A computer-based feedback model for design/build organizations

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ABSTRACT: Building production process is a multi-disciplinary and multi-phased activity. Various factors increased the complexity of building production process and consequently the number of participants taking place in the process. Co-ordination and integration of the production process became more important in the fragmented structure of construction industry. Obviously the lack of communication between designers and construction team causes quality problems. Insufficient communication between design and construction phases causes design failures regenerated in various projects. Design failures can be determined in both construction and occupation stages. Feedback of systematically recorded information of design failures, which were identified in construction stage would help to create and maintain the firm's memory and can be used as a medium to increase the quality of the design process as well as the design itself. In this paper, the conceptual and practical parts of a computer-based model developed for design/build organizations that aims to organize design failure information identified in construction stage are presented.

1 INTRODUCTION

1.1 *Background of the problem*

The fragmented structure of building production process resulting from multi-phased and multi-disciplinary nature of construction industry has brought out co-ordination and integration problems. Especially projects, which are delivered by fast-track approach, faced with integration problems because of information loss and quality problems.

Tan & Lu (1995) pointed out the most critical stage as planning and design stage throughout the building production process. Although the cost of this stage accounts relatively low (about 3-10 percent of the project cost), various specifications, layouts, schematics and procedures generated in this stage form the basis of the actual construction. The cost, scheduling, and performance problems can invariably be traced back to the problem of the quality of design, such as error, incompleteness, and lack of constructability.

Bubshait *et al.* (1999) reported a study by the Building Research Establishment (BRE) in which the causes of failure were analyzed to indicate whether they were due to faulty design, poor execution, the use of poor materials or unexpected user requirements. The percentages of failure, with some overlap between these categories, were found to be 58%, 35%, 12%, and 1% respectively. Faulty design was taken to include all cases where the failure could be attributed to not following the established design criteria.

Burati *et al.* (1992) identified causes of quality deviations in design and construction by analyzing nine fast-track industrial construction projects. The data were collected after the construction phase of the projects and identified the direct costs associated with rework (including redesign), repair, and replacement. It was concluded that deviations on the projects accounted for an average of 12.4% of the total project costs. Design deviations average 78% of the total number of deviations, 79% of the total deviation costs and 9.5% of the project cost. In this study, deviation data collected was classified as design, construction, fabrication, transportation and operability. Each of these areas was further subdivided by type of deviation. Design deviations categorized as design change/improvement, design change/construction, design change/field, design change/owner, design change/process, design change /fabrication, design change/unknown, design error, and design omission.

From design office's point of view, a design office is considered to undertake more than one complex project simultaneously and they have to work with different organizations to carry out these projects, which are in their various phases. In this circumstance, the intensity and complexity of the information flow is obviously high and the support of a computer-based information system is vital.

It is possible to increase the quality in building production process by the existing means such as choosing of appropriate organizational patterns and using of information technology, but these tools are not being used properly.

1.2 Related works

The idea of integrating building production process and improving design quality is not new. Various reference models for solving integration and coordination problems can be found in literature and also various computer models were generated. Conceptual models by Baldwin *et al*. (1999), Tan & Lu (1995), Matta *et al.* (1998), Chan & Chan (1999) were proposed to serve as interfaces of information management, design management and quality management.

Some of the application models which were developed by Kanoglu (2001), to serve integration of design and construction management; by Mokhtar *et al.* (1998), Hegazy *et al.* (2001) and Zaneldin *et al.* (2001), to serve design change management; by Miyatake & Kangari (1993) to serve computer integrated construction can be found in the literature.

These models are generated to provide integration of design and construction, to organize information flow between design and construction stages, to manage design changes, and to improve the quality of design. However, it has not been possible to locate an information system model to record and feedback design failures that can be identified in construction stage to improve the quality of design and design process.

1.3 Problem statement

The variety of building types, innovation of technical subsystems (security systems, intelligent buildings, etc.), improvement of technology and development of numerous materials causes complexity in building production process. Besides these developments, the number of organizations taking place in this process increase and the relationships among these organizations expose a fragmented structure.

Time becomes more critical in building production process and many efforts are seen to enhance projects complete rapidly. Fast-track approach to shorten the project delivery process causes an increase in change orders. Lack of communication between the parties arises integration problems among the designs of subsystems in buildings. These problems result as design failures.

Because of insufficient information flow among design and construction organizations, information of design failures do not turn back to design organization. That is why similar design failures continue to repeat, and deviations of cost, time and quality continue to occur.

In this context, one of the most important factors for design quality is identification of design failures that comes out in construction and occupation stages to avoid of repeating these failures by the help of a feedback mechanism. However feedback from construction organization to design organization cannot be achieved in most cases due to the fragmented structure stated above. The dimensions and the tools of solution can be classified as:

- Defragmentation at *physical* dimension by new organizational approaches such as design/build organizations, strategic approaches such as joint-ventures, partnering, etc.
- Defragmentation at *conceptual* dimension by new philosophies, such as total quality management, just-in-time, supply-chain management, lean production, etc.
- Defragmentation at *virtual* dimension by information systems, using the tools such as integration, unification, standardization, interoperability, customizability, etc.

1.4 Aim of the study

In this study the content of design failure is taken as any design change that causes rework and results in additional cost and time consumption in a project. These failures may be identified in both construction and occupation stages (Fig. 1).

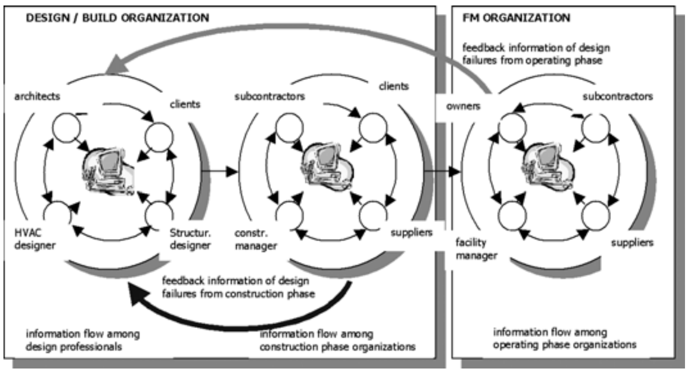

Figure 1 Information flow among the phases of building production process

Ransom (1987) pointed out maintenance organizations as the repository of failures and their cause, and such knowledge that is fed back to design office would be of great benefit. However, impacting factors for identification of design failures in occupation stage have different characteristics relating to marketing, customer requirements and customer satisfaction, etc., and these may appear in long terms. Since feedback of information from occupation stage may differ related to these factors occupation stage was handled in a separate study.

In this study a conceptual model is proposed aiming to realize information feedback from construction to design organization. The conceptual model is then converted to a practical model using relational database architecture. In the model, design failures identified in construction stage are recorded systematically. This information is accessible by design office since an integrated information system is proposed to use by both parties. Thus, design failures are categorized and kept to establish firm's memory to prevent repetition of similar design failures.

The reliability and functionality of the proposed model depends on mutual confidence. Both design and construction organizations should be able to track other parties' records mutually and this may be possible with an appropriate project procurement system. Design/build system seems to be the most appropriate model for this purpose, so the model is proposed for this sort of organizations.

2 A COMPUTER-BASED FEEDBACK MODEL FOR DESIGN/BUILD ORGANIZATIONS

2.1 Background of the study

After investigating the current practice in detail by analyzing the information systems of some leading design offices and construction firms in Turkey it is determined that information systems even in large-scale firms do not incorporate any feedback mechanism that organizes the historical data transmitted between the architectural office and construction firm. Since the problem in current practice is the lack of a systematical approach and support of an integrated information system, the proposed model should include these tools.

2.2 The model and its components

The model was developed to function as part of an integrated information system of design/build organizations designed and developed in a research project conducted by Kanoglu (1999 and 2001).

As stated above, a certain part of the design failures can be determined during the construction phase although some other part can only be determined at operating phase. The corrective actions for the first part take place within the process of change management. Change order procedures should record all kind of modifications related to the scope of the projects. Changes may occur due to various reasons such as client's demand, external factors, etc., as well as design failures. The model allows the construction team to indicate the reason of the change order (Fig. 2).

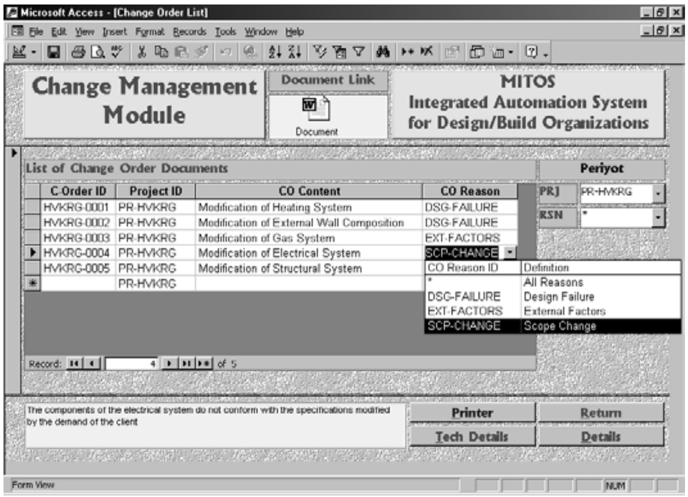

Figure 2 Change order information

In a design/build organization, the construction team can use the model to record and report the changes of current project whereas the design group utilizes these outputs composed by using the data of past projects in the same category for avoiding the same sort of mistakes in the projects that will be undertaken in the future.

In a change order process more than one item related to each other can be recorded. The detail information should include the responsible participant who caused the failure, the building subsystem and the production items that are affected by the change as well as the quantity, cost and duration effects of the change (Fig. 3).

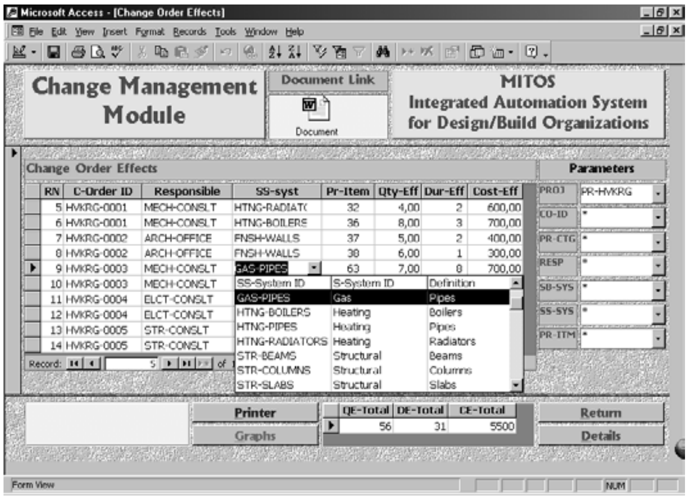

Figure 3 Change order detail information

The model allows to filter the data of the past projects by project, change order ID, building type (category), responsibility, subsystem (heating, lighting, structure, etc.), sub-subsystem (radiators, electrical appliances, fittings, etc.), and production items (takeoff items). Analyzes regarding to cost and duration effects can be made by using various combinations of these parameters (Fig. 4).

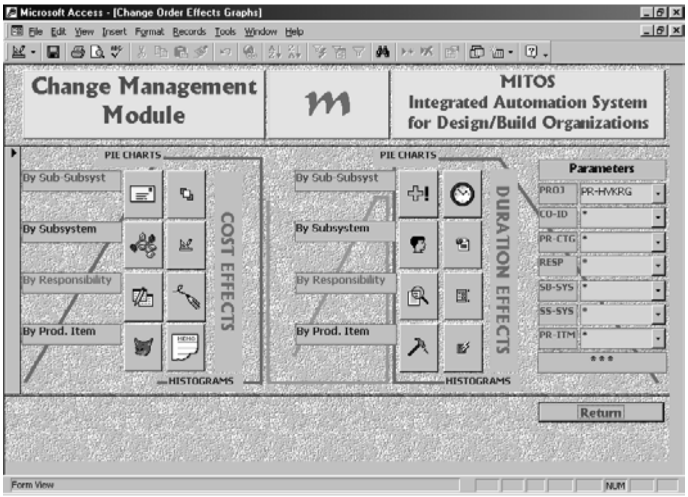

Figure 4 Analysis by cost and duration effects

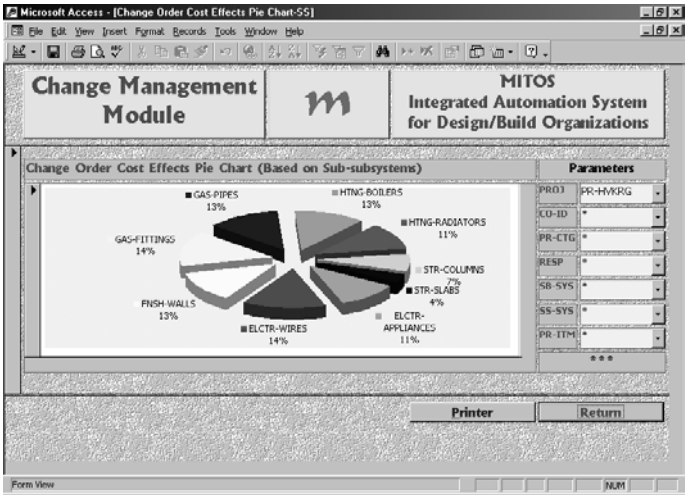

Figure 5 Analysis of cost effects by sub-subsystem (%)

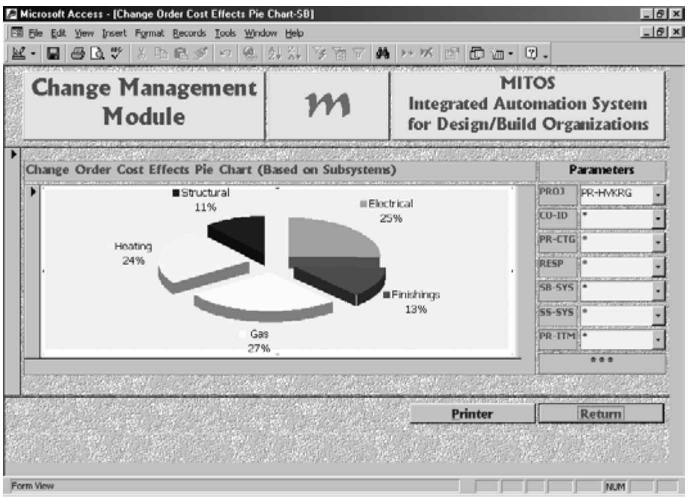

Figure 6 Analysis of cost effect by subsystem (%)

The outputs of the analyzes can be helpful for the participants of the design team in the design process of a certain type of building by indicating the ratios and weights of different types of mistakes related to subsystems (Figs. 5-12).

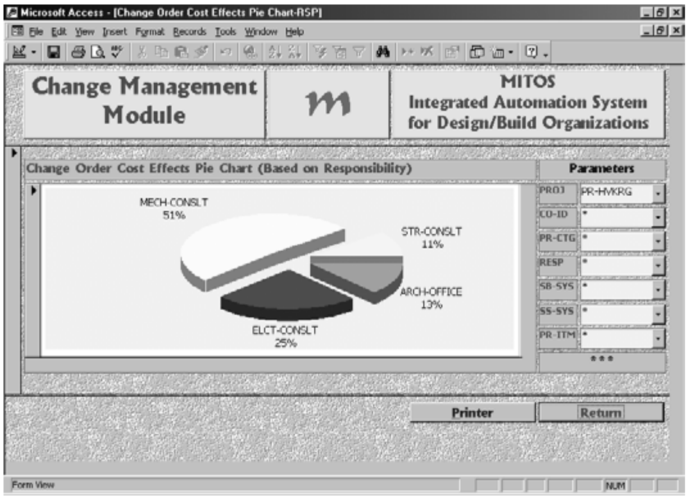

Figure 7 Analysis of cost effects by responsibility (%)

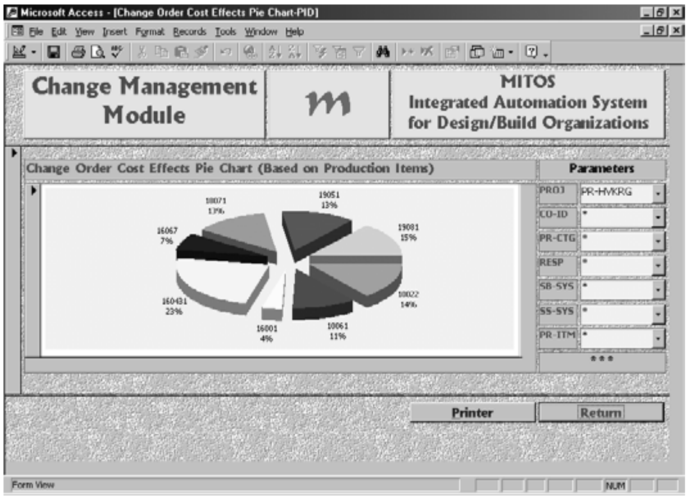

Figure 8 Analysis of cost effects by production items (%)

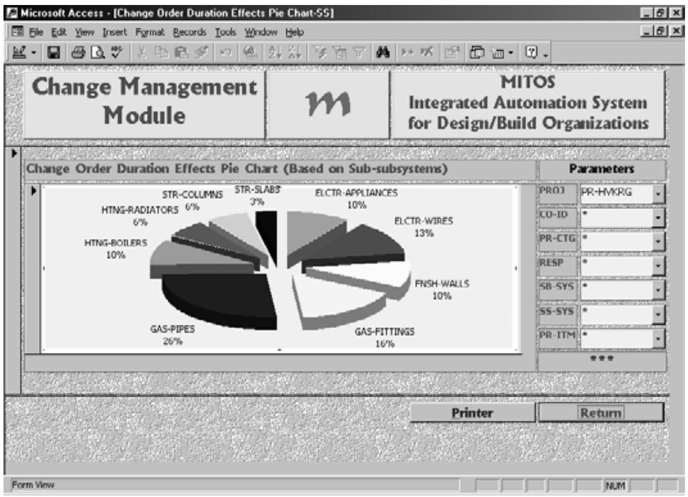

Figure 9 Analysis of duration effects by sub-subsystems (%)

The graphical outputs are provided by the model to display the weights (%) in pie charts and quantities in histograms. The effects of the parameters (i.e., reason, responsibility, related subsystem, etc.) can be obtained in both tabular and graphical formats.

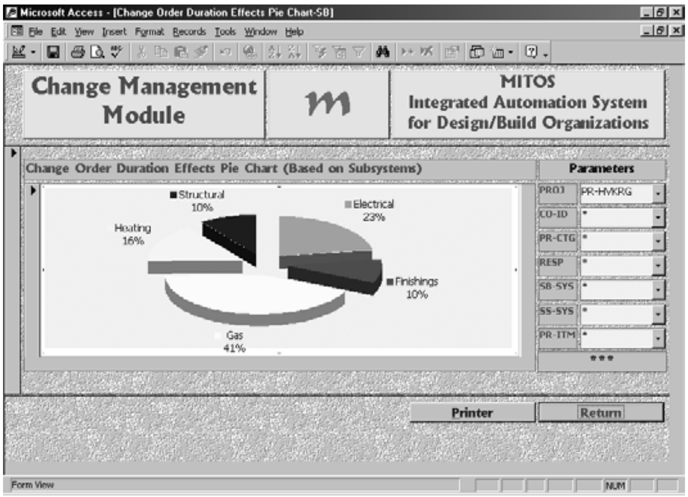

Figure 10 Analysis of duration effects by subsystems (%)

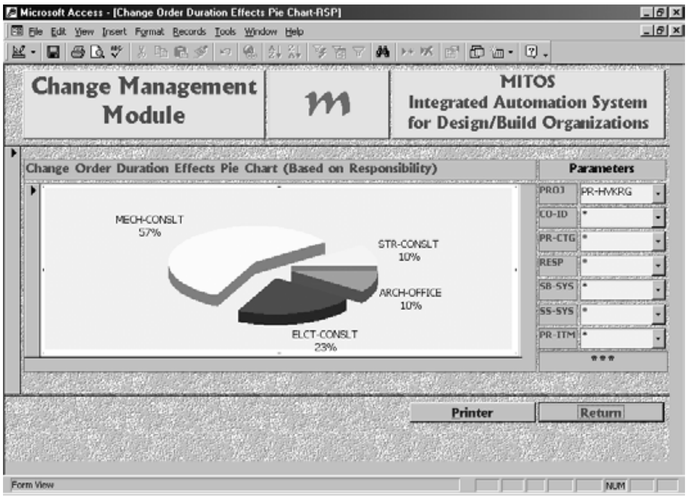

Figure 11 Analysis of duration effects by responsibility (%)

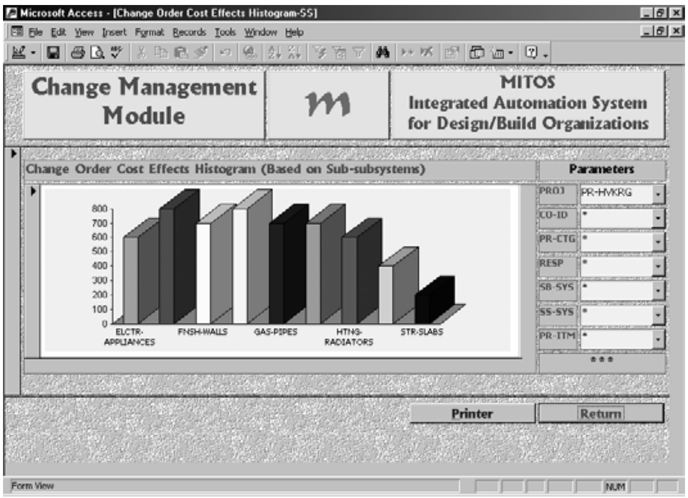

Figure 12 Analysis of cost effects by sub-subsystems ($)

These outputs can only be obtained from an integrated information system of both design offices and construction firms combined as a single entity that is referred to as design/build.

3 CONCLUSION

Design/build contracts combine design and construction under a single entity. Design/build is sometimes conducted by a company that has design and construction capabilities under the same roof or by a joint venture between a design firm and a construction company. This approach has gained the attention of the industry in the last decade and is expected to become the dominant project delivery system in the near future. This growth is justified by the reported benefits of the system, including faster delivery and lower cost. It is now time to have a management information system in place in design/build organizations that could facilitate the management of this delivery system. Such a system would facilitate the interactions of the members of the design/build team, but it would be particularly useful if the team members belong to different organizational cultures.

This paper describes efforts that are aimed at developing an integrated computerized automation environment that is expected to increase the efficiency and productivity of design/build project delivery organizations as well as design firms and construction companies that make it a point to effectively cooperate within the framework of a partnering arrangement or in traditional design-bid-build projects.

Although it has the stated advantages the design/build procurement route does not always achieve its claimed advantages. One aspect of this is the emphasis in the paper placed on integration, a claimed advantage of design/build. The suggestion of an automated system for design/build integration is worthy of examination. Such a support provided by an integrated information system will provide various advantages.

The paper addresses a problem that can be solved by an integrated information system developed for design/build organizations. The next step of the study will be the implementation of the model in selected design/build organizations in Turkey. This part of the research project is planned to last at least for two years.

Further analysis including the comparative evaluation of the design failures with their associated reasons and responsible parties are thought to be facilitating in the solution of various problems such as liquidated damages from claim management point of view in project level and to increase productivity from resource management point of view in corporate level as well. After collecting sufficient data the second part of the study is planned to start for testing the validity of the model and to determine the correlations among the parameters. According to the hypotheses some additional outputs may be added to the model.

4 ACKNOWLEDGEMENTS

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