Automation in Construction 43 (2014) 156–169

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

A new approach for automation of location-based earthwork scheduling in road construction projects

Raj Kapur Shah

School of the Built Environment, Faculty of Technology and Environment, Liverpool John Moores University, Liverpool L3 3AF, UK

ARTICLE INFO

Article history:
Received 30 November 2011
Received in revised form 27 January 2014
Accepted 8 March 2014
Available online 5 April 2014

Keywords:
Earthworks
Location-based schedules
Time–space congestion
Cut/fill optimisation
Weekly work locations

ABSTRACT

Accurate information of working locations is vital for efficient resource planning, safety of the construction site and monitoring the weekly progress of earthworks, which is missing in the existing linear scheduling methods. Construction managers have to depend on the subjective decisions for resources allocation and progress monitoring from location aspects. This has caused uncertainties in planning and scheduling, and consequently delays and cost overruns of projects. In this context, a prototype computer-based model was developed using the theory of the location-based planning. An arithmetic algorithm was designed by incorporating road design data, sectional quantities, variable productivity rates and haulage distance. This paper focuses on the improvement and demonstration of the model functions through a case study experiment, which include the automatic generation of location-based earthwork schedules and the optimisation of the weekly resource allocation when and where necessary from the location aspects, considering different options such as construction sequences of the cut/fill sections, site access points and the equipment sets with known productivity rates. The study concluded that the model is a decision supporting tool that assists in the resources planning, identifying time–space congestion, monitoring the activities progress on a weekly basis from the location aspects, and reducing the gap when communicating the scheduling information amongst the construction site teams.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The construction industry has distinct characteristics in comparison with other industries in terms of one-off projects, site production, and temporary organisation [14]. The planning and scheduling process is a challenging task in the construction projects, and the decisions taken at the planning stage have the foremost impact on the successful execution of the project from its early conceptual stage to the completion stage [1]. Planning and scheduling include the precise allocation of the construction resources at the required locations and when necessary, particularly in the linear construction projects, such as roads and railways. Failure to allocate the critical resources of work activities at required locations has an adverse impact on the linear project performance such as cost, time, work-space conflicts and the safety of the workers at the construction site [16].

Arditi et al. [3] suggested that an earthwork project requires a separate planning task due to the distinctive characteristics of earthworks. The effective applications of planning and scheduling techniques: such as the Critical Path Method (CPM) and the Program Evaluation Review Technique (PERT) are limited, because the work activities associated with the linear projects are fundamentally different from the other projects such as high-rise buildings or residential houses. The majority of the work activities in a road project are linear in nature. A linear scheduling method has the potential to provide significant enrichment in terms of visual and graphical representation but currently it is difficult to provide the information of work activities and the possible time–space congestion on a weekly plan from location aspects. Although the linear scheduling method allows the project schedulers and the construction managers to visually plan the road tasks and determine the controlling activity path, it cannot provide the weekly information of the exact work activities' locations and allocation of the resources to be mobilised at the required locations, and the time–space congestion throughout the construction period [9]. Therefore, to overcome the above issues, a new methodology with a computer-based model, is introduced in this paper.

The approach, which is developed and underpinned within the prototype model, aids to generate more precise time–locations information, particularly in the earthworks scheduling in linear construction projects such as roads and railways. The key outputs of the model includes the generation of location-based earthwork schedules automatically, optimisation of earthwork quantities, and the allocation of the required recourses on a weekly basis from the location aspects. In this paper, the location-based schedule is dubbed the "time–location plan". The remainder of the paper outlines the literature review, the design of the framework, and the prototype development, including inputs,

E-mail address: r.shah@ljmu.ac.uk.

http://dx.doi.org/10.1016/j.autcon.2014.03.003
0926-5805/© 2014 Elsevier B.V. All rights reserved.

processes and outputs followed by the case study experiments from a road project.

2. Literature review

Earthworks have unique characteristics and they take place normally at the early stage of the construction project, particularly in the linear projects such as roads, railways and pipelines. They constitute a major component in a road construction, absorb high costs, and deal with haul distances for balancing the cutting and filling sections in a cost effective way [13]. A study of 145 road construction projects revealed that the earthworks component was around 19.58% of the monetary value of the project [5]. The earthwork activities have direct relation to the sequencing of the rest of the road activities since the earthwork activities contribute a higher percentage in terms of project monetary value in comparison to the other road activities [4]. Hence, the decisions, which are normally taken at the planning stage of the earthworks, have enormous impact on the overall performance of the road construction project [16].

Mattila and Park [15] highlighted that the key limitations of CPM are the subjective partition of the repetitive activities from location to location, the inability to plan the continuity of resources and visualise the production rates, and the failure to provide any information of the performed works. Mawdesley et al. [16] also pointed out that CPM networks are more suitable for the large complex projects, however, the line of balance and the linear scheduling methods are more practical for the 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 locations of the work activities on any given time, but it is ineffective in addressing the weekly information of the locations and time–space congestion during the earthwork operations in the linear construction projects.

Arditi et al. [2] suggested that the line of balance technique is an example of the linear scheduling method. This technique is based on the hypothesis that the productivity of an activity is uniform. In other words, the production rate (productivity) of an activity is linear when time is plotted on the vertical axis, and location of an activity on the horizontal axis (or vice versa). The production rate of an activity is the slope of the production line, and is expressed in terms of linear metre per unit of time [2].

Scheduling methods such as line of balance, repetitive scheduling method, time–location matrix model, time–space scheduling method, linear scheduling method, time–distance diagram and linear-balance diagram are acknowledged as 'location-based scheduling'. These methods are based on the theory of location-based planning, particularly in the linear construction projects [11,12]. This method is important because it provides the vital information of the work locations throughout the earthworks with the aim of reducing the dependency on the subjective decisions. It is logical that the precise information of working locations assists to the construction managers in planning the resources including the construction equipment when and where necessary, and monitoring the site progress from the location aspects more effectively. The current linear scheduling methods, however, do not provide these information and possible location of time–space conflict throughout earthworks in the linear construction projects.

Furthermore, Kenley and Seppanen [11] pointed out that there are mainly two types of scheduling methodologies; an activity-based and a location-based methodology. The location-based methodology is further sub-divided into two: unit-production scheduling and location-production scheduling. It is also known as an alternative methodology, which is based on tracking the continuity of crews working on the production tasks. An example of unit-production scheduling is RoadSim [20]. It is a knowledge-based simulator that helps to produce scheduling by determining the productivity and unit cost of all road activities including earthworks. It was developed based on the theory of an atomic model in the earthwork operations, considering a large set of equipment data base, site constraints and site knowledge of the earthwork operations, however, it lacks to provide the precise information of the working locations and time–space conflict on a weekly throughout earthworks.

Moreover, DynaRoad [7] developed commercial software for producing a linear construction schedule and controlling path in the earthwork operations. This provides the location-based scheduling information but lacks the provision of the information of the working locations and time–space congestion information on a weekly. Similarly, TILOS is software that aids to produce time–location plans with aim of scheduling and visualising the tasks with linear nature in a construction project. It also provides the limited scheduling information in terms of time–space conflict and precise locations of work activates on weekly on a construction plan [19]. The time–distance charts, produced by DynaRoad and TILOS, are not a success tool to provide the information of time–space congestion and working locations on a daily or weekly basis, particularly in the earthwork operations. This is imperative for an effective planning and scheduling of required resources when and where necessary, including the identification of the time–space conflicts at the earthwork sites. Consequently, the construction managers have to depend on subjective decisions for planning the resources and scheduling the earthwork activities due to the limited information of the locations and time–space requirements.

Considering the findings highlighted by previous research studies [2,8,10–12,15,20,21], it is argued that the location-based scheduling, which is based on the theory of the location-based methodology, is an effective way of representing the planning and scheduling information of the earthwork activities in road projects. From the literature, it is also revealed that the existing scheduling methods are not capable of providing the precise scheduling information of work locations on a weekly or daily basis, which is imperative for the effective and efficient allocation of resources, and necessary to assist in the identification of the space of bottlenecks before execution during the earthwork operations. Therefore, this paper focuses on the improvement and the evaluation of a computer-based model that generates the location-based schedule of earthworks automatically, considering the productivity rates of the construction equipment sets, site access points, working sequences in forward or backward directions between the cutting and filling operations. The next section discusses a framework design of a prototype of computer-based model.

3. Framework of a prototype

The framework of a prototype model is outlined as shown in Fig. 1 by integrating the findings from the literature review and the construction industry survey [17]. The key input of the framework includes the road design data, sectional quantities of earthworks, productivity rates, unit cost of the cutting or filling activities, and an arithmetic algorithm. The model has several functions that include the visualisation of scheduling information, optimisation of the cutting and/or filling quantities, and the automatic generation of weekly progress profiles, location-based schedules, time–space congestion plans and the cost S-curves of the earthworks [18]. This paper, however, mainly focuses on the improvement and the evaluation of the computer-based prototype model's functions through the case study experiments, which are conducted considering what-if scenarios under different options at a road construction project.

The study outlines a methodology and presents a prototype model that aimed to provide the precise scheduling information of working locations, allocation of resources, and identification of time–space conflict on a weekly, particularly in the earthwork operations like roads and railways. Although the model is capable of generating weekly progress profiles, cost profiles and cost S-curves, the paper focuses on the methodology and algorithms for the generation of location-based

Download English Version:

https://daneshyari.com/en/article/246471

Download Persian Version:

https://daneshyari.com/article/246471

Daneshyari.com