \quad (11)$$

where kb - coefficient of working time utilization; L - length of the planned area in m; B - width of the blade in m; b - width of the overlapping strip in m; V - working speed of the motor grader in m/s; t - time for turning in s.

## 2.3 Calculation of shifts

Calculating the number of shifts of work depends on the specific situation and working conditions. Here are some methods for calculating the number of shifts:

- Production Calendar:
  - Consider the production calendar, which determines the number of working days in a month or year.
  - Divide the total number of hours worked by the length of one shift (usually 8 hours) to determine the number of shifts.
- Load Factor:
  - Consider the Load Factor, which accounts for planned and unplanned work interruptions (e.g., lunch breaks, technical downtime).
  - Multiply the total number of hours worked by the Load Factor to determine the actual hours worked.
- Labor Productivity and Intensity:
  - Evaluate the productivity and intensity of labor on each shift.
  - Consider what tasks are performed on each shift and how long it takes to complete them.
- Production Requirements:
  - Consider the requirements of the production or service you provide.
  - Determine how much time is required to complete specific tasks or handle a certain volume of production.
- Performance Standards:
  - Use the performance standards established for your industry or specific type of work.
  - Consider regulations and standards to determine the optimal number of shifts.
- Volume of Orders or Tasks:
  - Estimate the volume of orders, tasks, or projects that need to be completed.

- Allocate the workload between shifts, taking into account time constraints and deadlines.
- Load Forecasting:
  - Forecast labor load based on historical data or estimated workload.
  - Determine how many shifts will be required to handle the expected workload.

The specific method chosen depends on the nature of the work, working conditions, production requirements, and other factors considered in a particular situation.

The formula for calculating the number of shifts per stage is:

$$shift = \sum_{i=1}^g \left( \frac{V_i}{\sum_{j=1}^{eq_i} pr_j * k_j} \right), \quad (12)$$

where shift - number of shifts per stage; K - number of techniques; G - group of techniques per stage; Pr - productivity, V - volume of brought soil.

Formula for calculating the total number of shifts:

$$shifts = \sum_{i=1}^n shift, \quad (13)$$

where n - number of stages, shift - number of shifts per stage.

Formula for calculating the cost of shifts per stage:

$$cost = \sum_{i=1}^m t_i * c_i, \quad (14)$$

where cost is the cost of shifts per stage; t is the number of shifts; c is the cost of a shift.

Formula for calculating the total number of shifts:

$$costs = \sum_{i=1}^n cost, \quad (15)$$

where n - number of stages, - cost of shifts per stage

## 2.4 Drawing a timeline

Drawing calendar schedules, also known as gantt charts, is essential in various fields where it is important to visualize and manage project timelines and dependencies. Here are a few aspects of the importance of rendering calendar schedules:

### 1. Visualization of timelines:

- Gantt charts are an effective tool for presenting project timelines. They allow you to clearly see the sequence and duration of tasks.

### 2. Managing tasks and dependencies:

- Gantt charts help to identify dependencies between tasks, which helps to better manage the temporal and logical relationships in the project.

### 3. Resource Planning:

- Building timelines makes resource planning easier. Project managers can see which tasks require more time or resources and make decisions accordingly.

### 4. Progress Tracking:

- Gantt charts provide a tool to monitor and track the progress of tasks. This allows you to respond quickly to changes and problems in the project execution process.

### 5. Communication and Stakeholder Involvement:

- Calendar charts are an effective means of communicating with team members and other stakeholders. Visualization helps all participants to better understand the progress of the project.

### 6. Schedule Optimization:

- Gantt charts allow you to explore different scheduling options, which can help optimize timelines and achieve better results.

### 7. Decision making:

- Drawing timetables facilitates the decision-making process because all participants see the big picture and can work together to solve problems.

Gantt charts have become a standard tool in project management due to their simplicity, efficiency and ability to effectively represent and manage the time aspects of projects.

The construction of Gantt Diagrams involves the following methodology steps:

- Defining Tasks and Time Frames:
- Developing the Diagram Structure:
- Visualization of Tasks:
- Accounting for Dependencies:
- Use of Colors and Design:

Total construction days = (end-start)/(1000 \* 3600 \* 24 \* 365);

$$\frac{end\ of\ stage - \sum_{stage=1}^n end\ of\ stage_{stage-1}}{total\ construction\ days} \quad (16)$$

For j=startJ through (endJ+1), execute:

Shade cell(i-1, j) in RGB(118,190,39) color

## 3 RESULTS

### 3.1 Requirements for the software solution

The software solution shall solve the problem of automating the preliminary determination of

embankment design, geotextile material strength characteristics, resources, construction cost and work steps.

Requirements for the solution:

- realization of the possibility of design and embankment selection;
- calculation of soil volume and geotextile area taking into account the embankment geometry with the possibility of user editing;
- calculation of settlement value;
- determination of the amount of resources required;
- construction of calendar schedule;
- realization of the possibility of performance editing;
- output of the results of calculation of material volumes, resources and calendar schedule.

The technical requirement for the software solution is implementation in p7-office.

R7-Office is a Russian cross-platform application package for collaborative work with office documents. It is included in the unified register of Russian programs for computers and databases. It is available in cloud, local and mobile versions, supports private cloud deployment and a range of collaboration solutions.

### 3.2 Architecture of the program solution

To solve the problem of automation of preliminary assessment of feasibility of construction of a field road, a document of a special page structure and macros for working with the excel document were created.

Since the software solution should work in p7-office, the programming language for writing macros is JavaScript.

The software solution is divided into 2 components: macros for realizing the logic of actions for solving tasks and the sheets of the document that perform the necessary calculations. Such division was chosen for scalability of the software solution - the software product will continue to work correctly even if the calculation formulas are changed or new types of influencing parameters appear.

The sheets of the document are divided into 3 types:

- sheets with which the user actively works;
- sheets with which the user cannot interact. Such sheets have an introductory character;
- auxiliary sheets, with which the user interacts when it is necessary to change parameters for calculation or to enter new data.

### 3.3 Implementation of the software solution

For preliminary assessment of feasibility of field road construction with the help of the software solution the user should fill in active sheets (see Figure 1).

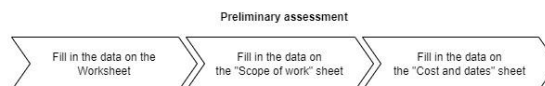


Figure 1: Filling sequence.

When filling in each sheet it is necessary to confirm and update the values using special buttons. These buttons are linked to the corresponding macros.

Filling in the initial data. The first step for preliminary estimation is the input of data by the user on the worksheet.

By receiving data on the estimated dimensions of the road and the type of soil on which the road will be laid, the LoadData macro determines the road design, the depth of settlement and the amount of resources required (see Figure 2).

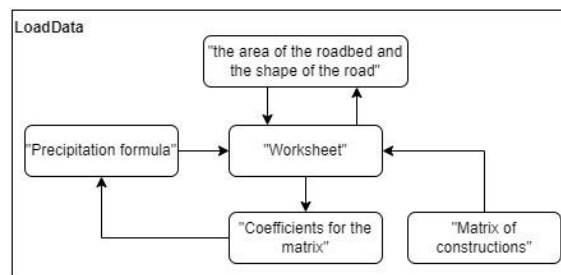


Figure 2: Structure of the LoadData macro worksheets.

Possible road constructions are listed on a separate sheet and can be added or changed if necessary. The data on structures has a certain structure:

- Strength entry: Strength - \*value\* \*units\*;
- Material entry: \*Material name\*;
- Enter the number of cages: Number of cages - \*value\*;
- Geotextile shape input: Shape - \*cell name of the row with the formula from the sheet "road surface area and shape "\*.

In are entered variable values by the user, outside the template words for the program operation.

When new structures are added because of a new value of embankment height, new rows must be added to the matrix. If the addition of new structures is due to the presence of a new soil type, the structures must be added to a new column.

The standard calculation of the volume of material to be brought in is done taking into account

the trapezoidal shape of the road. The calculation formulas are entered according to a defined structure and defined on a separate sheet, which will allow the user to modify or add a new formula if necessary.

The calculation of the depth of settlement is placed in a separate sheet that accesses the sheet with the values to be calculated.

In this case the gauge calculation function has 2 auxiliary sheets. For the possibility to change both the calculation formula and to change or add parameters for the calculation.

After clicking on the macro button the result with the main data necessary for further calculations is displayed.

Determining the amount of work. The table for entering the quantity of equipment is filled in automatically when the "Update table" button is pressed on the "Scope of work" sheet. The macro builds the table for distribution of the quantity of equipment by stages (see Figure 3).

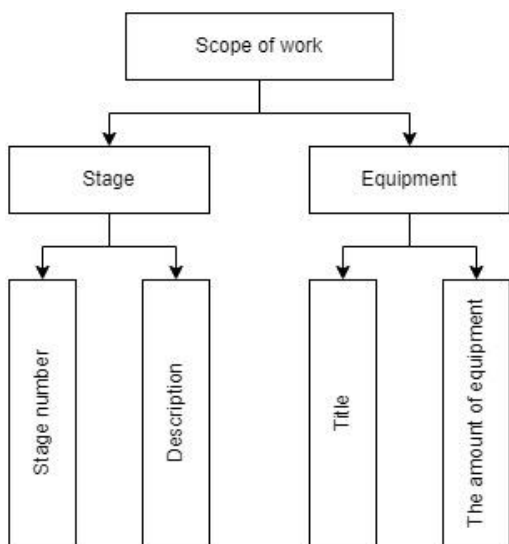


Figure 3: Structure of the sheet with the scope of work.

The macro correlates the technique and the stage, as well as the amount of material to be brought to each stage from a separate sheet (see Figure 4).

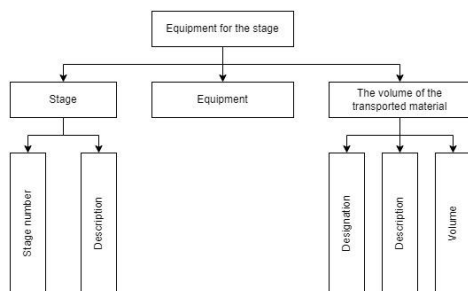


Figure 4: Structure of the sheet with technique per stage.

On a separate sheet there are alternatives of the technique for the possibility of calculating shifts, taking into account the replacement of the technique with an alternative one.

FillTablesWorks and Smeta macros interact with the same list of sheets of the document (see Figure 5).

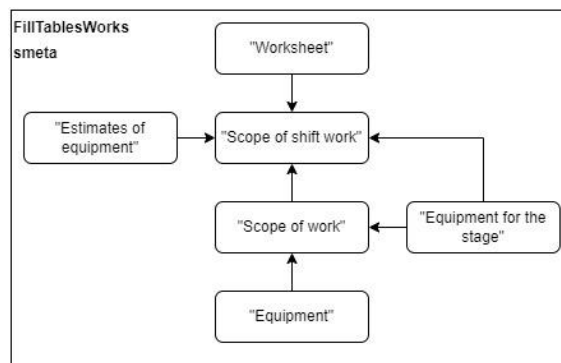


Figure 5: Structure of worksheets of FillTablesWorks and Smeta macros.

When calculating shifts of equipment for each stage of work, the macro collects data on stages, the volume of brought material and the number of sheets for each stage from the corresponding sheets. After the calculations have been performed, the user gets the results on the cost, number of shifts and volume of brought resources for each stage of works (see Figure 6).

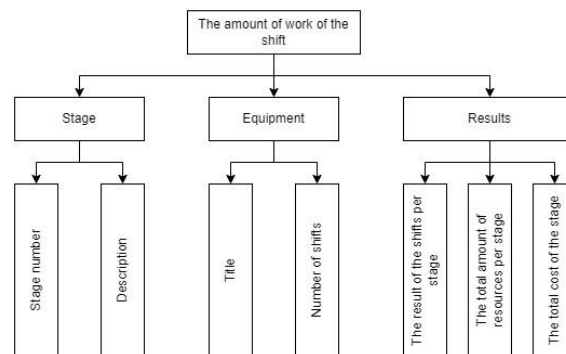


Figure 6: Sheet structure with work volume shifts.

Calculation of productivity and cost of equipment work per shift are placed on a separate sheet for the possibility of adjusting values and adding new data (see Figure 7).

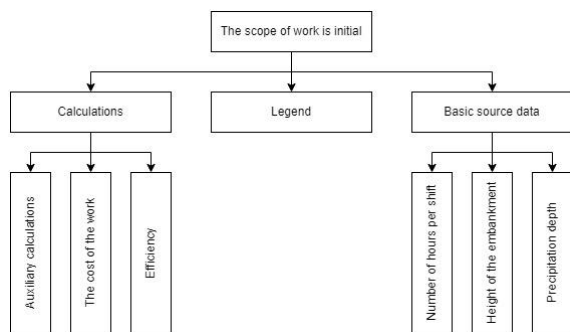


Figure 7: Sheet structure with productivity and cost of machinery work.

The sheet contains machinery and parameters for calculating its productivity. When hovering over a parameter, its description or name is displayed. The macro uses the values from the green and yellow cells, the values of other cells can be used as auxiliary for calculations:

- Summa (green cell) - the cost of equipment, manpower per shift, as well as the designation of the resource cost.
- Pr (yellow cell) - productivity of equipment, manpower.

Building a schedule of work stages and displaying the final cost. On the sheet "Cost and dates" when activating the macro with the help of the button the final cost of works for each stage, the dates of the beginning and end of each stage, the number of days per stage and the final price for materials are displayed (see Figure 8).



Figure 8. Structure of the sheet with the cost of works and dates per stage.

After reading data from the auxiliary sheets, the user enters the start date of the first stage, following which the macro is restarted.

After recalculation of the start and end dates of the stages, a schedule of the stages of work is built.

The size of each stage is proportional to the number of days for its execution relative to the total number of days for all stages.

## 4 DISCUSSION

The discussion of the current software solution highlights its ability to automate the calculation and design selection processes, which is a meaningful step towards the preliminary assessment of field road construction.

An important aspect is the fact that the macros are currently optimized to work exclusively with the P7-office product. This ensures that calculations can be

performed directly on the document sheets without the need to use third-party office programs such as Microsoft Office. However, it should be noted that adapting the program to other office products will require reworking the macro code to match the programming language used in those products.

Regarding the calendar, it should be noted that it is currently capable of building simple sequential tasks, but there is a need for improvement when working with tasks that start simultaneously. Duplication of dates in such cases is a potential improvement that could be introduced in future versions of the software solution to enhance its functionality and meet the diverse needs of users.

## 5 CONCLUSION

It can be emphasized that, in the present context, the automation of pre-assessment plays a key role in ensuring the successful completion of road construction projects, reducing both financial and time costs.

At the end of this phase of the study, which focused on the development of a software solution for a digital technical solution album for road construction, the key findings and conclusions are as follows:

1. The developed software product provides the user with the ability to select the optimal design and embankment for a road facility.
2. The software product successfully performs the calculation of settlement value, which is an important parameter in the design of road structures.
3. The user is able to perform editing of parameters such as soil volume and geotextile area with respect to embankment geometry, which provides flexibility in planning.
4. The software product successfully determines the required quantity of resources, which helps to manage the budget and material resources of the project efficiently.
5. The ability to create and edit the schedule, including machine and mechanism performance parameters and the amount of resources to be utilized, is provided.
6. The results of material, resource and schedule calculations are output by the software product in a convenient format, providing complete information for decision making.

These conclusions underline the importance and efficiency of the developed software solution in the field of road construction, providing engineers and specialists with all the necessary tools for successful and optimized planning, pre-estimation and execution of projects.

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