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EARTHWORK PLANNING & VISUALIZATION OF TIME LOCATION INFORMATION IN ROAD CONSTRUCTION PROJECTS

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Abstract : Accurate visual location information is vital for effective resource planning and managing workspace conflicts in earthworks, which is lacking in existing schedules. Therefore, construction managers must rely on subjective decisions and intangibles when it comes to resource allocation, work space, and monitoring the progress of earthworks. This has caused uncertainty in planning and scheduling and consequently project delays and cost overruns. To overcome these problems, a prototype model framework using location planning theory was developed. This paper focuses on case study experiments that demonstrate the model's functionality, which includes the automatic generation of location-based earthwork plans and the visualization of backfill locations on a weekly basis. The results of the experiment confirmed the model's ability to identify precise weekly locations and visualize the space-time conflict during earthworks. Therefore, the paper concludes that the model is useful for improving construction site productivity and reducing production costs for earthworks in projects such as roads and railways.

IndexTerms - **Earthworks, cut-fill, location-based scheduling, productivity, visualization**

I. INTRODUCTION

Compared to other manufacturing industries, the construction industry is characterized by one-off projects, production construction and temporary organization. The process of planning and scheduling a construction project is a challenging task and the decisions made at this stage have the greatest impact on the successful implementation of the project from its early conceptual stage to the project completion and operational stage. Planning and scheduling involves the careful allocation of resources, especially along linear construction projects, when necessary during construction operations. Failure to decide on optimal work activities with required resources from a site perspective has an adverse impact on project cost, time, quality, spatial conflicts, and safety of construction work in construction projects. Earthworks projects require a separate planning task for each project due to the characteristics of earthworks.

Effective application of planning and scheduling techniques such as CPM and PERT are limited because the activities involved in linear construction projects such as roads, railways and pipelines are fundamentally different from general construction and housing projects. Most activities in road projects are linear activities and require a linear planning method. The linear planning method has the potential to provide significant improvements in terms of visual representation of location and progress tracking as the method allows project planners and construction managers to plan road construction projects. visually and determine the path and location of the control activity. Therefore, a new methodology with a computer model is presented in this paper to overcome the above problems.

This paper presents a computer-based prototyping model that automatically generates location-based earthwork plans and provides a platform for visualizing location-based earthwork planning information, particularly in linear construction projects such as roads and railways. The research proposes a decision support tool to help construction and planning managers, especially in resource planning and progress monitoring more effectively, and to help them communicate location planning information during earthworks. In this document, location-based scheduling is called a "time-location schedule." The remainder of the paper outlines a literature review, a conceptual framework proposal, and details the development of a prototype model that includes inputs, processes, and outputs. Finally, case study experiments from a road construction project were used to demonstrate the purposes of the model.

II. LITERATURE SURVEY

Generally, in the early stages of a construction project, there are earthworks that have unique characteristics, especially for linear construction projects such as roads, railways and pipelines. They form a major component in the construction industry and absorb high costs and haulage distances need to be addressed to balance the amount of cutting and earthworks in a cost-effective approach. For example, a study of 145 road projects found that the earthworks component accounted for approximately 19.58% of the project's monetary value. Earthworks also have a direct impact on the ranking of remaining road activities, as earthworks contribute a higher percentage of project monitoring value. Therefore, decisions made during the earthworks planning phase have a major impact on the overall performance of the project.

Mattila and Abraham stated that the key limitations are the subjective distribution of repetitive activities from site to site, the inability to plan resource continuity and display progress rates, and the failure to provide any information on the work done on the project. critical path method (CPM). pointed out that CPM networks are more suitable for large complex projects, but line of balance and linear planning methods are more practical for repetitive and linear construction projects. A linear schedule is used to reduce the interruption of continuous or repetitive activities, to maintain resource continuity, and to determine the location of activities on any given day of the schedule.

Arditti et al. (2001) suggested that the break-even technique is an example of a linear planning method that is based on the hypothesis that activity productivity is uniform or linear. In other words, the productivity (production rate) of the activity is linear.

when time is plotted on the vertical axis and activity location is plotted on the horizontal axis (or vice versa). The production rate of the activity is the slope of the production line and is expressed in units/linear meter per time. Planning methods such as equilibrium, recurrent planning method, time-location matrix model, time-based planning method, linear planning methods, time-distance diagram and linear equilibrium diagram are known as "location-based planning".

Kenley and Seppanen [2010] pointed out that there are mainly two types of planning methodologies: activity-based methodology and location-based methodology. The localization methodology is also divided into two types: unit production and localization production planning. It is known as an alternative location-based scheduling methodology that is based on monitoring the continuity of crews working on production tasks. On the other hand, Dyna Road developed commercial software for a construction schedule and management of earthworks in linear projects. This provides site-based planning information for the entire section, but lacks the provision of weekly site information.

TILOS, which is a time-location planning software for managing linear construction projects, helps visualize repetitive tasks from a location perspective. It also provides a flow of planning data in terms of time and place on the building plan. However, the current time the distance charts produced by Dyna Road and TILOS do not provide weekly location information. This is essential for effective resource planning and reducing spatial conflicts on construction sites. As a result, construction mangers are dependent on subjective decision for planning earthworks due to limited information about jobs. Considering previous studies, it is concluded that location-based planning, which is based on the theory of location-based methodology, is an effective way to represent planning and scheduling information about earthworks in road projects.

From the reviewed literature, it was found that the existing time-distance chart is not able to provide information about site planning. Therefore, this research investigated a new methodology for automatically generating location planning that is capable of providing weekly or daily earthwork location information. The next section discusses the computer-based prototyping framework.

III. FRAMEWORK OF PROTOTYPE

The general specification and framework of the earthwork planning and visualization prototype is designed as shown in Fig. 1, taking into account the findings from the literature and industry review. The framework is state-of-the-art which is designed by integrating road design data, section quantities, productivity rates and unit costs per cut/fill quantity and an arithmetic algorithm. This helps automatically generate earthwork schedules based on location and visualize weekly planning information from a location perspective. The developed prototype has the ability to generate terrain modeling, cut/fill optimization, weekly progress profiles and congestion schedules in time and space, cost profiles and cost S-curves of earthworks in linear construction projects.

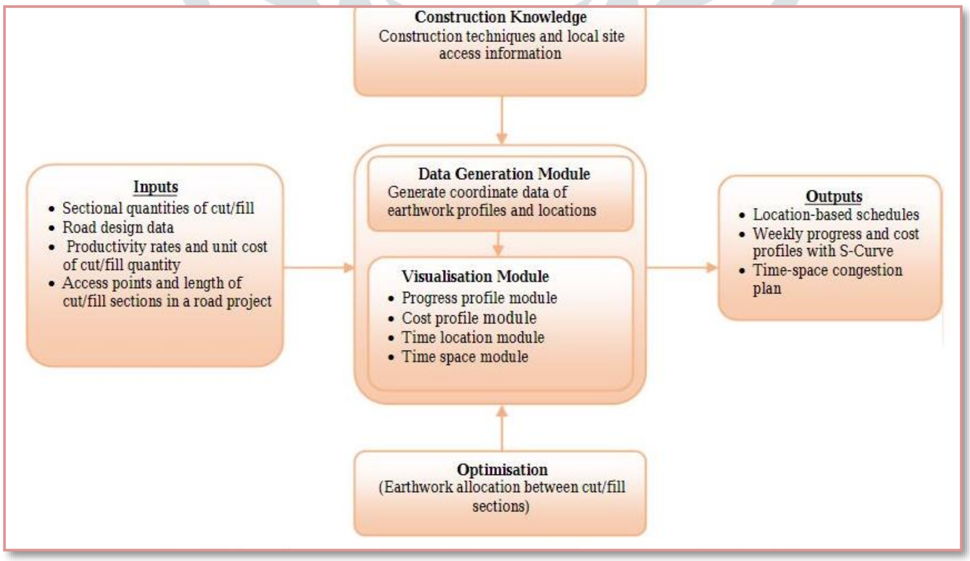


Fig.1. Framework of prototype of earthwork scheduling and visualization

3.1 Prototype model

The proposed methodology in the prototype model is original and intelligent to identify the start and end location as well as the start and end of the cut and fill period at the planning stage. It also helps to find up-to-date information about weekly locations, which ultimately helps planners and managers plan the required resources more effectively. The methodology is designed with an arithmetic algorithm that tracks the places (stations) along the road section, which are divided into weekly or daily schedules, meeting the characteristics of linearity (starting and ending places with the same production rate) in earthworks.

Equation 7 developed by Shah et al. is used to identify station numbers in each layer during earthworks by incorporating "variable" productivity data. Productivity data generated by Road Sim was used in the equation. Factors that affect earthworks productivity are incorporated into Road Sim to generate hourly productivity based on selected sets of resources and construction equipment.

$$V_r = [\{\sum_{i=1}^{i=n} (V_i) - P\}/n]$$

While,

Vr = Amount of earthwork remaining after each week's progress

Vi = amount of earthworks at each station along the selected road section, i = 1, 2, 3……… n.

n = number of workstations along the road section

P = Productivity applied to earthworks progress

This process is repeated in each layer of cut or fill sections to achieve that the residual volume (Vr) at each station is equivalent to zero (at the road design level) at selected working sections along the road design. In each layer, the start and end stations are identified and their lengths between these two stations are determined by an algorithm designed in the model with the help of VBA programming language. These lengths increase on each layer between work stations from the first to the last layer on both the cutting and filling sections of the earthworks. Similarly, according to the schedule of earthworks, cutting and filling sections are selected for the completion of earthworks throughout the construction period of the road section. If the cutting or filling sections are longer, these sections are divided into manageable sections and these processes are repeated to achieve the design level of the pavement.

3.2 Visualization of Time-Space Scheduling Information

This section presents the development of the visualization component of the prototype model. This provides visual information on earthwork planning, space congestion, progress profiles and communicates construction process sequences with respect to location aspects. The Visualization Module (VM) processes the coordinate data of the location-based plans and converts them into a visual format for visualizing earthwork planning information. The VM was developed using the programming language C# and VBA on the MS Excel platform. The required input data was stored in MS Excel worksheets and used as a database. Several VBA macros have been designed to process input data and generate visual outputs of the model. The VM imports data using a Structured Query Language (SQL) query and transforms the imported data into a visual representation of earthwork planning information in a tabular and graphical format.

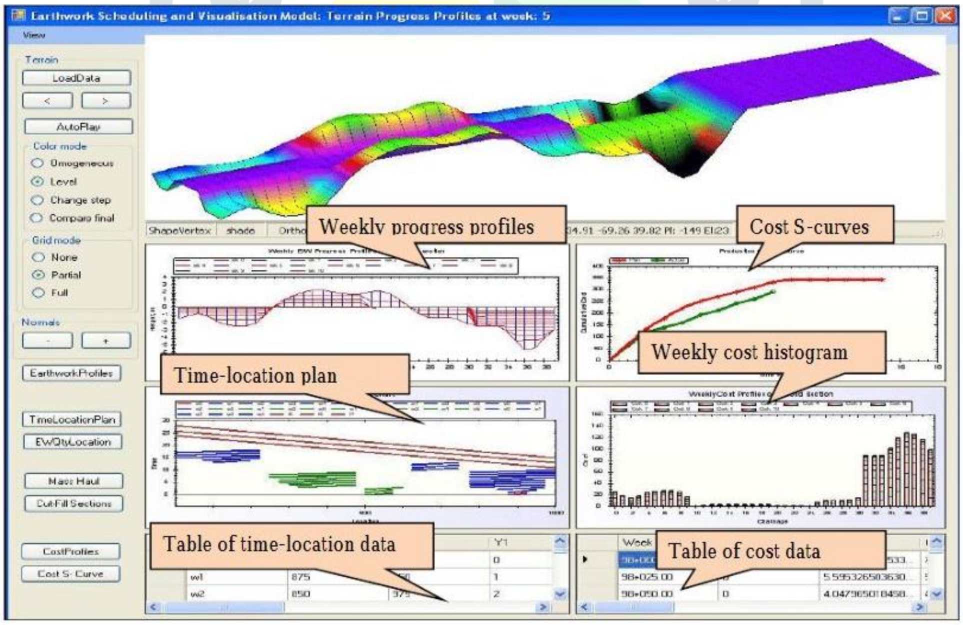


Fig.2. Snapshot of Visual Output of Model

A snapshot of the model's visual outputs is shown in Fig. 2, which includes weekly progress and cost profiles, a cost S-curve, earthwork scheduling information by location, and an overburden schedule in time and space. The location-based plan provides information related to congested locations and pavement activities such as subbase, base course, and upper surface tasks (see Fig. 2). The visualization component also provides tabular information on start and end locations on a weekly basis during earthworks and pavement construction operations. The following section describes a case study experiment to evaluate model functions (generation and visualization of location information and earthwork planning) using site data from a road project.

IV. CASE STUDY

A case study involving a 1.0 kilometer road section with actual road design data including L-profile and X-profile is considered and the sectional amount of earthwork is calculated assuming a typical trapezoidal section at 25 m intervals along the selected road section. Cut or fill productivity data is considered a key factor that affects construction time, jobs and the number of construction layers required to complete earthworks. As the model outputs directly depend on the accuracy of the productivity data, a case study was conducted to compare the variation in productivity value between the actual construction progress and the value used in the earthworks model.

• The results of the case study revealed that the actual productivity was 2% lower compared to the productivity value generated by the model for creating an earthwork schedule for site-specific road projects. The outputs of the model are; automatic generation of earthwork progress profiles, 4D terrain surfaces, cost profile, production S-curve and location-based plans for earthwork planning and visualization of planning information from a location perspective.

• With the assistance of the company, a 7 km section of the road was selected for the validation of the time-location plan (location planning) created by the prototype model. The duration of the earthworks shown in the time-location plan provided by the company was compared with the duration shown in the time-location plan created by the prototype model

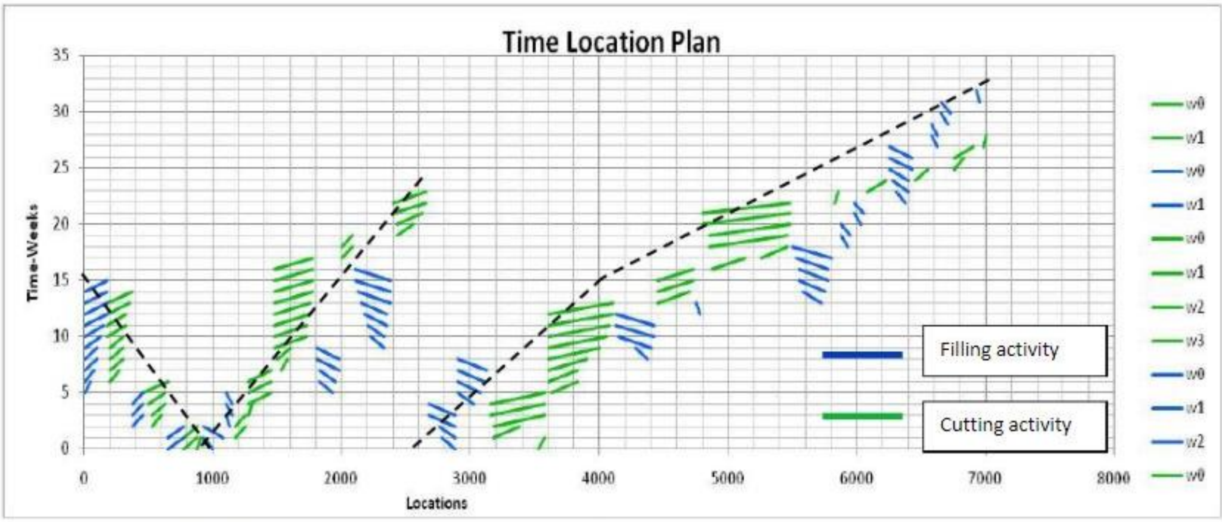
The comparative results, including detailed information on weekly work lengths/road section locations, earthwork quantity, productivity and total earthwork duration, are shown in the table

Table 1. Comparison of between Company Provided and Model Generated Time Location Plan

S. N.	Road section	Sectional Length (m)	E/W Qty. (m3)	Cut/Fill Activity	Used Production Rate m^3/wk	Company-produced Results		Model-generated Results		Variation in Time
						Time (wk)	Locations	Time (wk)	Locations	Time %
1	0+000 to 0+925	925	32,400	Cutting	2309	14.03	0+000 & 0+925	15	Fig 3	6.45%
			34,433	Filling		14.91		15		0.58%
2	0+925 to 2+675	1750	64,700	Cutting	3464	18.68	0+925 & 2+675	21	Fig 3	11.06%
			51,352	Filling		14.82		16		7.35%
3	2+675 to 3+600	925	23,357	Cutting	5196	4.50	2+675 & 3+600	5	Fig 3	10.10%
			36,204	Filling		6.97		8		12.90%
4	3+600 to 7+000	3400	204,294	Cutting	10392	19.56	3+600 & 7+000	22	Fig 3	10.64%
			213,168	Filling		19.64		23		10.81%

The road project plan, which includes both the model-generated time-location plan in colored lines, while the dotted line represents the company-created and used time-location plan. The plan was created by dividing the road section into four sub-sections (0+000 to 0+925, 0+925 to 2+675, 2+675 to 3+600 and 3+600 to 7+000). Each section was scheduled with different sets of equipment separately at different production rates

Furthermore, several experiments with the generation of a time-location plan of earthworks were carried out on plot No. 4. 5 sections in a road construction project in Portugal. The experiments revealed that the actual production time was 2.34% lower than the model-simulated earthwork production time due to the changes in soil characteristics in the cut sections along the road project, which is assumed to be a small variation in the earthwork.



Graph 1. Model Generated Time Location Plan of 7km Road Project.

Thus, it is concluded that model-generated location plans or time location plans are acceptable for earthworks in road construction projects. As a result, these plans support the improvement of resource planning and scheduling information on weekly jobs, mobilization of construction equipment sets and required material including the size of the workforce in terms of location.

V. CONCLUSION

The paper presents the development of the framework and the prototype model. The model was designed by integrating road design data; earthwork sectional quantities, productivity rates and cut/fill unit costs and arithmetic algorithms. The model automatically generates information on weekly site planning, space congestion plan and resource allocation for earthworks projects. A case study experiment was conducted to demonstrate the model's functionality using site data from road projects. The results of the experiment showed that the model provides weekly information about jobs and required resources, such as the amount of material, sets of construction equipment and the size of the earthmoving crew. Evaluation by road experts also recommended that the model is a useful tool to support strategic decisions at the planning stage and helps to more accurately inform planning in terms of location. Running different strategies with the model would allow optimization of resources, including construction equipment sets and crew sizes, suitable for earthworks on a particular stretch of road.

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