AN IT ORIENTED APPROACH SUPPORTING THE INTEGRATION OF TECHNICAL RISK, QUALITY, ENVIRONMENT AND SAFETY MANAGEMENT IN CONSTRUCTION

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ABSTRACT: I.T. plays a key role in connecting risk management with an integrated three dimensional management system integrating quality, environment and safety management. Planning Techniques in construction aim to support decision integration in the on/off site interfaces of construction processes. Starting just from the design phase, quality management strategies integrated with performance theory allow the formulation of a full list of requirements for project activities which can be effectively stored in product models of construction elements. Technical risk analysis aims at operating a detailed performance analysis in on/off site processes. Risk analysis supports quality management in construction planning to determine a graduation of performance levels required for the management system, which means identifying specific project criticality in the time, cost and quality fields and combining the most appropriate prevention measures.
The objective for the developing research has been focused on a planning technique integrating the information flow from the design phase to the construction process, oriented to allow the main contractor and the subcontractors to utilise quality plan schemes and risk analysis deriving from the design phases as input in the detailing of risk analysis and the refinement of quality plans.
By a wide-ranging collaborative analysis, using an AI planning methodology applied in the construction domain, it might be possible to identify all actions aiming at reducing and preventing failure risk, intended as the specific non-conformance risk of element and activity characteristics, and develop the right organising strategies to increase the contractor's reactivity toward failure and defects. The Failure Mode and Effect Analysis (FMEA) methodology and quality management applied to construction planning are developed by means of an intensive data exchange involving the project operators – e.g. designer, owner, contractor and subcontractor – in identifying the failure risk and in planning the prevention and control measures.

KEYWORDS: Information Technology, Construction Planning, FMEA, Quality Management

1. INTRODUCTION

In current practice there is a well-defined requirement on the part of each project partner to supply and receive appropriate information. The perception is widespread that traditional communication tools are inadequate to sustain the quantity of exchanged information in a short time during construction management (Low B. K. Sloan B, 1999). Current technical and organisational conditions do not permit concise information exchange processes that do not gather the innumerable characteristics and details of the project. The passage from the conception of a building to its construction is especially critical in this respect. Uniting the project to construction system characteristics requires a process of information specification and integration that involves work planning. In the management of the technical description of project quality – specifications, dossiers and specific techniques, price lists etc. – this

process performs a strategic role and is a key success factor in the buildability and reliability of the project. It regulates the contractual aspects and involves information transformation throughout the work, regulates the passage of skills, supports construction organisation, and so on. The writing up of the internal regulation of the project is expensive, in man hours, and risky in terms of the consequences that might thereby affect construction quality, time and costs. It is a complex operation because it becomes successively more exhaustive as project decisions develop, and it requires specialised skills and co-operative work, and finally because, in current praxis the planner often has little time available and inadequate sources of information.

2. BACKGROUND

Information Technology is one of the most dynamic innovation agents in the construction industry of the last few years. Many studies, begun at the end of the 1980's and receiving ever more financial support, were carried out in northern Europe and North America to provide basic methodological and conceptual tools to improve project management, communication among the process operators. I.T. does not describe a single technology but includes a wide range of methodological and technological approaches aimed at an equally wide range of problems. In agreement with Froese (1999) and Mohamed and Tucker (1996) some applications can be distinguished that closely affect the reorganisation of productive processes in the construction industry:

- The **2D CAD e 3D CAD** for which there is under way an extension of the semantic representation of construction by means of the introduction of **Building Product Models** capable of integrating geometrical information in non-standard form through **Data Model Standards** that make reference to the Industry Foundation Classes (IFC's) or to the ISO 10303 STEP norm. The expected objective, interactive CAD, planning shared on-line, parametric CAD, sees the commitment, on the front of technological development, of the main companies in the sector and the many European research centres that have been sustained within the framework of the IV programme - CIMSTEEL, COMBI, PISA etc.;
- **Production Engineering** includes some tendencies – Process Re-Engineering, TQM and Lean Construction – to the use of **data modelling and process modelling** for the integration of project management applications that support planning, programming, estimating, calculating, etc. The tools aiming to graft themselves onto traditional programming tools to allow semantic planning representation and extensive treatment of connected information techniques are defined as **Process Design Tools**. They include:
  - Knowledge Based System;
  - Support systems to construction cost analysis;
  - Support systems to the project organisation decision;
  - The bases of relational data as environments (shells)for contractual activities;
  - The use of virtual reality for construction activity planning;
- **On-line technologies** widening innovation allowing the experimentation of data sharing models and information treatment processes that decidedly surpass even the vanguard of electronic techniques of data production, distribution and updating. In this field distributed systems**,** and **generic data exchange** are used. The connection with product data modelling is one of the more workable short-term prospects for both the setting up of data exchange technologies and for information integration among different software.

3. RESEARCH ISSUES

Among IT techniques, some have begun to be sufficiently robust for widespread use. This is the case, with regard to design, of ALLPLAN of the Nemetscheck Company that uses the Application Protocol 225 of the ISO 10303 (Monceyron, Poyet, 1997). In addition, the

connection between product and process modelling has started to reveal some application areas other than in that of research experimentation. The need to introduce I.T. approaches in construction management has matured through the development of some research themes on building production that have raised many questions from the point of view of information treatment that we retain able to enrich a study oriented towards a Total Project System (Froese, 1999). The problem to be faced regards the representation of production management knowledge, in three homogeneous areas from the point of view of I.T. techniques application:

- technical risk analysis;
- construction planning;
- (total) quality management.

4. TECHNICAL RISK ANALYSIS

Decision support through an FMEA approach to risk technique analysis, is a valid example of how a decision-making tool can be useful with respect to information management. The tool requires ever updated information on the state of the project in the site preparation phase, is able to substantially modify the plans and, determining factor, is able to orientate the development of the information system representing a project. Failure Mode and Effects Analysis is an analytical technique capable of supporting decision making and quality planning in various planning and management phases of the project. FMEA has the aim of predicting the non-conformity of the construction and supplying information for the effective quality management of the project. Its application to the building industry is greatly dependent on the kind of information to be handled.

The typical analysis phases of the FMEA are:

- identifying the error modes, defects, non-conformities and investigating their cause and effect;
- identifying a risk index on the basis of probability, severity and visibility of the error;
- providing adequate measures for treating risk;
- applications in different project phases are specified with respect to the characteristics of the decision-making process: in quality planning aimed at prevention and control.

The tools that are applied in the various passages are presented in the table in figure 1.

Analysis procedure	Tools		
Re-examination of project	Working analysis	Wbs, Obs, Pbs	Flow Chart
Construction pathology diagnosis	Analysis of the interfaces	Cause and effect diagram	Tree of breakdowns
Risk analysis	Risk factor analysis	Risk conditions analysis	Risk assessment
Treatment of risks	Decision support	Prevention measures	Control measures

Figure 1. Technical non-quality risk analysis tools

FMEA is effective if it succeeds in treatment available information and producing reliable evaluations. In the field of building construction the challenge of correct information management is crucial because:

- the risk dependence of many factors makes measurement of both quantitative and qualitative evaluation difficult;
- the factors vary notably from project to project and their weight in the determination of causes is uncertain. Consider, for example, the usefulness of having reliable and structured information available on possible technical pathologies and defects to be prevented during

the analysis of the specific techniques of a technological system. Once the basic elements of the project are known, the study of potential defects can be conducted at a later time;

- by means of data bases a diagnostic framework of recurrent faults and possible non-conformities can be constructed. The diagnosis of pathological processes enables description of the effects of deviation from the required conditions and the performance losses that could result from it. Technical norms supply a frame of reference for suitable performance levels;

a comparison of the diagnostic framework with the project allows identification of conceptual or specification shortcomings.

The availability of adequately structured information for data comparison, with timing and costs retained to be in keeping with respect to the aims, is the problem that often leads to a preference for summary evaluation, riskier but at a more acceptable cost.

5. PLANNING AND QUALITY MANAGEMENT

Many contributions (Stumpf *et al*, 1996) (Jägbeck, 1994), have underlined the aim of integrating product with process information to allow procedure to construction planning. In the tender and the site preparation phases it is necessary to bridge the gap between process and product representation with consistent data and information management tools that are adaptable effectively to decision-making processes.

The question of introducing a rich representation of the process into planning and scheduling systems has been greatly studied (Kähkönen, 1994). The introduction of product models into the management process is present in the PreFacto System (Jägbeck, 1998), that provides a valid example of model elaboration together with decision management.

The starting point for an analysis of the problem is made up of an understanding of the planning problem in the indicated phases according to the planning acceptance that one intends to exploit.

- Planning seeks to bind together information coming from many sources. Information connected to the composition of costs and information of a financial nature, parameters and constraints that come from management processes, or to technical characteristics of products, the prerogative of the suppliers.
- Moreover, planning necessitates specialist approaches oriented to assuring definite classes of process performances, such as for quality planning, safety or environmental control.
- There is the need to re-conduct planning into a unitary integration domain aimed at representing the process as a necessary condition for decision taking and governing construction.
- Planning is made up of autonomous decisional aspects that tend to take on the shape of tools, computers and others, that draw information from the project/process representation and supply support to the decision.
- Process modelling assumes product models elaborated in the design stage as one of the inputs, but not the only one among those necessary for project organisation. Frequently, and in some organisational approaches in an explicit way, the product model is not definitely determined in the conceptual phase of the building, but requires that this be the result of selection among suppliers or firms in concomitance with the presentation of an economic offer. It is therefore necessary to consider the fact that process and product modelling are not , except in certain cases, sequentially operative, whereas they are often, if not all in part, interdependent.

Quality management makes many complex demands on information treatment; among the most widespread qualification objectives is the improvement of information exchange(Torricelli and Mecca, 1996).

The excessive production of documents and bureaucratisation of the procedure is cited as a common inefficiency factor for the first quality management experiences.
Sharpening of a quality plan's detail by means of closer examination of hierarchical analysis levels is a consequence of technical risk assessment that is connected to contingent factors, precisely of the project under examination.

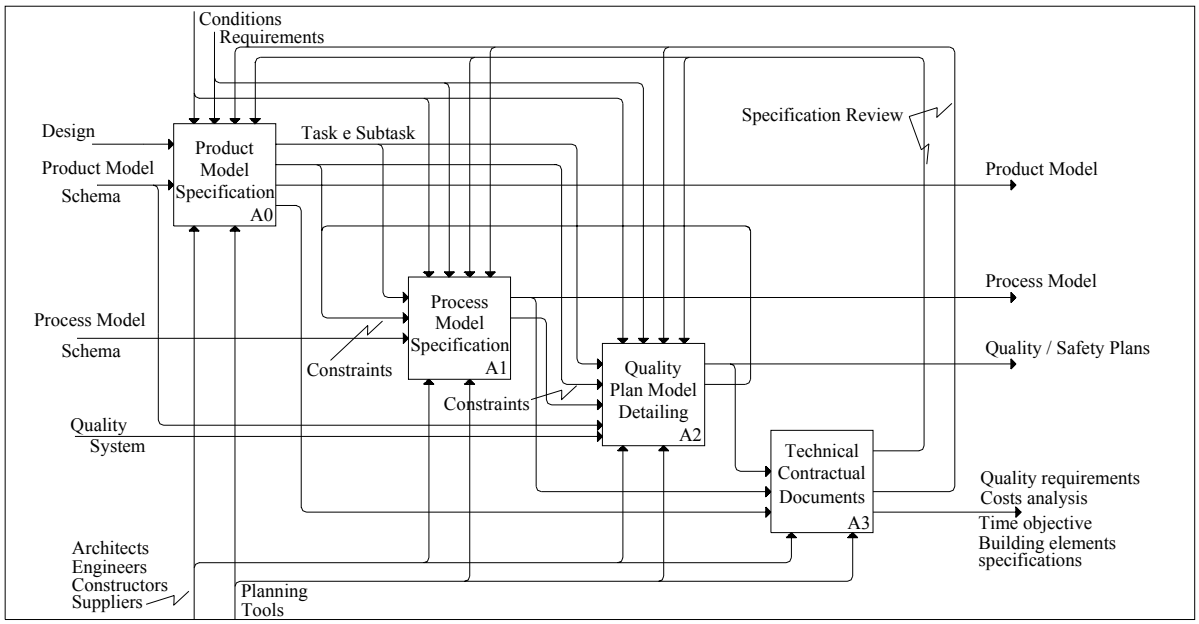

Figure 2. Generic process of information integration in the planning phase

In the same way the technical documentation is susceptible to a greater or lesser in-depth study in relation, for example, to risk assessment about the reliability of a supplier or an executive detail.

6. AIMS OF THE RESEARCH

I.T. tools potentially allow the interconnection of different semantic domains of the construction process. The arguments raised in the area of tool development for project management and directed at the development of an I.T. approach pose two questions:

- What problems can a data interchange system solve from the point of view of the use of project management tools?
- What is the innovative potential and what is the impact that we can produce on these tools with respect to the availability of greater and qualitatively superior data?

The first question is the equivalent of making an analysis of the needs and functions of the system to identify the problems that can be solved through a technique of that kind. Therefore it aims to obtain a useful modelling process for rationalising data production, treatment and exchange.
The second question stresses the possibility of improving the assessment and decision-making techniques on the basis of an information structure at present unavailable.
The aim of the research can be defined as follows:

- develop a data interchange approach to integrate planning in some of its basic sections with a technical risk analysis;
- develop a proposal of a conceptual I.T. system structure that supports planning during the elaboration of the project specifications and during site preparation.

With respect to the framework of emerging technologies the focus of the work is circumscribed to the problem of integrating product and process models to support the elaboration of technical information for planning. The I.T. system specifically requires the capacity to integrate specialist planning aspects with the technical description of the project.
This operation is conducted by users with differing profiles in planning/designing phases and levels. Moreover, it is located in a thread of information elaboration sensitive to the uncertainties, particulars and sources of the project.
The objective of the research is aimed at the construction of a support system for the elaboration and the management of technical information used in the executive planning phase and design of the construction.
It is divided into two levels:

- Analysis of the information transformation process and modelling of some of the significant knowledge bases in relation to technological systems or elements used in construction projects;
- Planning and experimentation of data exchange technology.

7. DESCRIPTION OF THE SYSTEM

The system is aimed at the exchange of technical information relative to the products and building technologies market and at the European system of regulations for construction products and processes.

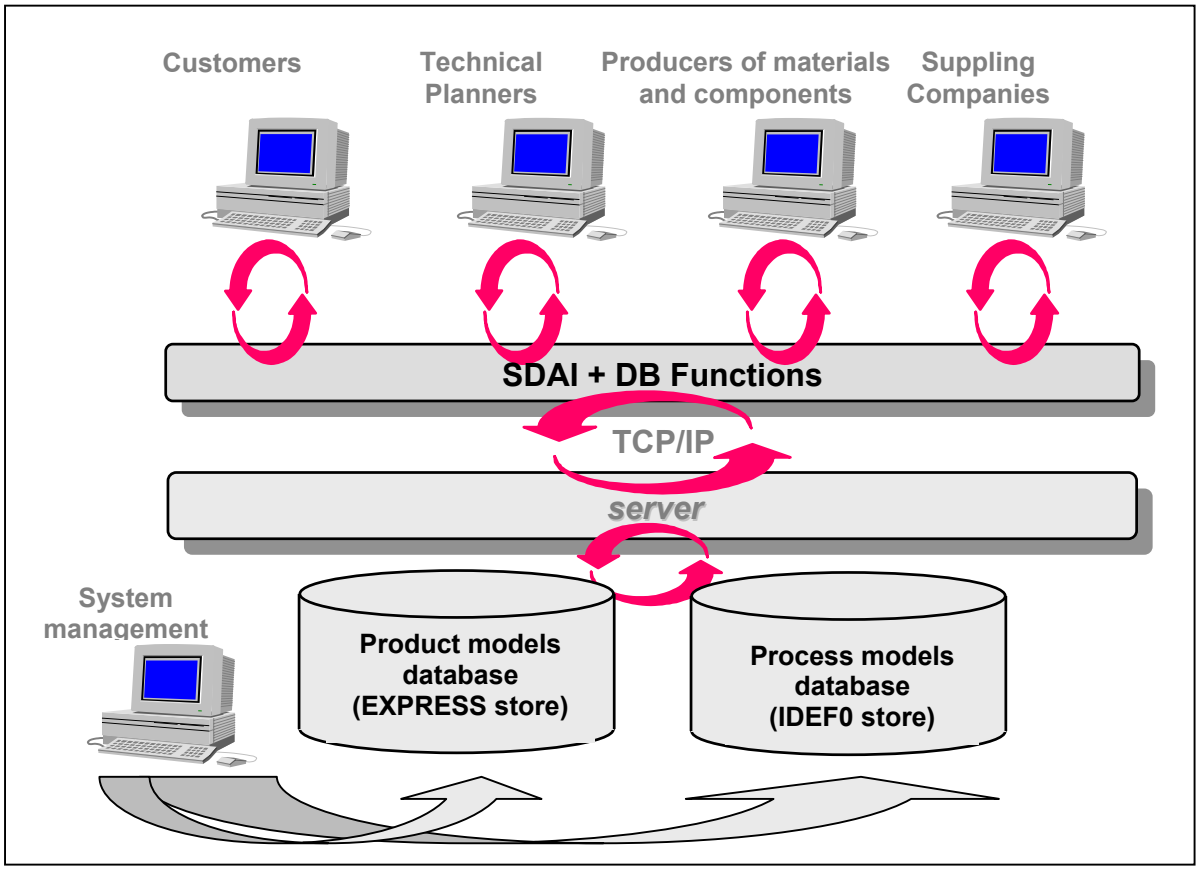

Figure 3. Technical Data exchange during technical risk analysis for quality planning

The target is to identify and develop an evolved technology founded on some results emerging from basic I.T. research applied to A/E/C processes. The reference elements are:

- **product/process modelling**, applied to technical information management;
- **a methodology** for the definition e analysis of knowledge bases;

- **the sharing and exchange** of data among operatives on-line;
- **data exchange**, for the integration of computerised applications used in the work management phases concerned;

The functions of the system are directed at allowing the inter-linking of different user profiles and of different applications for planning and technical risk analysis:

- **at planners,** who use the construction planning environment to elaborate tender, technical regulation, technical specification documents, and so on;
- **at builders,** who acquire the project, in both the offer preparation phase and in the construction planning phase and that require aggregated data, in the former case, and research information or implement specification processes, in the latter case, in relation to supply planning, sub-contracting, and so on;
- **at suppliers and producers** who interface at various project levels with planners and producers and introduce detailed basic technical information into the system;
- **at third parties;** in charge of the management system, data elaboration of general interest (technical specifications, prices etc.), organisational assistance and validation of on-line information, voluntary qualification of the processes, innovative development of computerised applications and so on.

5. CONCLUSIONS

The research aims at setting up several key processes in the construction preparation and production phases of project management. The treatment of written technical information in the form of product and process models is a result of I.T. research that can be implemented in on-line information management systems. The scenario of a global information flow integration in the project is the reference point for partial approaches. The construction planning phases requires data integration, specifications and instructions, coming from different knowledge domains. Product modelling as a support tool to technical information elaboration allows the organisation of disseminated on-line available information for the description of project specifications. An interface with a technical risk analysis module enables modelling development to be scaled to keep the project effectively under control. During construction planning information is introduced regarding the organisation of construction activities and therefore of quality and safety management. Product and process modelling integration allows process management study to be focused on the various aspects that make it up. In addition, it allows the formatting of reports in documents that meet the need to separate documents in such a way as to respect the contractual or legal requirements, or equally, the technical specifications, or the norms in force or the safety plans and so on. Data exchange support allows producers of materials and components to represent information that accompanies the products effectively. The tools used throughout planning are directed at improving the production and management of the project's technical information and at contributing to the reduction of conflicts, non-conformity costs, errors and so forth in the construction phase and that originate from the project's specification phase. Moreover, the tools aim to improve the information support services of suppliers and producers in supplying building products and technologies.

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