AN INNOVATIVE PLANNING TECHNIQUE IN QUALITY MANAGEMENT

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A planning paradigm, borrowed from an AI formal theory, effectively to improve the representation of knowledge in construction planning, is introduced. The planning methodology is tested to assist in the quality performance specification, in the integration of work task, quality and safety plans, in the information exchange aiming at plan refinement and flexible plan adaptation. The paradigm transfer of a general-purpose planning system (O plan) in the construction management domain is directed to improve the quality management. It requires, in fact , an intensive analysis both of construction activity requirements and performances as well as of construction component characteristics. Plan model elaboration through a hierarchical planning system allows the understanding of technical, organizational and environmental constraints to be clarified, with the aim of improving the buildability of the project and reduce uncertainty in the scheduling of resources. Preliminary to a proposal of a planning system the research is developed in three ways: to analyse a conceptual architecture of planning in construction, to analyse the requirements and the functions of a planning system posed in a collaborative environment, to model the construction planning semantic through the O-Plan expressiveness.

Keywords: buildability, planning, quality management.

REVIEW OF CONCEPTS

The evolution of planning techniques is currently deeply influenced by efforts made by Information Technology in the development of the product model. The objective is to structure information on constructions and provide an information model for construction process management (Björk 1995), such as in GARM (Gielingh 1988), research that rotates around the basic data model defined by the Standard for Exchange of Product (STEP), norm ISO 10303.

The development of a planning technique for constructions moves out of the research area regarding information integration in construction projects. Some design systems oriented to the object-oriented analysis and design, and computer aided software/systems engineering, aim at the co-ordination and integration of planning contributions. An example is ALLPLAN of the Nemetscheck company that uses the Application Protocol 225 of the ISO 10303 (Monceyron and Poyet 1997). Others like the Architecture Methodologies and Tools for Computer Integrated Large Scale Engineering (ATLAS LSE) that set the development of tools for the management of integrated information - enable the interaction of many designers and managers. Both types of IT applications in design are potential source of data for planning.

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In this conceptual framework, research has been inserted that develops IT approaches to planning or that tries to integrate IT techniques with customized planning algorithms. The MDA (Jägbeck 1993) system tests a half-calculator scheduling model suitable for on-site working conditions. The system consists of a prototype that exemplifies the management of a medium/large-sized project. It is conceived as an integrated part of an information flow that connects the planning model to a knowledge base concerning construction consisting of methods and resources internal and external to company organization.

Many attempts have been made to apply Artificial Intelligence techniques to construction planning, but of most interest, those that apply general-purpose paradigms to the construction domain, should be pointed out.

OARPLAN (Winstanley and Levitt 1993) aims to apply a planner in the design-to-construction process, through the integration of CAD and Computer Aided Scheduling. Converging with IT techniques are proposed:

- The construction of a *knowledge base* regarding a *construction model* that enables integration of information technology with the objects that make it up
- The application of the *planning* paradigm (Artificial Intelligence) to the automatic generation of possible construction processes with *inferential rule techniques*

The definition of a construction system based on automatic planning is present in the work of Jarvis (1997), that uses KADS, Knowledge Analysis and Design Support, to develop an expert system for model-based planning. It uses a Hierarchical task Network general purpose planner, O Plan (Tate 1997). The system, tested in the construction domain is aimed at transforming the product model into construction plans.

The approach is useful for formulating a proposal on this basis, which instead of developing a model-based planner, assumes product modelling to be a data exchange base with plan modelling, to which it provides tasks that have to be developed in the specific domain of construction

AIMS OF PLANNING IN CONSTRUCTION

Modern organization of construction planning assigns some critical functions to planning, such as:

1. To satisfy the principles of the ability to construct as defined by CIIA (McGeorge and Palmer 1997) and to build an interface with the design to obtain a balancing of the various project and environmental constraints ‘to achieve maximization of project goals and construction performance’;
2. to improve manageability and the stability of processes and to allow an effective scheduling of construction activities;
3. to integrate effectively decisions and information regarding the specific domains of quality planning, safety planning and of environmental systems management,
4. to support integration of the organizational complexity of the project by means of ergonomic techniques of automatic information manipulation.

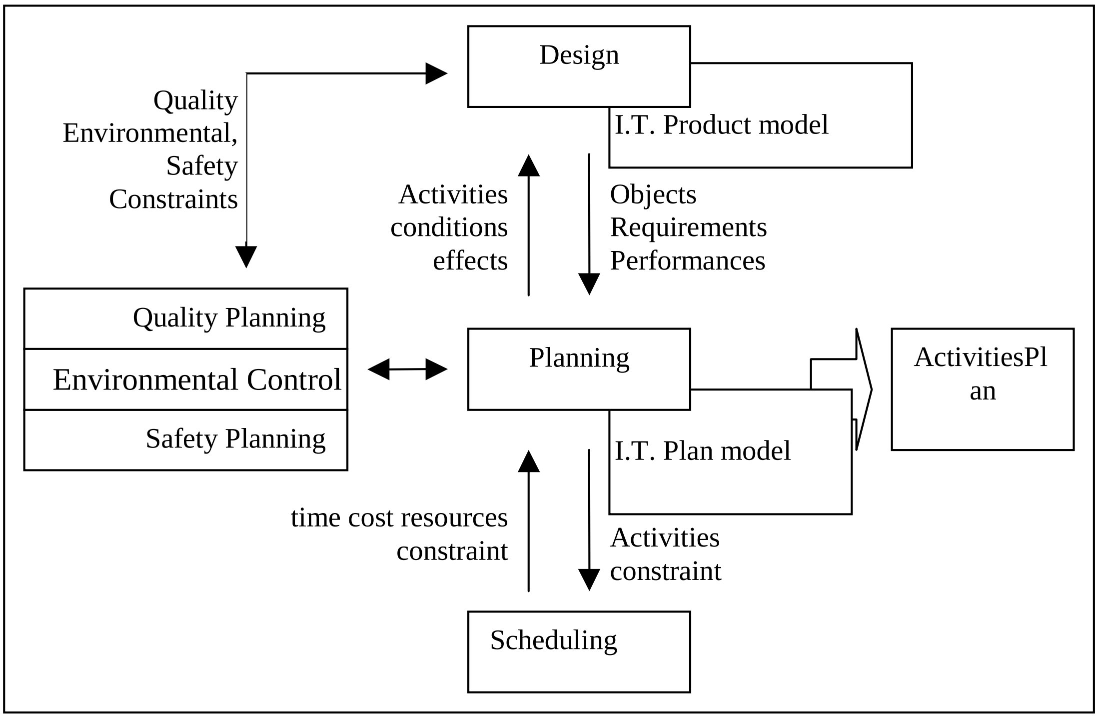

Figure 1

Buildability aims for construction planning

In particular planning can play a key role in increasing the ability to construct and the manageability of construction processes tending to:

- satisfy the need to develop planning techniques that effectively represent planning semantics and the representation of the project under construction;
- to improve the interfaces between design and planning, and design and scheduling to achieve construction planning able to represent construction knowledge (Figure 1).

Tate (1996) proposes an ontology for planning, IN-O-VA, in which the problem of planning representation is formally defined through sets of constraints in a suitable way for construction planning. The description of construction by means of planning states allows the definition of preconditions, so that an action is aimed at the post-conditions, like the effects produced by the said action. Analogous conceptualization is also found in the MDA planner ((Jägbeck 1993) for resource scheduling. The approach to the modelling of planning changes if the problem is observed from the point of view of constructability and quality management, and only secondarily as a problem of resources management.

A building construction plan requires a specification of construction methods with regard to quality management, to the pre-establishment of environmental controls, according to the respective models of standards EN ISO 9000, EN ISO 14000 and finally, with regard to safety management.

In the prospective of constructability construction planning is a necessary step to link design and scheduling as well as off-site phases of construction management and the on-site ones.

The scheduling of construction activities for computer use has been developed in many techniques and algorithms for the construction of expert systems that enable the representation of the variability of factors and the interdependence between activities (Kähkönen 1993).

QUALITY MANAGEMENT OBJECTIVE FOR CONSTRUCTION PLANNING

The reliability of the constructive process, the objective of keeping construction activities under control are the subject of quality management. Quality management has focused on production control as one of the main objectives of project and construction qualification. The application of management tools and quality control are basically geared to the identification of requirements, or of the conditions and performances, or effects, of construction activities, as well as of the conditions and events occurring in the environment where the project is being effected. The objective for safety management in construction activities is complementary and methodologically analogous also to environmental management systems.

The construction activities are subject to variable context conditions and constraints depending related to the technical elements, contractors, standards, environmental factors, geographical factors and so on. Such conditions weigh significantly on the determination of cost and on duration. The uncertainty deriving from this affects the scheduling of recurrent errors and consequent adjustments. That create difficulties for the effectiveness of planning tools and provide the on-site manager with little reliability of data quality to be inserted into the system and the of the predictions deriving from them. Furthermore re-planning in on-site phase cost time and is source of risk because it requires to the managers the ability to make provision for the effects of new decision introduced in the project. The planning objective of a stabilization of construction processes imposes the conditions for scheduling to be effective in the estimate of times and costs.

Representing plans through a set of constraints, the analysis of construction activities can be detailed and the activity requirements specified and formally described as “conditions” with their performance being formally described as “effects”.

Thus there is a close conceptual analogy between a quality plan and the working of a planner such as the O-plan that is able to describe construction through planning states that specify the attributes of construction activities. Managers and sub-contractors spend resources in developing plan details, formally through contract specifications, substantially through organizational integration and technical co-operation. O-plan permit to build construction plan interactively checking a large amount of information generally related to a context or particularly referred to the specific project. This feature plays an important role in quality planning because it becomes possible a formal control of a supplier plan which has to satisfy the conditions described in the client plan.

The relation client-supplier could be managed by means set of constraints which are to be satisfied from the supplier through “formal” declaration representing quality specification and performances. In general there follows from this, the possibility of:

- integrating these three planning construction dimensions - quality, safety and environmental - and adequately managing the information contained in each of them;

- adequately integrating the information relative to each single activity;
- planning specific actions that describe behaviour in a domain;
- integrating these actions by means of communication with the objective of information on internal and external constraints.

HOW APPLY AN HTN PLANNER IN CONSTRUCTION PLANNING

O Plan is a Hierarchical Task Network planner (Tate 1997) that consents the ordering and sequencing of activities that group described actions and constraints with a sharper resolution of detail. The assigning of a task is the same as identifying a planning objective that regards a specific construction element or an individual performance.

- The planning problem is specified as one or more non-primitive tasks that the system has to explode in detail.
- The ordering of constraints among these tasks has to be specified by the domain analyst.

The planning system proceeds through the manipulation of attributes that define the state of a system. The state space includes the set of states attributable to the system.

The analysis of a state space facilitates the definition of the conditions that allow the application of an action and the effects that result from it. The initial state of the system is represented as a set of logical statements: the state of the plan being carried out is obtained by an action aged in the plan which represent a construction process.

The states of the plan are modified through the effectuation of activities that represent actions linked to construction:

- A technological system is sub-divided into a set of construction method tasks to acquire each task.
- The tasks have to be organized in the plan hierarchy with a distinct and homogenous level of abstraction.
- The preconditions relative to the technical or organizational interfaces and in any case relative to quality, the environment, and to safety are inserted as obtainable objectives;
- A construction process is posed in the plan if the condition for its execution are verified;
- Types of condition inform the planning system how to satisfy and maintain the conditions besides reducing the research space.
- The effects of actions can be specified as preconditions of the plan to be acquired and as elements that modify the state of construction.
- The hierarchy of task specification allows the introduction of the effects at different levels of abstraction. A task assigned to a sub-contractor is obtained by means of the specification of construction methods with regard to the technical, organizational and environmental characteristics of the project.

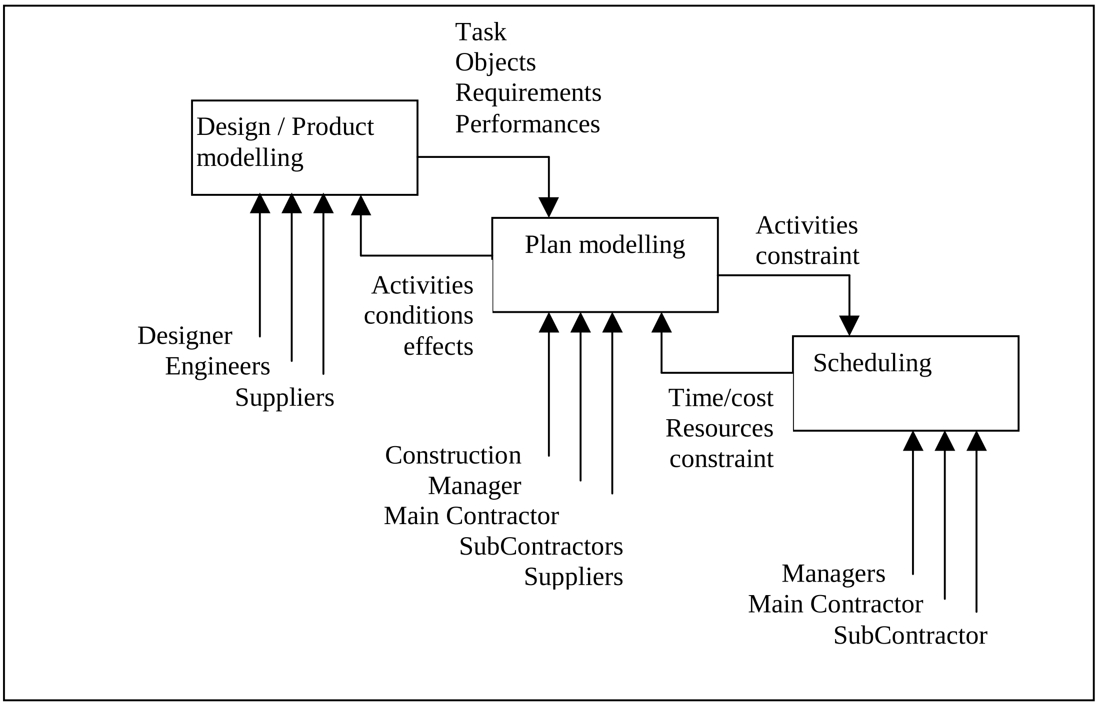

Figure 2

Hierarchical planning is extremely functional for the management of a building construction process:

- allowing description of activities with various detail levels, in an analogous way to the process of refinement of design to detailed design,
- allowing representation then of various plan phases and contemporaneously maintaining coherence and making decisions traceable by means of the imposition of solution research constraints and spaces with a dynamic adaptation to the context,
- allowing the various phases of plan development to be structured in a hierarchy.

The system prototype is based on the implementation of the general purpose planner system O plan on a LISP shell and on the identification of the functions for construction planning. The system is conceived as the transformation of information flows through a series of interfaces:

- between design and planning. Task plans are derived from the design phase in one direction and activities plans in the other. Information exchange comes between product model and plan model. Flow in the two directions proceeds up to the detail level required.
- between planning and scheduling. The consolidation of planning through the analysis of constraints allows the passage to scheduling cycles for resources management and for the achievement of sub-optimal conditions of their use (Figure 2).

Tests on case studies provide proof that the non-linear planning model, based on sequences of partially ordered activities is very eloquent for the production of construction plans that adapt to contextual constraints. The ordering of activities and activities sequences as a function of pre-ordered constraints produce the required plan for a specific application, on the basis of selection of specific construction procedures

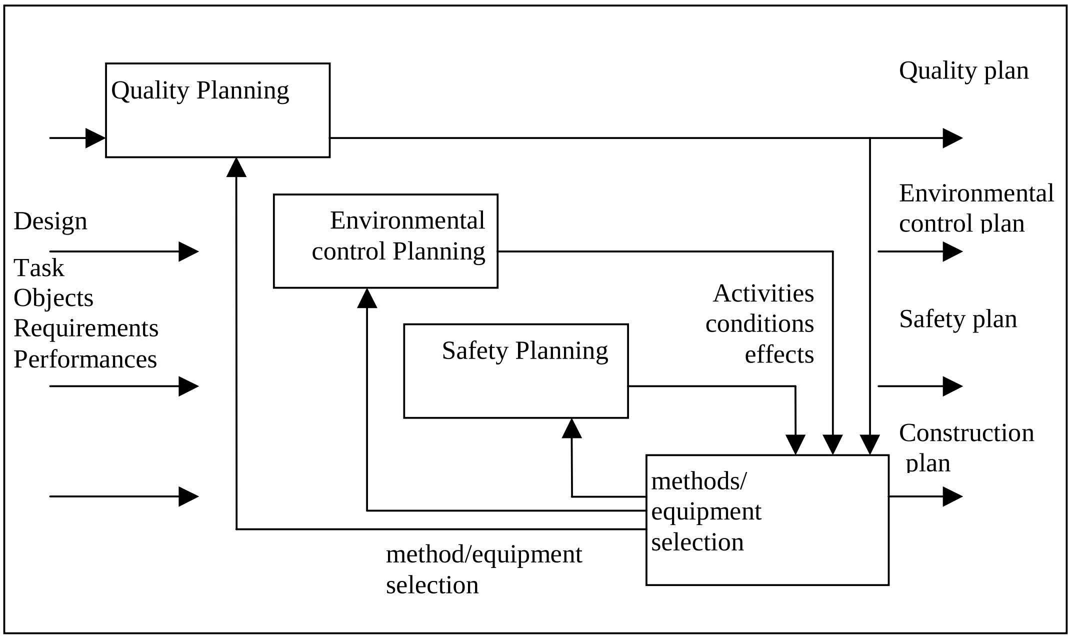

Figure 3

that satisfy the described conditions. The orchestration of a project through communication that has the objective of constraints and technical specifications, therefore constitutes the rational basis for effective quality management.

BASIC FEATURES OF A QUALITY PLANNING SYSTEM

The proposal concern to achieve a planning system able to integrate technical knowledge diffuse between project partners. In case of a concrete wall erection, it is supposed that e.g. the task states some particular conditions regarding dimensional tolerance or surface treatment characteristics. The plan of the wall erection has to obtain the fixed goals by means methods and equipment, prevention measures and control able to assure the effects required. If one of the basic quality management statement is “write what you do”, and “how you do it”, then it is possible to check automatically through a HTN planner the requirements satisfaction through a proposed plan.

Automatic construction serves to explore and refine the plan together with the development of the project. The specification of conditions allows exploration of the hierarchically imposed constraints by an agenda of tasks and to point out the plan failure conditions that do not satisfy the described constraints in the plan states conditioned in a limited way by the constraints assigned by the upper hierarchical level, or temporally antecedent.

It is useful to take advantage the eloquence of a planner to represent variable conditions that orientate the plan towards flexible solutions in executive modalities.

The failure to satisfy conditions laid down in the plan and their recognition is the cause of breakdown in communication between two partners in the project and (Winograd and Flores 1992) and consequently the research of the failure causes.

A complementary task of the planning system is to support to an organizational integration of the project. Homogenous planning spheres such as quality and safety are brought back to the same plan model that evolves with time and allows the integration of different levels of decisions (Figure 3).

The analysis and development of the technical, organizational and environmental conditions in relation to the technical quality, safety and environmental dimensions make the use of planning possible as support to prevent potential conflicts among project participants.

The ability to trace the constraints laid down by anybody either in the preceding phase or concurrently, is moreover a requirement that allows the maintenance of a decisional hierarchy in planning. Orchestration allows project partners to be directed together through collaborative planning interfaces.

CONCLUSION AND FURTHER DEVELOPMENTS

The substantial progress in AI planning techniques permit to assume a general purpose planner emphasizing the research in the domain analysis of construction process and information flows.

The research aims to achieve that an application of a non-linear hierarchical planning system is an effective tool to represent the semantics of quality management and its integration with environmental control management and with safety planning. Some pilot test demonstrate that the transfer of a general purpose planning technique through a hierarchical Task Network non-linear planner can support the quality management objectives.

Furthermore plan models permit to improve the project buildability and its characteristics are applied for:

- automation in construction planning oriented to identify the assigned constraints and therefore to clarify the performances that allow satisfaction of the constraints imposed.
- plan integration through a communications management technique among project partners.

From the outlined proposal of a planning system case studies are carrying out assuming the scenario of the normalization of data exchange, through Express as described in ISO 10303, which allows the definition of the interfaces between product models and plan models. The selected domain for the experimental phase of a system prototype on case studies is the quality management in concrete activities and particularly in form-work planning directed to provide the knowledge base for construction planning to an engineering company specialized in supply form-work systems.

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