Development of a software tool to study and simulate organisation and production on building sites.

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Our proposal aims to establish an information system to be a decision support system for engineers in building construction. The management of building sites is a permanent challenge because of a wide range of different activities required to build the project. In order to improve productivity on construction sites, it is necessary to use the right material and human resources in the right place and time. This is to create a balance, day by day, to efficient use of formworks, cranes and workers. Prototype "Building Site (BS)" comprises: a central system and six subsystems. It has a number of calculating models, and a data management system which includes different databases. All subsystems are used to simulate and study organisation and production on building sites. These subsystems are connected with each other and with the central system. The central system is used to manage and control the subsystems. Three of these subsystems allow engineers to generate some possible solutions for constructive modes or equipment choices and to evaluate their performances. They help the user to make a decision that should help to perform the best productivity. The other three subsystems, which are based on Genetic Algorithms, are used for optimizing the location of tower crane, generating the planning, defining the repetitive cycle of main works and generating the supply chain management in the building construction, especially for great projects. This work is currently under development.

Keywords; production;organisation; management; software; building site; productivity; constructive mode; DSS; subsystem.

I. INTRODUCTION

The particularities of construction sector such as multiplicity and diversity of partners, character of prototype of product etc., make obstacle with the control of production [1]. Alarcon and Bastias presented a support system of strategic decision-making process for construction firms. It was designed to help the system users in building a conceptual model for decision making problems [2]. Al-Abo Omar and Mangin, identified and measured the indicators of building site productivity according to various modes of evaluation, with the prototype "OSEP"[3]. Aljazaerli and Mangin developed a tool "G2-Cycle", based on Genetic Algorithms, which handled the repetitive cycles of the main works in all cases: building-wall, building-columns, building- columns-wall, building-columns-beams, [4]. Integrated logistics, management of building site and computer-integrated manufacturing (CIM) are new terms for improving the productivity, and consequently the control of production [5], [6].

The control of project management process can be considered as one of the essential tool to ensure that the project is delivered at budget, on time and with a specific quality. Contractors look at the maximum, to better manage their work for the maximum benefit of time and money. On the other hand, a very difficult situation is faced by construction companies in the case of negative margins. The reasons for this are difficult to be identified. The reasons might be relevant to low productivity, wrong decisions, bad follow-up, costs of defects in work, risks, etc.

Currently, no tool meets the real needs of companies. This is why companies need a methodology which helps them to control their production. This paper proposes a new approach about control and organisation of the management and production process of a project in the construction sector. It presents a decision support system (DSS) called ("Building Site (BS)") to help project engineers to forecast and follow-up the production on building site. This prototype contains a central system which is made up of six subsystems. We shall identify the methods, ways, procedures and process used in each of these subsystems to support an evolution of production means in construction.

The main aim of this system is to allow engineers to generate various solutions based on different scenarios. It should also enable them to optimize production means and adopt the solution ensuring the best productivity.

The comparison of various solutions is based on a precise cost model on total quantity of labour and on cranes workload required for the works linked to different constructive modes. The chosen solution will be used by one of subsystems of prototype, which are based on Genetic Algorithms, to optimize the installation of a building site, especially, the location of tower crane. Other subsystems are used for generating the planning, defining repetitive cycles of main works, and lastly, generating the supply chain management in the building construction.

II. DESCRIPTION OF THE PRODUCTION SYSTEM

The production process in the construction sector requires several devices that can lead at the end to the creation of a structure. These devices are: (a) labours (b) materials (c) equipments (d) subcontractors. Therefore, the management of production aims to deliver the project by ensuring the right balance between the three dimensions that often are contradictory:

(1) Technical dimension;
(2) Time dimension;
(3) Cost dimension.

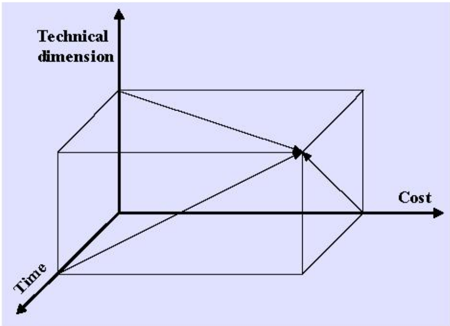

Figure 1. The three dimensions of a project mangement.

If we want to get closer to one dimension, we go away of the other automatically. Project management covers all the techniques and methods that allow the project manager to accomplish this mission.

III. STRUCTURE OF THE PROPOSED PROTOTYPE

Simulation is considered by many authors as a very powerful analytical tool for studies about building sites. It is recommended to couple simulation and virtual reality to display the results of simulation. *"Fig. 2"* presents the different parts of the structure of the proposed decision-making support tool. In fact, the simulation in this approach is employed as a decision-making support tool. It is simply simulates several modes constructive by changing either a construction option or a logistic option.

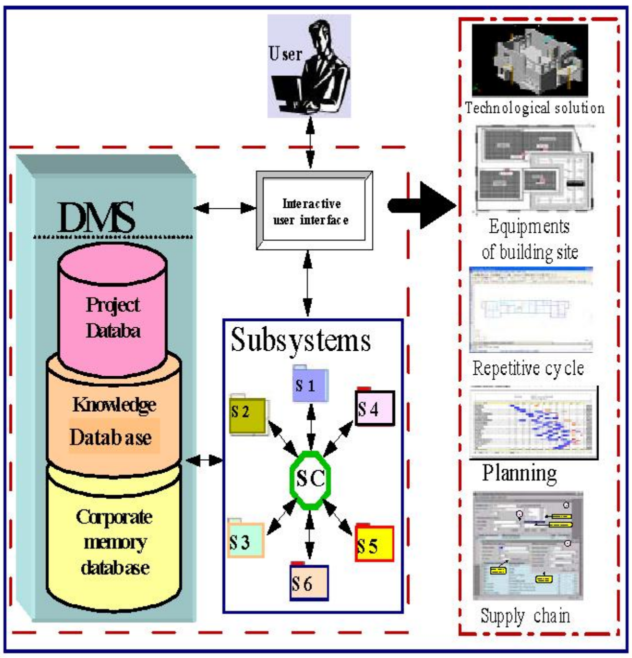

Figure 2. General structure of the tool« Building Site (BS) ».

This tool comprises three principal components:

1) An interface: It must be interactive and dynamic, allowing to easily set the data from the user and to return to him the results in a simple and clear way.

2) The Data Management Systems(DMS): The DMS is a system of information management and control that is concerned with site components and objects during their life cycle through the applications. The DMS here includes three databases:

- Knowledge database: it gathers generic data such as daily works for each part of site, materials, equipments available in the company, unit times, unit costs, hours of work per day of the crane, type of formworks, construction options of works, generic tasks for each technical solution and each production option assigned to a specific work… Only an expert user can modify it.
- Project Database: The user should be able to define and store in its various components of the project such as planning areas, dimensions of the works, their quantities and their characteristics, etc.
- Corporate memory database: After evaluation of various solutions through total cost, labour duration and cranes workload, the user adopts the best solution It is then stored in a specific database entitled "Corporate memory database" for the ongoing project. Corporate memory database is useful to save the specific data and results of each operation of the subsystems.

3) Subsystems: Each of the subsystems is independent, but it interacts with each other to improve the productivity. Each one gives results for a specific part of organization and preparation of building sites. These results are made up with the models of calculation. Our aim is to provide support to exchange and shareof data in different subsystems.

The development of data-processing tools can not be carried out in only one phase because of its complexities. It is indispensable to go through a project cycle where organization and development phases are very important. The heart of these phases is the development of specifications document for each activity. *"Fig. 3"* shows the (A-0) diagram of "Study and simulates production on building sites" which is drawn up by the SADT method, Structured Analysis and Design Technique. The inputs are design data, hypothesis of study and project data. The outputs are the optimal constructive mode, duration and costs of the project, building site equipments and supply chains for products and materials. Different kinds of constraints must be taken into account, such as knowledge data, corporate memory, regulations or space constraints. The mechanisms are the engineers, platform, and software such as Visual basic, AutoCAD, Visual FORTRAN, and Access. The A-0 activity can be broken down into six activities: A1, A2, A3, A4, A5 and A6. These activities will represent the subsystems of our prototype *"Fig. 5"*. Each one has inputs and outputs, where outputs of each stage form a part of the inputs of following activities. Each activity can also be refined further (Level 2). The decomposition process continues in the same way until each activity of the process becomes enough detailed, simple and clear.

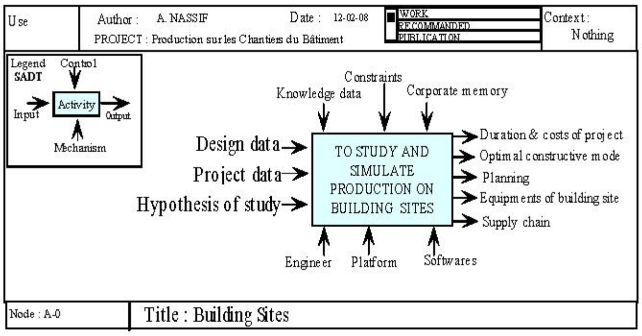

Figure 3. " Building Site (BS)" activity diagram legend

IV. OPERATIONS REQUIRED FOR STUDYING AND SIMULATING THE ORGANIATION AND THE PRODUCTION ON BUILDING SITES

Despite differences in construction projects, some basic operations are always the same in these projects. Examples of these operations are: calculation of total labour duration, calculation of crane workload required for different constructive works, costs, tasks duration. These calculations are carried out according to the needs of the building sites. For example, for ski resort sites where the research of a short site duration is the rule, we need to optimize the crane workload; this will not be necessary the case for an urban site, where minimizing the total labour duration seems to be more important.

We identify the different operations required to manage and organize construction sites:

1) Defining constructive modes

The constructive mode characterizes the construction process used to execute the different parts of the building structure. The better constructive mode allows the company to construct the building in the best conditions;

2) Calculating the crane workload(TchG)

The crane workload is the length of crane time required for the realisation of the different works for the building;

3) Determining the duration of repetitive cycle for the crane (DC1)

The cycle is the number of days necessary to execute vertical and horizontal works in a storey. This cycle is repeated at each level of the building. DC1 is the duration of the cycle if the cranes are saturated;

4) Defining the number of cranes (NbrG) on site and their type

Two crane types are possible: tower crane and fast-erecting crane. The number of cranes is given by geometric conditions or calculated from crane workload (TchG) and number of crane hours per day;

5) Defining the location of the differnet cranes on site

6) Calculating the total labour duration(Touv)

It is calculated from the average unitary time (TU). TU is the necessary duration for realising of a unit of work by one worker; that time is determined by statistical analysis from previous projects. They must integrate specific conditions (geography, climate, social) of each site;

7) Calculating the number of workers(NbrOuv)

It is the number of workers required to perform the construction and logistic tasks on the site;

8) Determining the duration of repetitive cycle from the total time of labour (DC2)

DC2 is the cycle duration obtained from total duration of labour required to achieve a level of the building.

9) Determining the duration of repetitive cycle from the deadline (DC3)

DC3 is the greatest duration allocated by level compatible with the deadline imposed by the owner;

10) Calculating the project costs

The cost of a project is obtained by cumulating different costs. The model proposed is based on an analytical approach, taking into account labour, materials, products and components costs, and the expenses of building site related to equipments.

11) Defining the concrete production modes

The choice is between ready-mixer concrete delivered by trucks and concrete produced by a concrete mixer on site. An economic comparison of these two solutions is made;

12) Defining the required areas on building site

For example: storage areas, prefabrication yards;

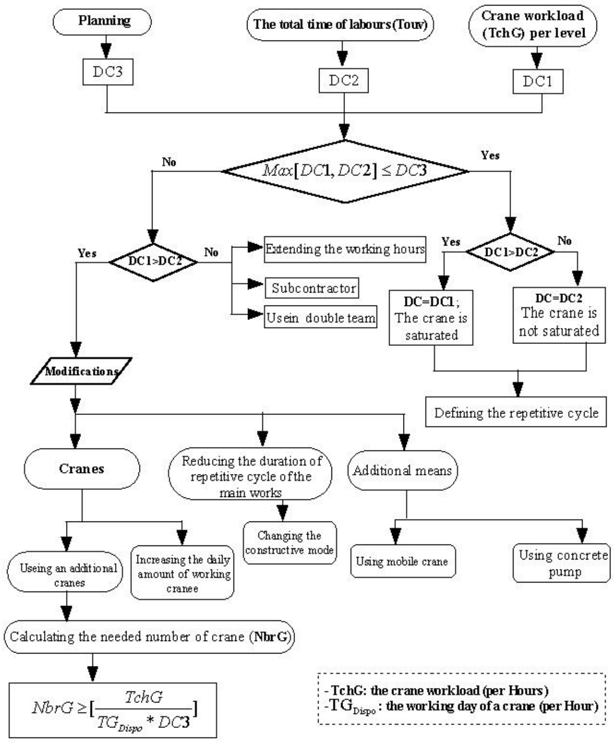

Figure 4. The duration of repetitive cycle for the main works(DC)

13) Determining the Concrete Batching Plant

14) Generating the construction tasks scheduling

15) Determining supply operations, planning and logistics tasks.

16) Determining the repetitive cycle duration of the main works(DC)

The cycle duration (DC) is defined from the different cycle durations obtained by cranes saturation (DC1), or by labour saturation (DC2), or by the deadline time (DC3). DC is decided according to the following model *"Fig. 4"*;

17) Generating the repetitive cycle for main works

For a given cycle duration, horizontal and vertical works which are realised each day are defined. An optimizing tool has been developed to perform this task.

These different operations must be performed simultaneously to obtain a good productivity.

V. THE INTERACTIVE "BUILDING SITE (BS)" SYSTEM

The environment of "Building site" is developed as multi-documents. The platform used for BS system development is made up of four tools: VISUAL BASIC 6, AutoCAD, Visual FORTRAN and the data management system. This database will be implemented using ACCESS under Microsoft Windows. It shall improve communication and data exchange between the different processes, taking into account the technical data needed in the different phases. Along the various phases of the project, BS simplifies data and document management, exchange and storage (plans, technical notes, reports). The information used comes from different sources: inventory files, drawings files, databases. Exchanges between the different subsystems are standardized. Some results are produced by software tools developed in our laboratory (LOCIE), such as GENEVA [7] and G2-Cycle [4].

The central system is used to manage and control the different subsystems of BS which are presented in *"Fig. 5"* and are described as follows:

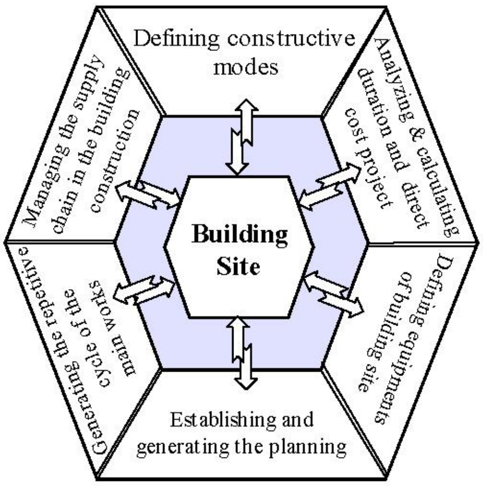

Figure 5. Interface user of prototype "Building Site"

A. Defining constructive modes

This subsystem allows to the user to select equipment choices and technological solutions for horizontal and vertical works, with different options of realization. The output of this module is a list of possible technological solutions depending on the user objectives, taking into account the site constraints, the precise location of the site (city, district, …), and enterprise data (materials available, own equipment available).

The *"Fig. 6"* shows the different available choices for each kind of constructive work (walls, slabs, beams, columns).

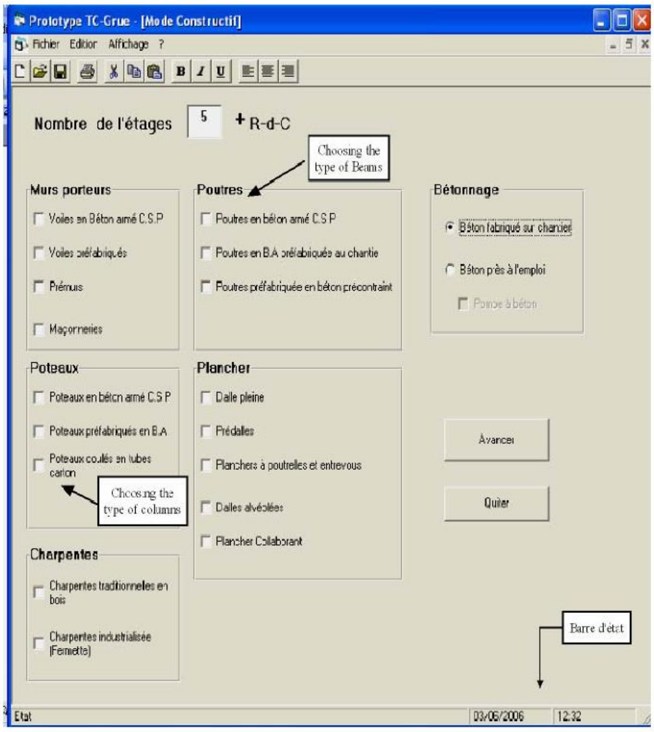

Figure 6. Difining the constructive modes.

B. Analyzing and calculating duration and direct cost project

This subsystem allows the user to calculate and assess time and cost of a project for different possible constructive modes. We define the characteristics, properties, and the quantities of each work; then the subsystem calculates and evaluates the various solutions through total direct cost, labour duration and cranes workload, At the end, the user can choose a final solution which will be recorded in the "Project database". He can also assign other solutions as alternatives if the retained solution is ever infeasible for such or such reason, "Fig. 7". The cost of a project is obtained by cumulating costs of labour, materials, products and components costs.

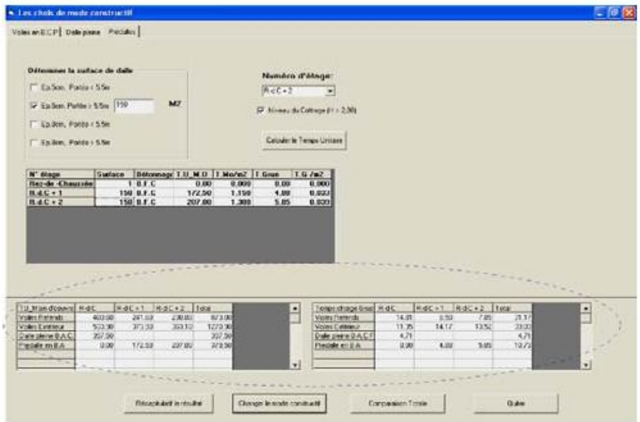

Figure 7. Calculating the different technical solutions

In order to compare the solutions, BS has an interface which shows the list of solutions. Figure 8 shows this table of solutions. The best one will be retained and the other will be rejected or considered as alternative.

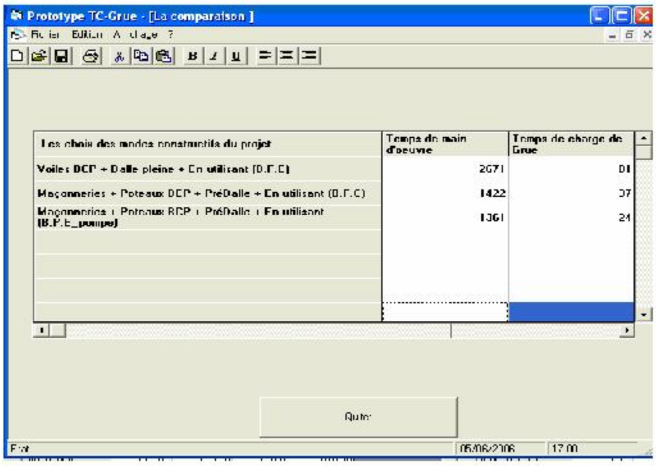

Figure 8. Choosing the optimal technical solution

C. *Defining the equipments of building site*

This subsystem is currently under development by another researcher [8] as a part of the whole research project. It enables the user to perform operations 4, 5, 11, 12 and 13 of the paragraph IV.

This tool depends on a building site spatial modelling for its elements (buildings, equipments and facilities, possible zones for their positions). A specific method of optimisation based on genetic algorithms (GAs) is used. Several criteria of assessment (functions of objectives) are proposed in order to assess the performance of the different solutions. These criteria are: crane workload, balancing of work's quantities for the different cranes and severity of the intersections between them.

D. *Establishing and generating the planning*

The adopted solution can be followed-up during the construction phase in terms of tasks and planning. A subsystem called "GENEVA" which developed by A. PUTERA [7] allows calculating the total cost estimation and planning duration. GENEVA is used to generate and evaluate activities, to optimize the planning with resource constraints. It also allows to estimate the direct project costs associated with the planning and to produce data for the project management software «Microsoft Project 98 ". Genetic algorithms are used to optimize the planning, as can be seen in *"Fig. 9"*.

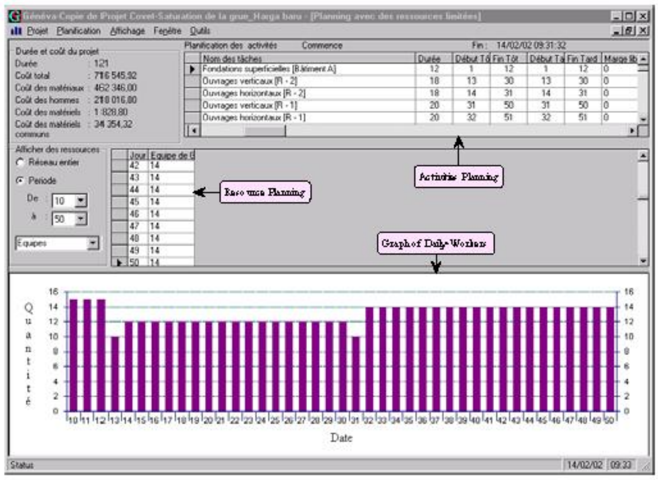

Figure 9. Result of planning simulation with limited resources[7]

E. *Generating the repetitive cycle of the main works*

In order to apply this subsystem, the prototype G2-Cycle [4] was developed to automate the generation of repetitive cycle. This prototype retrieves the variable data and fixed data of the cycle by AutoCAD and Visual Basic, then, it conceives the technical constraints between the works and lances the algorithm genetic by Visual Fortran to give an optimized solution of the cycle by the genetic operators, selection, crossover and mutation. The solution is presented graphically by AutoCAD, *"Fig. 10"*. The criteria of evaluation give the performance of cycle.

G2-Cycle gives optimized solution of repetitive cycle in short time which offers the possibility to modify the hypotheses of works and have different solutions depending on the objectives of user.

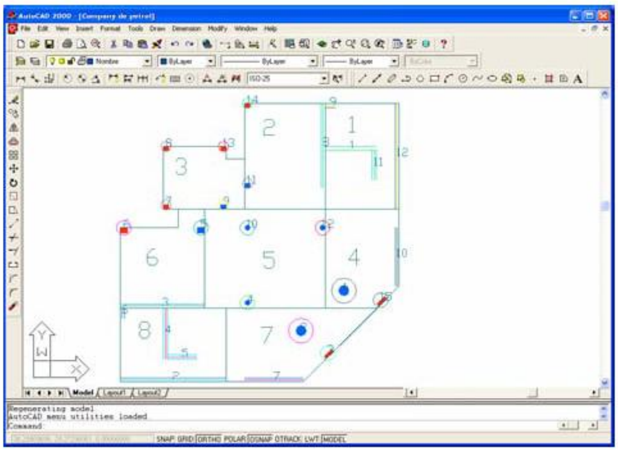

Figure 10. Optimized solution of ripititve [10].

F. *Managing the supply chain in the building construction*

This subsystem generates logistics solutions that can clearly define the means and materials used to carry the different supply chains of for materials and products. It also helps to define and evaluate the logistics tasks of the project, to plan these tasks by logistical constraints of planning, and then assigns specific renewable resources of the project. This tool is currently under development.

VI. CONCLUSION

Building Site (BS) is a decision support system for organising, controlling, and evaluating the production on building sites. It is proposed to help engineers to simulate several technological and logistic solutions in order to have a better profit margin and to ensure a best productivity. It is also destined to project manager to control, manage and follow-up the project in real time.

BS is composed of several subsystems, of databases. Interfaces are interactive, convivial in order to facilitate data capture and to minimise errors.

BS system also can bring a real assistance to users to enable them to measure and evaluate the duration and cost project according to various constructive modes. The chosen solution could be followed by the subsystems, which are based on Genetic Algorithms, to optimize the installation of a building site, to generate the planning, define the repetitive cycles of main works, and lastly, generate the supply chain management. BS reveals that if the company had made such a comparative study, it would never have lost a significant part of the profit margin as well as time and resources. In conclusion, it seems that BS system is a powerful tool and offers very promising prospects so that construction firms can achieve their operations with efficiency performance and effectiveness.

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