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# Application of 4D for dynamic site layout and management of construction projects

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**Abstract**

Construction schedules and site space arrangement are essential to project management, as they directly influence security, machine running, material deployment, power distribution as well as construction progress and cost. There has been a strong need for more effective planning and management of site space and facilities. This paper introduces a 4D Integrated Site Planning System (4D-ISPS) which integrates schedules, 3D models, resources and site spaces together with 4D CAD technology to provide 4D graphical visualization capability for construction site planning. The features of 4D-ISPS are described in detail. The implementation techniques of this system are also discussed and a real life case is presented.
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## 1. Introduction

Visual 4D planning and scheduling technique that combines static 3D CAD models with construction schedules has proven to be beneficial over traditional tools such as bar charts or network analyses. The concept and development of 4D CAD in the construction field can be traced back to mid 1980s, when 3D CAD models were combined with the project timeline to form 4D models [1], and systems linking 3D CAD models with schedules started to be developed [2,3]. However, representative and influential applications do not appear until late nineties. In the 1990s, high-performance computer hardware, complex graphical software and object-oriented programming (OOP) made it possible to develop impressive 4D applications. 4D Annotator and 4D-Planner are two representative systems. 4D Annotator can visually explain to planners potential constructability problems or how a proposed construction sequence affects decision criteria such as cost, productivity and safety to commonly mentioned 4D components [4]. 4D-Planner is a visualization, simulation and

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communication tool that provides simultaneous access to design and schedule data [5]. It provides a graphical simulation of the work plan that allows early problem identification, including interference detection, and supports scenario analysis. Kamat and Martinez [6] designed a visualization methodology that allows developers of simulation models to verify and validate simulated construction operations. Recently, 4D technology has been further developed by professional software vendors. Typical products include Schedule Simulator by Bentley™ and Project Navigator 2000 by Virtual STEP™. The benefits of 4D CAD systems are apparent as they can display the assembling sequences of construction projects, simulate different scenarios before construction begins and/or help users conduct constructability analyses of the designs.

Another trend of investigation for construction management has targeted on the strategies or algorithms of locating site facilities on a set of predetermined sites and aims to develop 2D interactive management systems. The Critical Operations Planning Environment (COPE) [7] is an interactive plan management software package, used for planning critical construction operations involving large semi-stationary equipment such as cranes and concrete pumps. Similarly, various approaches for automatically locating site facilities have been presented [8–12]. It is common to see artificial neural networks, expert systems, genetic algorithms or hybrid intelligence utilized in the implementation of these approaches. The developed systems can help project managers make decisions and avoid inappropriate or incorrect layouts based on 2D drawings.

Nevertheless, for a large-scale construction project, site facilities generally are not limited to 2D static site layout. When some resources or facilities are put inside the buildings under construction, the above management systems can no longer meet the needs. Moreover, construction process itself is a very complicated production and generally contains three main phases: excavation–foundation–substructure work, superstructure work and fitting-out work [13]. Some projects may comprise of several buildings with the three phases having different durations and different starting time points. This adds to the complexity of construction layout. As shown in Fig. 1, a sample project contains two buildings A and B with A started earlier but the duration of its substructure is shorter than building B. The construction of the project is then divided into seven phases. In different phases, the site layout will change accordingly to meet the changing demands for materials. So site layout should never be static and two-dimensional, instead, it should be a dynamic activity across the whole 3D site.

Many researchers have already realized the importance of time to site layout. Tommelein and Zouein [14] developed MovePlan to support dynamic layout planning. Zouein [15] developed MoveSchedule, an extension to MovePlan, which can alleviate space conflicts by adjusting the construction schedule. A layout design system, called SEED-Layout was used to conduct dynamic site layout [16]. Temporary facilities ranging from material storage such as long-term lay-down areas to building structures such as temporary offices can be located with SEED-Layout. Guo [17] also takes time as an important part of site

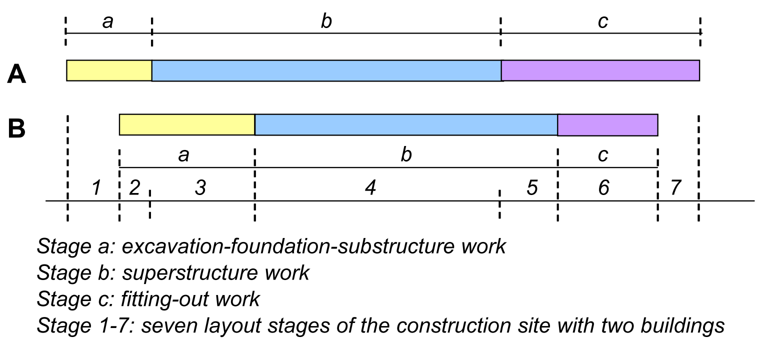


Fig. 1. Complex site layout periods.

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