INTEGRATION OF CONSTRUCTION MANAGEMENT FUNCTIONS

Integration of construction management functions

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Abstract

To date, the development of construction management software has focussed primarily on the generation of a project plan and schedule, its monitoring, updating and revision, i.e., it has adopted a process-centric approach. However, there is a growing awareness of the need to support other functions such as productivity analysis, change management and quality management, to name a few. The development of computer-based systems that support a broad spectrum of interdependent functions (interdependent in terms of data and information requirements) leads to the topic of integration and how best to achieve it. Described in this paper is a multiple-view representation of projects that facilitates the integration of and computer assistance for a diverse range of functions. Productivity analysis is used as a context to present the opportunities such a representation offers for integration and an enriched and expanded function set.

Keywords: Integration; management functions; project views; productivity analysis.

1 Introduction

The purpose of this paper is to outline an approach for enhancing and enlarging the software tool kit for construction management personnel. To date, those involved in developing software tools for such personnel have tended to focus on the generation of a project plan and schedule, its monitoring, updating and revision. Consequently, a process-centric approach has been used to represent projects – i.e., the belief is that a project can be described in terms of a set of activities, and all essential information can be associated with these activities in the form of attributes. The reality of construction management functions is that planning and schedule control constitutes only a small part. Consequently, managers have pursued the use of spreadsheets, and custom and commercial data base systems to support other functions, including the mining of data to generate insights on project performance or to conduct post project analyses in support of claims or knowledge for use on future jobs. As a result, management does not end up with a coherent representation of the various facets of a project, leading to redundancy in data, errors, and inadequate support for many functions.

We seek to break out of such a narrow process-centric definition for construction management software, and move closer to the range of tasks actually carried out by management personnel during the execution and post-construction phases of a project. We do not include the estimating and cost accounting functions in our scope because practices are ingrained, head or regional office personnel generally perform them, and they invariably involve the use of dedicated systems. However, one has to be concerned how construction management systems can interface with these other systems to facilitate the seamless transfer of information in both directions – i.e., site to office, office to site, and thus support the broadest range of functions possible. The development of computer-based systems that satisfy the desire to support the broad spectrum of interdependent functions (interdependent in terms of data and information requirements) leads to the topic of integration and how best to achieve it. Integration refers to the support within a single system and through connectivity to other systems of a comprehensive set of construction management functions.

As a step toward integration, we have adopted a six-view representation of a project as follows: (1) Physical View – what is to be built and the site context; (2) Process View – how, when, where and by whom; (3) As-Built View – what happened, why and actions taken; (4) Cost View – how much and from whose perspective; (5) Quality View – compliance requirements and achievements for input and output products; and, (5) Change View – what changed, why and consequences for other views. These views are not unique (i.e., other definitions are possible), but they tend to mirror the thought processes of construction personnel and we have found our choice to be useful for supporting new functions and enhancing existing ones.

Current work directed at expanding the scope of functions supported through software systems includes the representation, tracking, selection and evaluation of construction methods (Udaipurwala & Russell 1998), intelligent assistance in formulating a schedule based on a physical description of a project (Chevallier & Russell 1998), (Russell 1998), and automated assistance in terms of evaluating the quality of a schedule. All of this work involves the use of the Physical View of a project as well as the Process View. New or complementary functions being pursued include productivity analysis as described in the next section, the detection and diagnosis of site problems which involves four views (Physical, Process, As-built and Cost), and the detection and diagnosis of quality problems (Battikha & Russell 1998).

In the remainder of this paper, we describe selected aspects of a research system that uses a multiple-view representation. (The system is in transition from a DOS world to a Windows one.) By integrating these views, i.e., allowing them to share data, new opportunities can be created to enlarge and enrich the function set that can be supported through software. Within several of the views, use is made of generalized, hierarchical classification structures, as construction projects lend themselves naturally to a hierarchical decomposition. Due to space constraints, attention is directed mainly at the first three views described previously. The topic of productivity analysis is used to focus the discussion, although reference is made from time to time to other functions.

2 Productivity analysis

Fig. 1 provides an overview of the function that we have called productivity analysis. By productivity analysis, we mean developing productivity profiles and comparing them to expectations set out in the estimate (P_A as shown in Fig. 1), establishing benchmarks for control (location and/or time varying profiles of productivity) generating as-built productivity profiles using payroll data and Physical View data, conducting variance analysis to explain differences between as-planned and as-built performance, and generating productivity functions for estimating future jobs. On the left-hand side of Fig. 1, a hierarchical representation of the Physical View of a project is depicted, which is elaborated upon in Figs. 2-4. Data from the Physical View is used as the numerator (output) in the productivity equation, and for input to productivity and duration estimating relationships. The Cost View on the left-hand side is also represented in a hierarchical structure, and relates to the need to connect the Process View with the As-Built View in order to assess capital productivity and compare as-built with as-planned achievements. The lower left-hand side of Fig. 1 depicts the Process View of the project, including a detailed methods statement for purposes of assessing productivity at a number of levels. This aspect of Fig. 1 is elaborated upon in Figs. 5-9. The shaded area in the middle depicts the as-planned and as-built productivity achievements for the superstructure slab form element (similar profiles can be developed for any other component in the Physical View). Generation of these profiles requires input from the Physical, Process, As-Built and Cost Views. A system-generated version of this profile is shown in Fig. 12. The As-Built View on the top of Fig. 1 reflects the gathering of information to document and explain actual performance, and involves an intersection with the Cost View in terms of the collection of payroll data. Aspects of the As-Built view are elaborated upon in Figs. 13-15. The Diagnosis and Control component of Fig. 1 highlights the potential for improved assistance to construction personnel through integration of views and functions and the incorporation of expert knowledge. Lastly, the right hand side of Fig. 1 deals with the processing of project data after project completion in order to provide feedback to the firm's estimating function. We think this approach provides a more holistic view of the productivity analysis problem through the construction phases as opposed to the traditional approach to modeling productivity that concentrates on the planning phase alone (Randolph et al. 1990 and Tavakoli 1985).

Figs. 2-4 depict various aspects of a Physical View or Physical Component Breakdown Structure (PCBS) of a project that we believe are essential to support a range of functions. Fig. 2 shows the hierarchical structure of the Physical View. It involves a simple language dealing with allowable components, and a limited rule set regarding the structure required. Considerable flexibility exists in terms of the level of detail that the user specifies. The formulation of the PCBS can be facilitated through the use of user-defined standards and templates (see Standards, Fig. 13). Components of the PCBS hierarchy can be described in terms of Attributes, Values, Multi-Media Records, and association with Activities, Pay-Items (Cost), Quality and

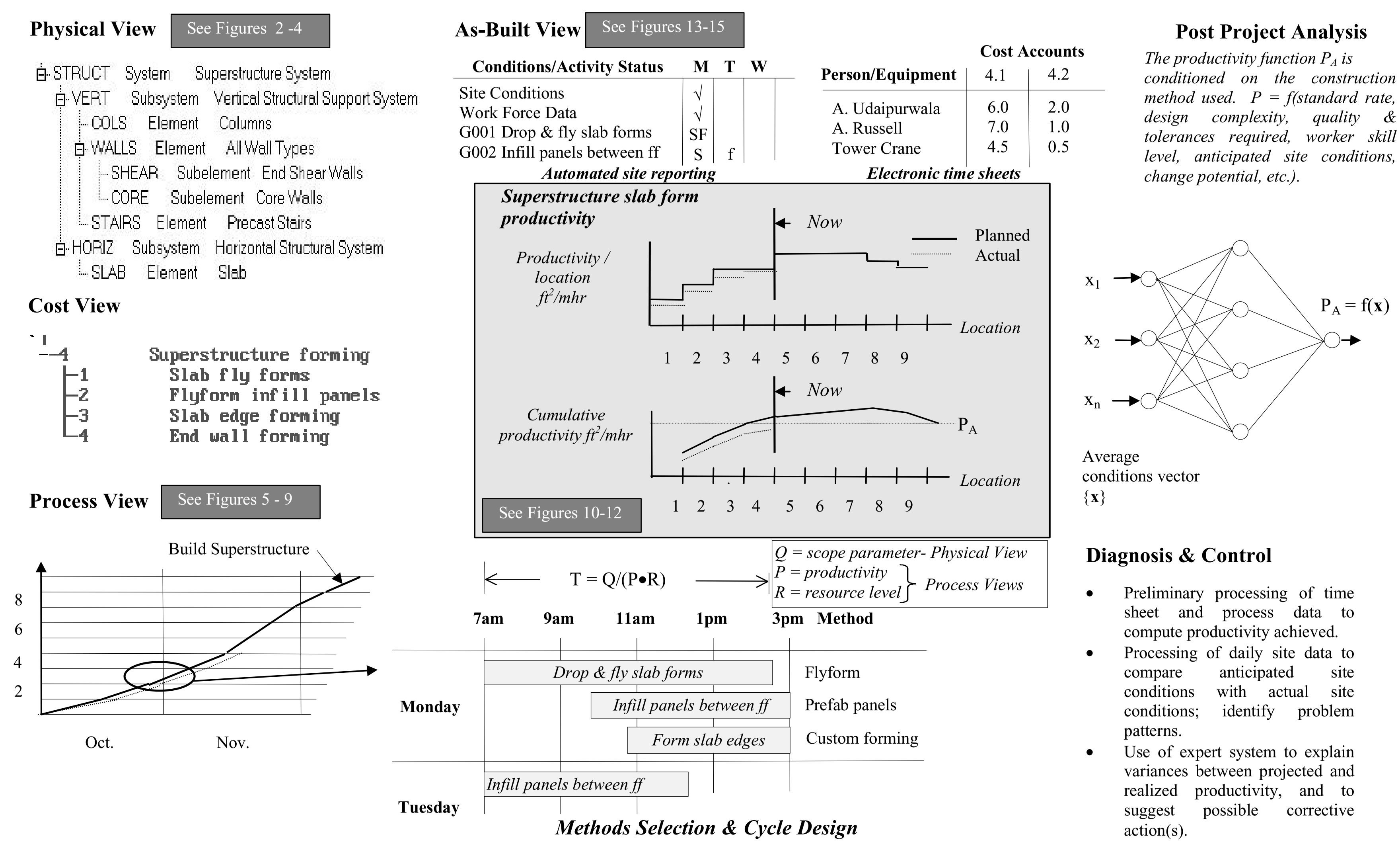

Fig. 1: Productivity analysis and its relationship to various project views

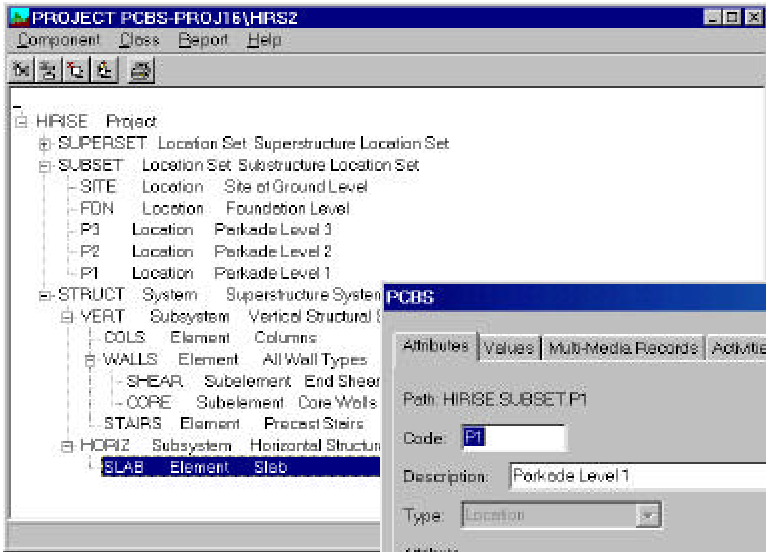

Fig. 2: PCBS structure

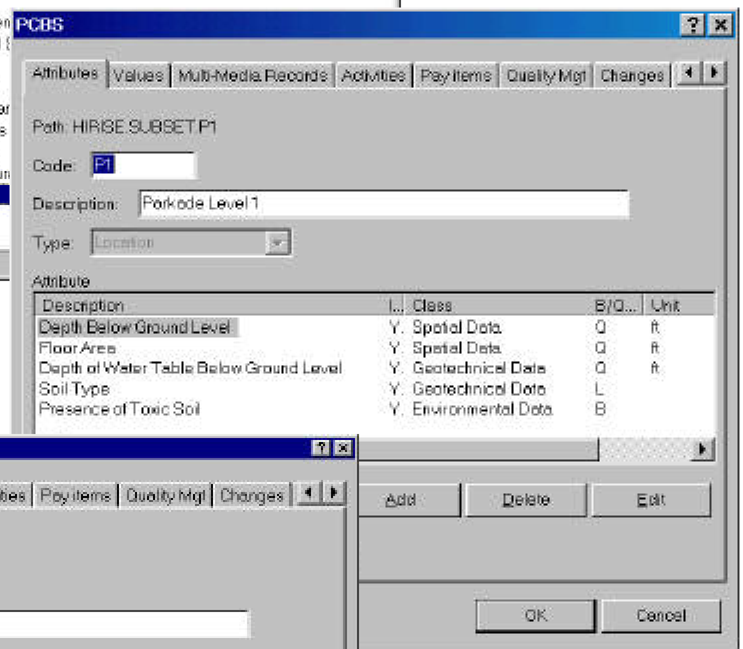

Fig. 3: User-defined PCBS location attributes

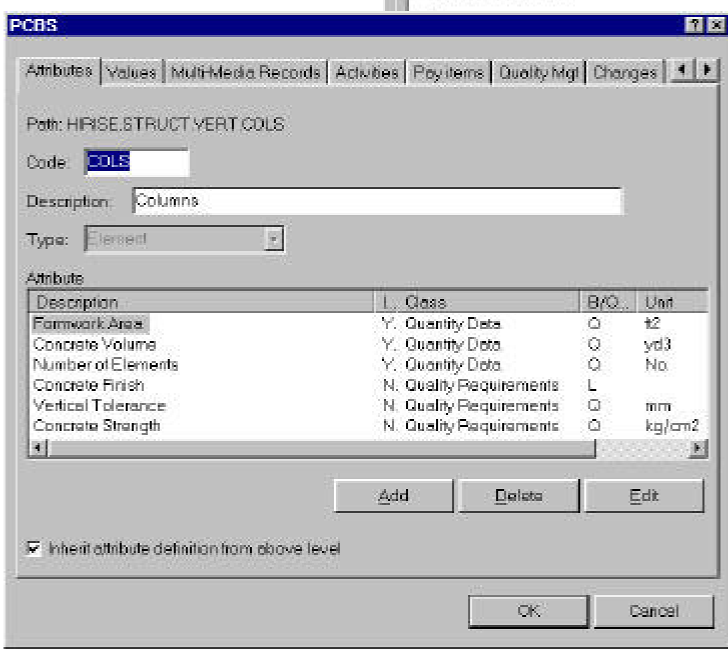

Fig. 4: User-defined PCBS element attributes

Change Views. Figs. 3 and 4 show the user specification of attributes for a spatial element (Location) (Parkade Level 1), and a physical Element (Columns). Note that inheritance is supported. The concept of locations shown in Fig. 2 is central to the Physical View, as it allows one to carry out functions/reasoning that depends on the project's spatial context and anticipated site conditions (e.g., checking for congestion, assessing the feasibility of a construction method). Attributes can be Quantitative, Boolean or Linguistic, and further can be grouped into user-defined classes to facilitate various functions (e.g., duration estimation, quality management).

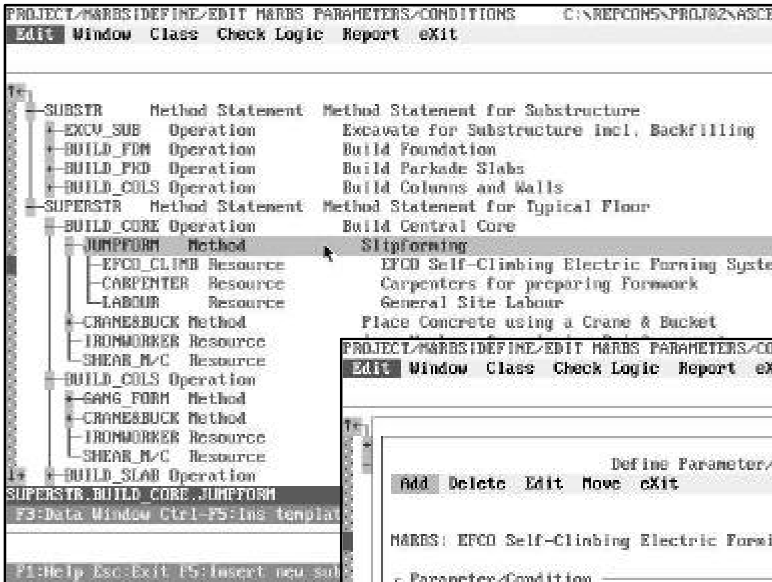

Fig. 5: Process view: M&RBS structure

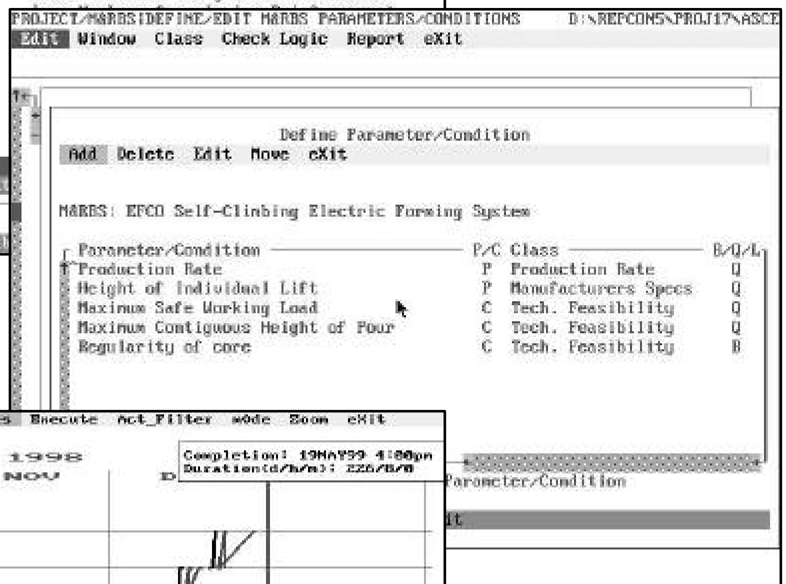

Fig. 6: User-defined M&RBS component attributes

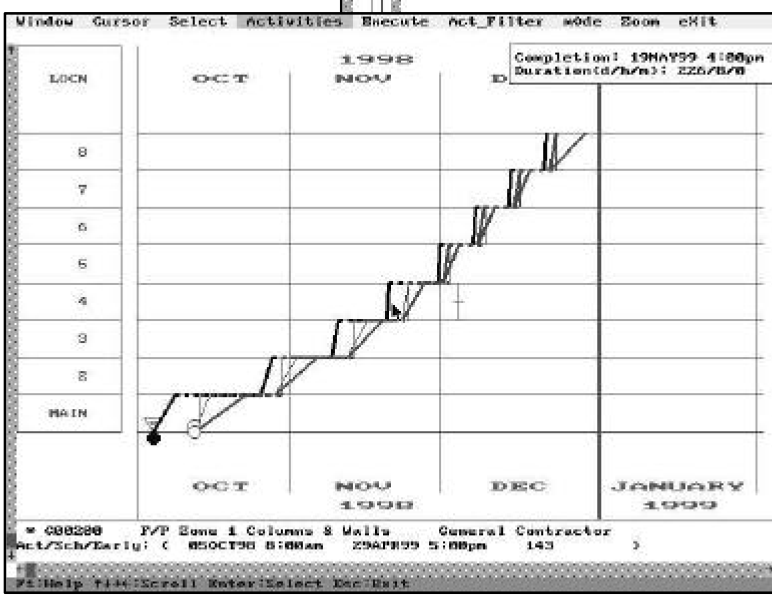

Fig. 7: Process view: linear planning chart

The description of any member of the hierarchy in terms of its associations with other views is key to the goal of integration. This is an area of research focus at the present time as current industry practice does not preclude very different levels of detail in terms of Process, Cost and As-Built representations of a project. Imposing the constraint of one to one mappings is far too simplistic.

Fig. 5 depicts a hierarchical methods & resource breakdown structure (M&RBS), in support of the Process View. The user is able to formulate, using a simple language (method statement, operation, method, resource, fragnet), detailed method statements. Similar to the PCBS structure, the user is allowed to associate different

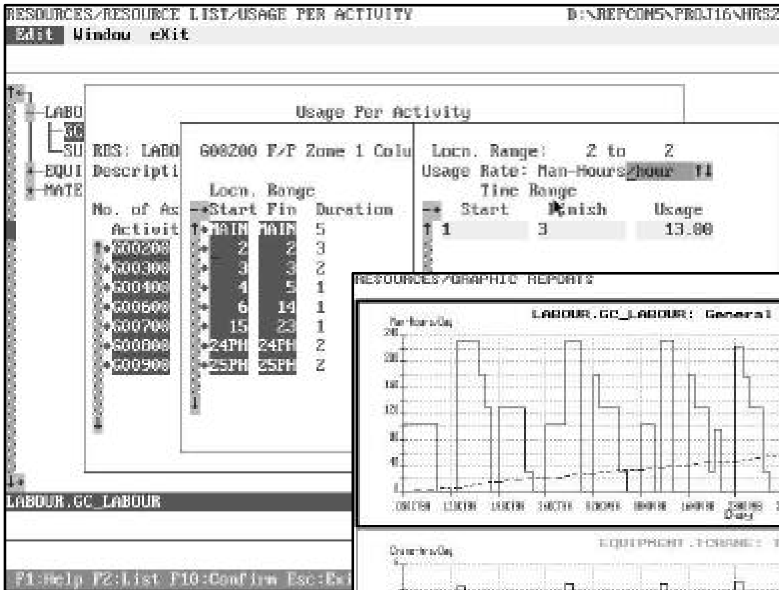

Fig. 8: Resource loading a schedule

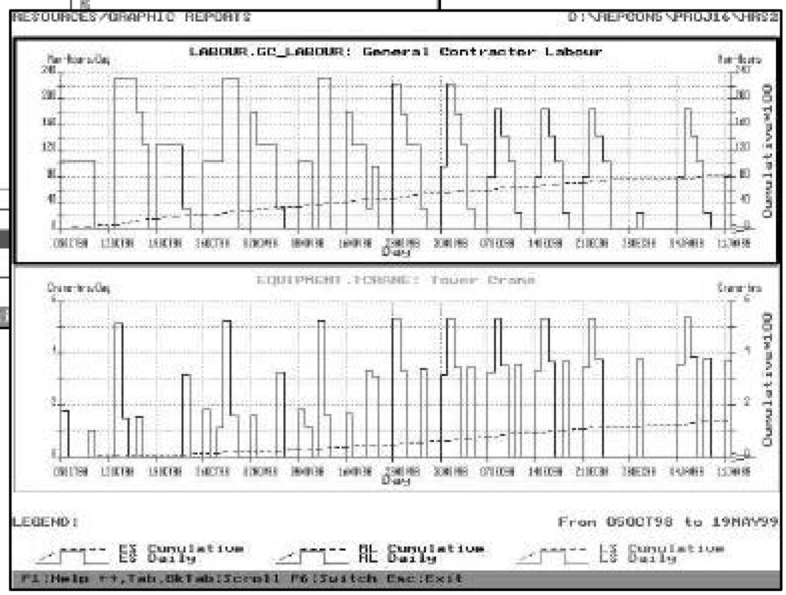

Fig. 9: **Resource usage histogram**

kinds of information with each component in the M&RBS. For example, Fig. 6 shows a set of user-specified parameters and conditions that relate both to a project's physical context and production capabilities of the technology at hand. This information can be used for assessing the suitability of a method for a project and for estimating activity durations. Association with a Physical View is essential for both.

Once a set of activities are defined, sequenced and a duration estimated for each (Process View), all of which are a function of the physical properties and site context of a project and methods selected, the project schedule can be computed. A project plan in the form of a linear planning chart is shown in Fig. 7. If one attaches additional attributes to activities in terms of a resource assignment (Fig. 8), then resource usage histograms can be generated both for time (Fig. 9), and for space (not shown). For the latter, the existence of a Physical View will then allow additional analysis to be performed, such as checking for congestion at peak work times at various work locations (knowing spatial attribute values such as area per work location and resource usage at a given location and point in time, the potential for crowding can be assessed, and hence the quality of the schedule can be evaluated).

Figs. 10-12 show a value-added function in the form of productivity analysis for the planning phase. Fig. 10 shows the association of activities with a component of the PCBS. Fig. 11 shows the user selection of activities to be examined (the activities associated with the physical component of interest), the physical component (slab) and its attribute (formwork area) of interest, and the resource (general contractor labour) of interest (resources can also be described in terms of a hierarchy). The

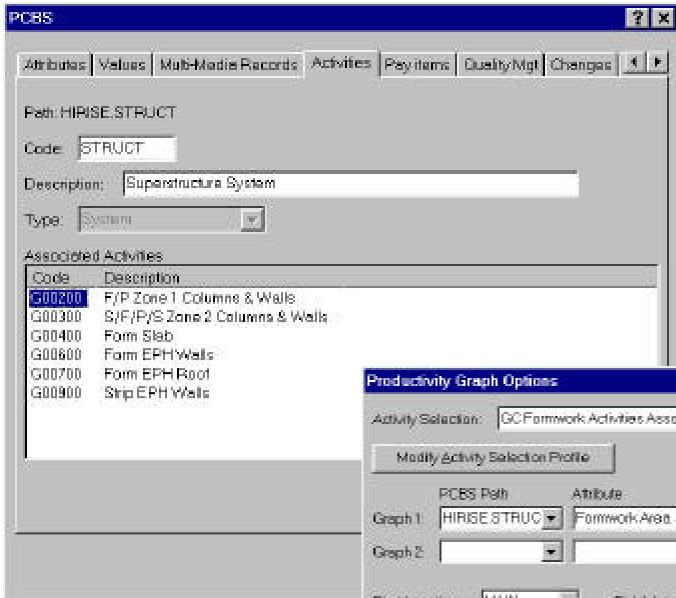

Fig. 10: Association of activities and PCBS component

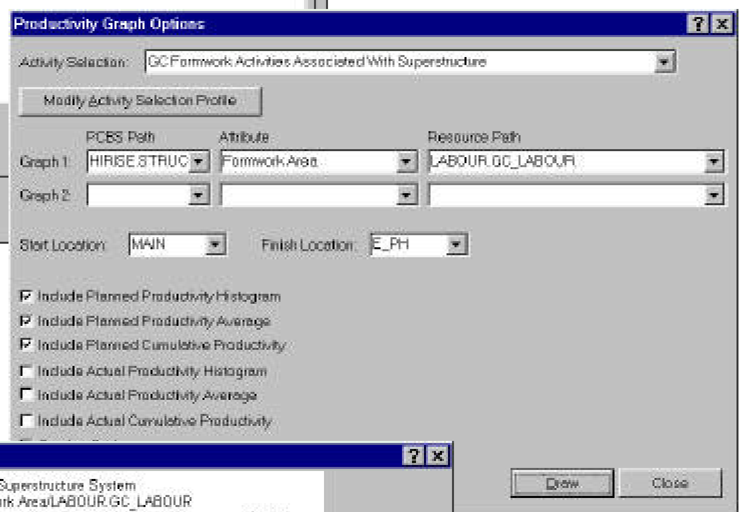

Fig. 11: Specifying productivity analysis profile parameters

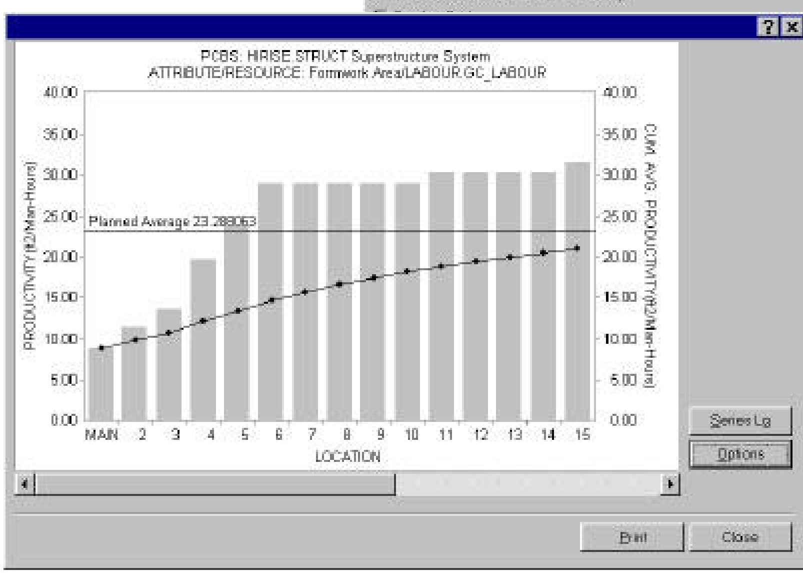

Fig. 12: Productivity analiysis profile

system then extracts the relevant data from the Physical and Process Views to generate the productivity profile sought. The average productivity over all locations can also be computed, and it can be used to check consistency with the original estimate, which is generally based on an estimate of average productivity. Such a consistency check is very important, and is often not done. An additional benefit from generating the productivity profile is that it can be used as a benchmark for control. Later on, when payroll data is collected from the field (the Cost View), actual productivity profiles can be generated, although that may have to be done for

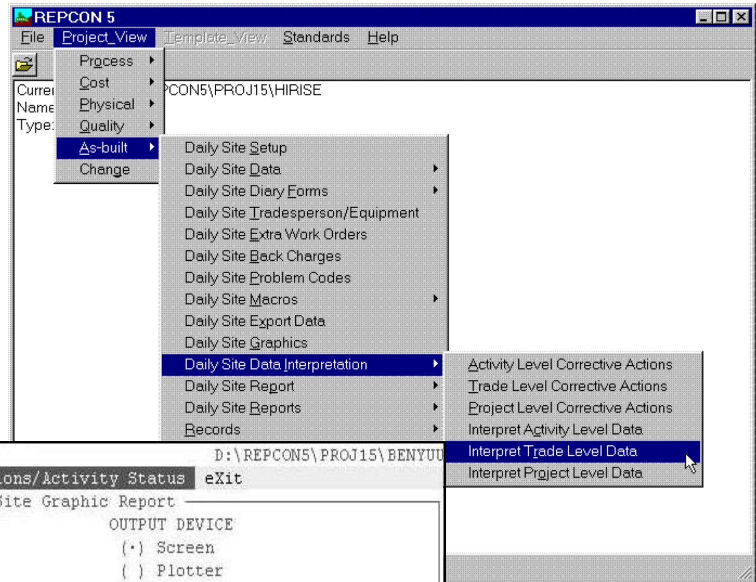

Fig. 13: As-built view functions

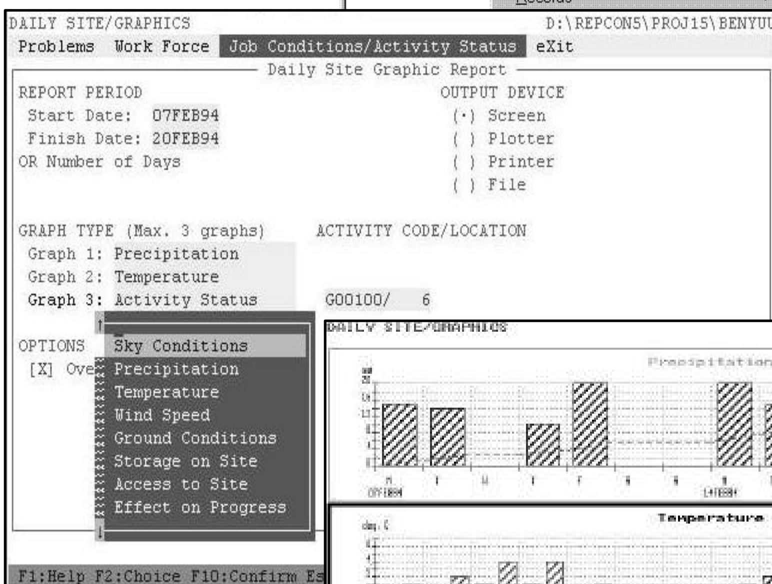

Fig. 14: Viewing as-built database

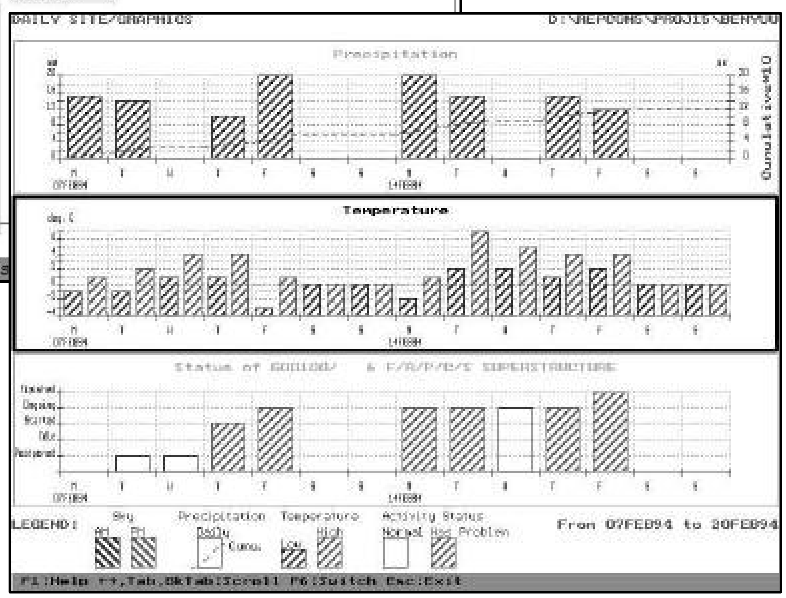

Fig. 15: Searching for cause-effect relationships

more aggregated components in the physical hierarchy as field personnel may not code data at the same level of detail found in the estimate or project.

Fig. 13 shows the ingredients of the As-Built View. Data collected in this view is essential for comparing actual performance against planned performance, and for explaining reasons for schedule, cost and productivity variances. A tie in exists between the As-Built View and the Cost View in the form of the Daily Site Tradesperson/Equipment data collected as part of the As-Built View. This design feature allows the interception of cost-coded payroll data for speedy profiling of actual productivity – i.e., one does not have to wait for feedback from the cost accounting department. Figs. 13-15 highlight two other features of the daily site system that arise from integrating the Process, Physical and As-Built Views of a project. The submenu on Fig. 13 illustrates the opportunity to enhance system functionality by having it "mine" its own data in order to detect problem areas, and through the addition of expertise, to possibly suggest corrective actions (Russell 1998). Our current work in this area needs to be augmented by more fully integrating data from the Physical View into the corrective action reasoning process. Figs. 14 and 15 illustrate other opportunities from integration – that of superimposing data from the Process and As-Built Views in order to determine cause and effect and seek explanations for inadequate performance.

3 Conclusions and future work

We have found that the use of a multiple-view representation of a project contributes significantly to the integration of functions and the support of more functions than found in traditional construction management software systems

Future work will be directed at connectivity issues amongst the project views and on enriching the function set supported.

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