A PLANNING APPROACH ORIENTED TO A TECHNICAL AND ORGANISATIONAL RISK ANALYSIS OF FLOW MANAGEMENT

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ABSTRACT

A lean approach to the planning of the construction process is a strategic challenge to analyse and manage organisational and technical factors that characterise decisions. Towards a non-schematic, non-repetitive, shared planning, construction managers need a flexible technique, tailored to the organisational process and able to represent an articulated semantic of the construction process.

The in-progress research aims at the application of a planning technique, that permits flow processes to be represented through plan state sequences . Based on a careful description of activities, it may be possible to manage an interface analysis and to explicitly outline the complex frame of constraints put backward by every activities sequence. The objective is to support the contractors and the construction managers at the planning stage, paying attention to risk factors influencing quality and constructability performances.

A planning system model representing interrelated construction activity requirement and performance data sets of is proposed. The aim is to extend the temporal and resource constraint of traditional planning techniques to sets of detailed constraints, formally described as conditions and effects, logically connected to pursue a quality goal.

Quality planning requires clear decision traceability, planning consistency related to information availability, partial planning integration and flexible replanning while respecting external constraints.

Related work and an experimental schema of integrated techniques oriented to a quality management implementation program are presented.

KEY WORDS

Technical Risk Analysis, Planning, Lean Construction

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INTRODUCTION

The evolution of planning techniques is currently deeply influenced by efforts made in some research areas that offer an articulated approach:

- Information Technology is providing techniques in the development of the product model in order 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 area of uncertainty regarding information integration in construction projects. IT applications in design are a potential source of planning data . Systems oriented to the information engineering method, object-oriented analysis and design, and computer aided software/systems engineering, like ALLPLAN of the Nemetscheck company that uses the Application Protocol 225 of the ISO 10303 (Monceyron, Poyet, 1997), aim at the co-ordination and integration of planning contributions. 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.
- In this conceptual framework, research has been inserted that develops IT approaches to planning or that tries to integrate IT techniques with customised 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 organisation.
- 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, 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 (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.

RISK ANALYSIS IN CONSTRUCTION

Many researchers are trying to apply risk analysis techniques to construction planning (Chapman, Ward 1997). The better results emerge in the cost planning and in the time planning field, in which the causal distribution of random events in project development are analysed to improve predictions.

Although numerous techniques are at present available to practitioners for project risk management (Giard, 1991; Flanagan, 1993) sophisticated simulation techniques or statistical techniques can be with difficulty adapted to technical risk multidimensionality. Risk management has been developed mostly on the basis of cost and time risk, while technical risk analysis has not yet aroused wide interest on non-quality risk. (Courtot, 1996).

Risk management is becoming an important management method in the planning of a reliable, suitable, adequate and subsequently more efficient project system (ECOSIP 1991; Giard 1991), as it plays a key role in the quality management field toward a suitable, adequate and subsequently more efficient quality system for building in conformity to specifications (Mecca 1996).

Quality planning, environmental control and safety planning require holistic approaches in construction process representation and a basic qualitative risk evaluation. The Failure Method and Effects Analysis (FMEA) (Mecca, Masera, 1999; Andery, Carvalho, Helman, 1998; Nichel 1992, Socotec 1992), specified in the construction domain plays an effective role for a qualitative failure process analysis and provides a systematic, indexed order of technical risks.

Quality planning substantially derives from a collaborative risk analysis adapted to the customer's requirements and to the complexity of the activities, graded in relation to failure risks. The main functions of quality plan prevention, control and non-conformity treatment are concentrated on the critical events and every construction partner can play his own role to avoid failure and conflicts towards a substantial performance goal acquisition and towards an improvement in the quality of processes.

A LEAN APPROACH FOR ORGANISATIONAL DESIGN

Frequently the organisational process and structure become factors of uncertainty in construction. Project singularity requires an organisational design that keeps control of the process.

Construction literature presents a frame of models and approaches oriented to organisational innovation: production theories, such as JIT and TQM, and also a number of methodologies such as Re-engineering, Concurrent Engineering (Mcgeorge 1997), sequential flow management shows a methodological core related to organisational questions. These approaches share the objective of process control improvement and the objective of enhancing planning reliability suffering from a lack of theory with paradigms and approaches inadequate to construction peculiarities (Koskela 1999).

In construction the organisation structure are episodic. This fact marks a determinant gap in the face of the fixed hierarchical structure required by scientific management. In construction, social and technical systems should be harmonised in an overall system. In the social technical system approach (STS) we can recognise a common methodological issue aiming at reducing uncertainty and waste in the construction process. The authors intend to contribute to the production management field by investigating a planning approach that permits the workflow in construction to be represented from an organisational point of view and to implement organisational strategies in plans.

Reduction in organisational uncertainty is an objective consistent with the lean construction paradigm; it can be obtained through collaborative planning and by means of a concurrent process emphasising diffuse corporate knowledge .

AIMS FOR CONSTRUCTION PLANNING

The organisational models tested in the process reengineering field often require a close control of social, technical and organisational conditions of the experimental context. That limits transfer to other situations in which external conditions or characteristics are quite different.

Aiming at an empirical approach directed to a partial implementation of models and contingent solution of problems, planning representing the semantics of the organisation process is required. Process modelling has to be adequate and consistent, easy to manage and coherent with the decision process.

The objective of integrating an innovative planning technique with a technical risk analysis FMEA approach is strictly bound up with strategic planning task . Some of these also explain the actual problematic frame of planning, such as:

1. to satisfy the principles of the ability to construct as defined by CIIA (McGeorge, Palmer, 1997) and to build an interface with the design of obtaining a balancing of the various project and environmental constraints to achieve maximisation of project goals and construction performance;
2. to integrate effectively decisions and information regarding the specific domains of quality planning, safety planning and of environmental systems management,
3. to improve manageability and the stability of processes and to allow an effective scheduling of construction activities;

Planning can be a crucial key to perform reliable and settled construction processes. The aims are related to:

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

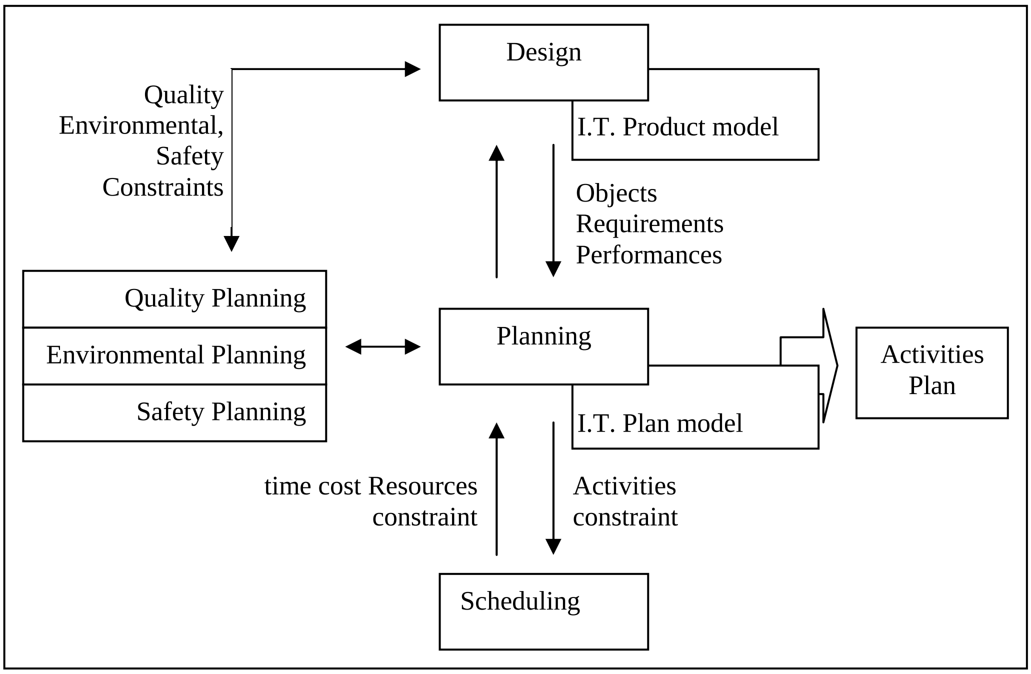
Tate (Tate, 1996) proposes an ontology for planning, IN-O-VA, in which the problem of planning representation is formally defined through sets of constraints in a suitable way for construction planning. The description of construction by means of planning states allows the definition of preconditions, which permit to develop an action and its post-conditions, like the effects produced by the said action. Analogous conceptualisation 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 e EN ISO 14000 and finally, with regard to safety management.

In construction activities, from one project to another, there are variable conditions and constraints related to the technical elements to be realised, which weigh significantly on the determination of cost and on duration. The risk 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.

Figure 1



A PLANNING TECHINQUE SUPPORTING A QFD/FMEA APPROACH

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 achievement of sub-optimal conditions of their use (figure 2).

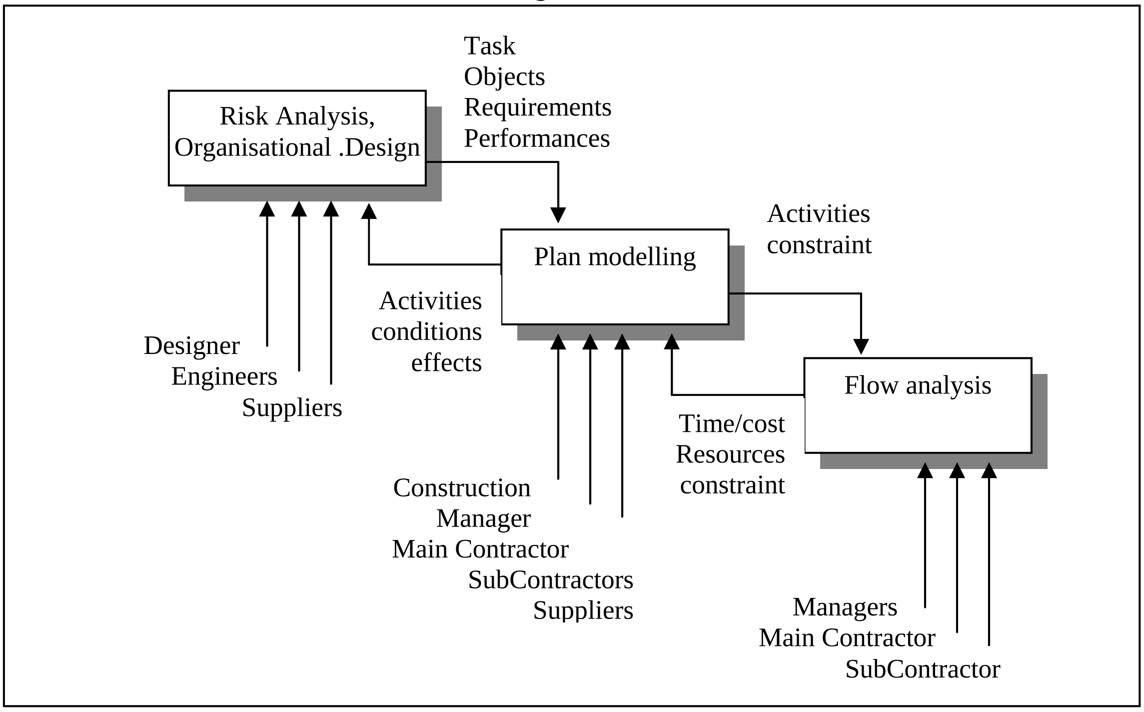
O Plan is a Hierarchical Task Network planner (Tate, 1997) that consents the ordering and sequencing of activities that group described actions and constraints with a sharper resolution of detail. The assigning of a task is the same as identifying a planning objective that regards a specific construction 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 represents 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 organised in the plan hierarchy with a distinct and homogenous level of abstraction.
- The preconditions relative to the technical or organisational 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 on 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 subcontractor is obtained by means of the specification of construction methods with regard to the technical, organisational and environmental characteristics of the project.

Figure 2



Through an HTN planning technique we may represent the technical risk information output by QFD/FMEA tools. In an FMEA for construction we also need to consider, besides the technical conditions of the fault, the environmental and organisational conditions the possible effects of which should be foreseen for effective project management.

The effectiveness of the activity of project management and the relationships among firms, are sources of risk of non-quality that may have a decisive impact on the technical quality of the construction. In a systematic approach, every organisational company level is involved to perform risk analysis. In the same way the environmental risk factors related to the environmental conditions where work is carried out are highly relevant. Such factors as geographic, regulations-standards and social-economic onesneed to be examined.

The integration of risk analysis with planning aims to perform adequate plan in construction management means function like:

- **Activities criticality identification and specification** performed by risk analysis means emphasise more or less the conditions and effects description of every task and activity. The critical activities are carefully detailed and their requirements, and performances, the external and environmental factors are deeply analysed;
- **Prevention and control Plan graduation** that is a measure of process control effectiveness in quality management, comes about through the identification of the hierarchical level of plan development. The HTN plan is flexibly adapted to the need to identify the right detailing level in relation to a global level of project criticality**;**
- **Information enrichment** in project partnership:
  - Permit explanation of why prevention and control measures are decided and why a plan is more or less formal;
  - Permit specification of a risk treatment query and its communication to partners with technical competence or specific role;
  - Permit process management solution negotiation adequate to a concurrent evaluation of the risk level.

RESULTS

An HTN planner in conjunction with QFD/FMEA tools are a proposal for an innovative approach to construction planning Homogenous planning domains 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. A methods database constitutes the information background on which plan detailing in the specific context arises.

The analysis and development of the technical, organisational and environmental conditions in relation to the technical quality, safety and environmental dimensions make the use of planning possible as support to the organisational integration of the project with the purpose of preventing potential conflicts among project participants. Orchestration allows project partners to be directed together through collaborative planning of the interfaces.

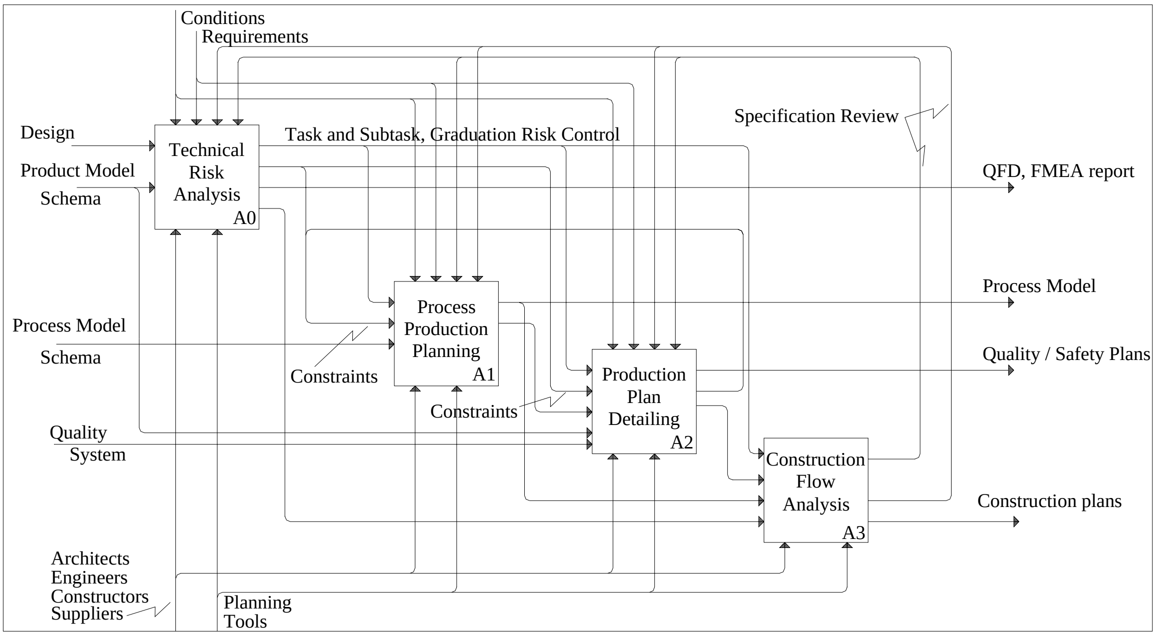
A hierarchical non-linear planning system based on partial ordered activities sequences is expressive to produce construction plans that satisfy contextual constraints:

- 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 activity ordering and sequencing related to external constraints produces the required plan for a specific application based on the selection of methods satisfying implemented conditions. Specifying the partners' engagement in progress, a basic requirement of quality management is obtained in order to explicate a construction process and in order to control it, adapting the management to a contingency context .

The collaborative negotiation process, the object of which is the constraints and technical requirements specification, support quality management as a rationale

Figure 3



The reliability of the building process and the goal 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.

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. There follows from this, the possibility of:

- integrating these three planning construction dimensions 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.

CONCLUSION

A critical condition for on site management is access to complete project information. A partial vision of the project and a short time to arrange contingency plans pushes the construction manager into errors. Risk analysis also supports contingency planning and refinement of the plan and weighs on information quality. A correct perspective on an activity risk helps to satisfy the results expected by the client and to manage the reduction of potential conflicts.

The transfer of a general purpose planning technique through a hierarchical Task Network non-linear planner can be inserted into the conceptual framework of the quality management objectives for risk analysis and quality management both oriented to project constructability. The normalisation of data exchange, through Express as described in ISO 10303, allows definition of the interfaces and circumscribes the specific domain of the planning.. The application of computer aids in the passage from off-site to on-site activities requires a careful planning of functions from the point of view of interface ergonomics for real progress in information management.

The application of a non-linear hierarchical planning system is an effective tool for the representation of the semantics of risk analysis and quality management and its integration with environmental control management and with safety planning.

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