CHANGE MANAGEMENT IN CONSTRUCTION PROJECTS

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ABSTRACT

Decisions are made everyday in construction processes based on incomplete information, assumptions and the personal experience of the construction professionals. Project changes and/or adjustments are inevitable as they are a fact-of-life at all stages of a project's life cycle. Managing changes effectively is crucial to the success of a construction project.

Change management in construction requires an integrated solution to discipline and coordinate the process, for example, documentation, drawing, process, flow, information, cost, schedule and personnel. The construction industrial needs an effective construction change management process. This paper summarizes various aspects of the existing construction change management processes and provides a comprehensive literature review as well as some comments on possible future directions.

1. INTRODUCTION

In much of the world, construction is an extremely fragmented industry. For example, in Canada more than 95 percent of construction companies employ less than 10 employees. Except for a few large general contractors, the capacity of most companies in the constructor sector is fragmented, for example, structural design and specialty trades. A construction project can be classified as "one-of-a-kind" production in manufacturing terms, or simply "one-off" projects. Project management in the construction sector faces some critical issues that are very different from other industrial sectors: 1) the team involves multiple players at multiple locations; 2) the construction supply chains are short-term and project-based; 3) different styles of project management and costing systems are used with different product delivery systems, i.e. "design-bid-build", "construction manager" and "design-build" contracts; 4) unique needs to manage the involved legal contracts and other related documents (for example change orders); 5) the scope has extended to the life-cycle operation and maintenance management of the finished product, in addition to the architect-design-construction process.

Project changes and/or adjustments are inevitable as they are a fact-of-life at all stages of design and construction. In an EPSRC (Engineering and Physical Sciences Research Council, U.K.) report (Sun et al., 2004), it states that "*More than a third of major clients are dissatisfied with contractors' performance in keeping to the quoted price and to time, resolving defects, and delivering a final product of the required quality.*" It may be inferred that the clients' dissatisfaction is likely caused by change orders running through the construction projects. The effort of managing change orders has imposed a huge burden on project management, and it is a nightmare that industry people wished they never have to face. Changes in construction also cause serious ethical problems and disputes. According to an ethical survey done in 2004 (available at: http://www.acce-hq/documents/ ethics_survey.pdf), 84 percent of respondents expressed that they had encountered situations that they considered unethical in their business dealings, while 61 percent of respondents stated that the industry was "tainted" by unethical acts. Owners are blamed for bid shopping and for playing tricks in payments; contractors were accused of over billing, front-end loading and playing change-order games.

Change management is a pure application-oriented issue and requires engineering innovation to solve the problem. Based on our investigation of the construction change management area, and a pressing need from industry versus the scarcity of literature and software tools in the domain, poses a promising opportunity for research and development in construction. The following sections of this paper summarize the various aspects of construction change management and provides a comprehensive literature review as well as some insightful thoughts on this topic.

2. CHANGES IN CONSTRUCTION PROJECTS

Changes in construction projects are very common and likely to occur from different sources, by various causes, at any stage of a project, and may have considerable negative impacts on items such as costs and schedule delays. A critical change may cause consecutive delays in project schedule, re-estimation of work statement, and extra demands of equipment, materials, labor, and overtime. Changes, if not resolved through a formalized change management process, can become the major source of contract disputes, which is a severe risk contributing to project failure.

Classifications of changes in general terms apply to changes in construction domain. Motawa et al. (2007) summarize that: "*Based on time, change could be anticipated or emergent, proactive or reactive, or pre-fixity or post-fixity. Based on need, change could be elective or required, discretionary or non-discretionary, or preferential or regulatory. Based on effect, change could be beneficial, neutral or disruptive.*" However, since the construction industry is project-based, the best classification is to discuss changes in the context of typical stages/phases in a construction project. Table 1 summarizes stages, sources and impacts of construction changes.

Table 1: Summary of construction changes

Stage	Stakeholder	Types of changes	Impacts	Actions
Specification	Owner/Client/User or architect	Changes to requirements including specification, scope of projects, design brief, etc.	Changes in design and construction processes	Carefully provide detailed specification documents before bidding.
Design	Design/engineering Consultant	Incomplete/inconsistent drawings; design error/defect; design change; omissions of site conditions and buildability; changes in codes and regulations	Rework of design and drawing; rework in construction; change orders	Better control of design versions, drawings; site investigation; consider buildability in design
Construction	Contractor/sub-contractors	As-builts not confirm with as-design; quality defect; unanticipated site conditions; value engineering; materials or equipment not available; inclement weather	Rework; change orders; changes in design	Quality control; site operational control; coordinated documents and drawings; daily logs

The primary causes of change orders are owner-initiated changes and designer's errors and omissions (Issac and Navon, 2008). The impact of changes to a construction project needs to be evaluated case by case in order to assist with the decision making process. Though some changes may bring in "benefits" to the stakeholders especially to the owner in the long run, most changes, if not managed properly, will result in "negative" impacts, most likely resulting in time and cost overruns. In general, upper-stream changes have larger impacts. Lu and Issa (2005) believe that most frequent and most costly changes are often related to design, such as design changes and design errors.

3. LITERATURE

The industrial need of effective construction change management versus the scarcity of meaningful R&D work appears to be a fact in the construction industry. There is very limited research work addressing the change management issues specifically within the construction project management context.

- Sun et al. (2006) designed a change management toolkit for construction projects that includes a change dependency framework, a change prediction tool, a workflow tool, and a knowledge management guide.
- Ipek and Ömer (2007) investigate requirement-design relationships and enable traceable requirement in architectural design. They developed a prototype system called DesignTrack and used LEED requirements as a case study.
- Lee and Peña-Mora (2005) proposed using system dynamics to build dynamic project models to assist planning and control of construction projects. This dynamic project model captures several non-value adding change iterations (rework cycles and managerial change cycles). The simulation is demonstrated using a case study in Road Bridge Construction, and many change option/policy implications are summarized based on this case study.
- Motawa et al. (2007) presented some preliminary results on proactive change management through an integrated change management system composed of a fuzzy logic-based change prediction model and a system dynamics model based on the Dynamic Planning and control Methodology (DPM).
- Charoenngam et al (2003) discussed Web-based project management and a Change Order Management System (COMS) specifically developed for coping with changes in construction projects. Standard web technologies were used and a change order procedure involving workflows, roles/actors, documents, records keeping, and a centralized database were developed.
- Recently, Issac and Navon (2008) have proposed a change control tool (CCT) which creates requirement traceability through links between client requirements and the building design. They believe that number of changes or the impact of changes can be controlled by capturing client

requirements accurately at the beginning of the project and through the requirement traceability that is build up afterwards.

Apart from the project management domain, some other researchers have been trying to address change management issues in various other ways:
- 4D or 5D integration which integrates time and cost models in addition to 3D geometry models. In this way, changes can not only be controlled in the design and engineering stages in the whole construction process, but also be controlled in the built environment lift-cycle to some extent. Jongeling and Olofsson (2007) suggest that location based scheduling provides a promising alternative to activity-based planning approaches for planning of work-flow with 4D CAD. In this approach, work schedules are integrated with design models so that changes in design or during construction can be better coordinated. In the latest 5D technologies of Graphisoft, automation extends beyond design changes. ArchiCAD also automates and coordinates the creation of documents, schedules, bills of materials, and quantities estimates through its integrated "virtual building" model based on IFC's BIM models (available at: http://www.vicosoftware.com/).
- Data sharing and interoperation. Bakis et al. (2007) proposed an approach to model the complex interrelations of the different components of the various aspects of the design and the different versions of each component in order to maintain consistency in architectural design. When changes happen, the interrelation models help notification/propagation of version changes.
- Web-based integration and collaboration approaches. Lottaz et al. (1999) proposed using constraint satisfaction techniques to express possibly large families of acceptable solutions in order to facilitate and abbreviate the collaboration and negotiation processes, ultimately to improve the change management and the productivity during phases of design and construction.
- By combining Web services and intelligent agents, collaborative workflow technologies can be used to handle dynamic and complex business processes on the Web and can be applied to construction project management systems for effective and flexible change management. In a recent work, we conducted a comprehensive literature review of collaborative workflows in design and manufacturing integration (Hao and Shen, 2007a).

The concept of engineering change in manufacturing typically deals with any changes or inconsistencies between product design, engineering and manufacturing life-cycles. Engineering change management (ECM) is thus focused on the co-ordinance of product life-cycle model (PLM) and the enterprise management model in ERP, as shown in Figure 3. Since engineering change is not contractual, the impact of engineering changes stays generally within an organization and is well controlled via the vast adoption of integrated systems in manufacturing enterprises, such as CAD/CAE/CAPP, PLM, and ERP software tools. Construction changes, on the other hand, are harder to control because of the fragmented nature of the industry as well as a low investment and limited adoption of IT technologies.

4. REWORK, CHANGE ORDER AND CCD

Most researchers distinguish three kinds of changes: rework, change order, and Construction Change Directive (CCD) (Huang et al., 2007; Levy, 2006). Figure 1 shows the relationship of change orders, reworks, and CCDs.

Change

Evaluation & Analysis

Proposed Change Order
(PCO)

not agreed

*PCO is
discarded*

agreed and approved

Rework

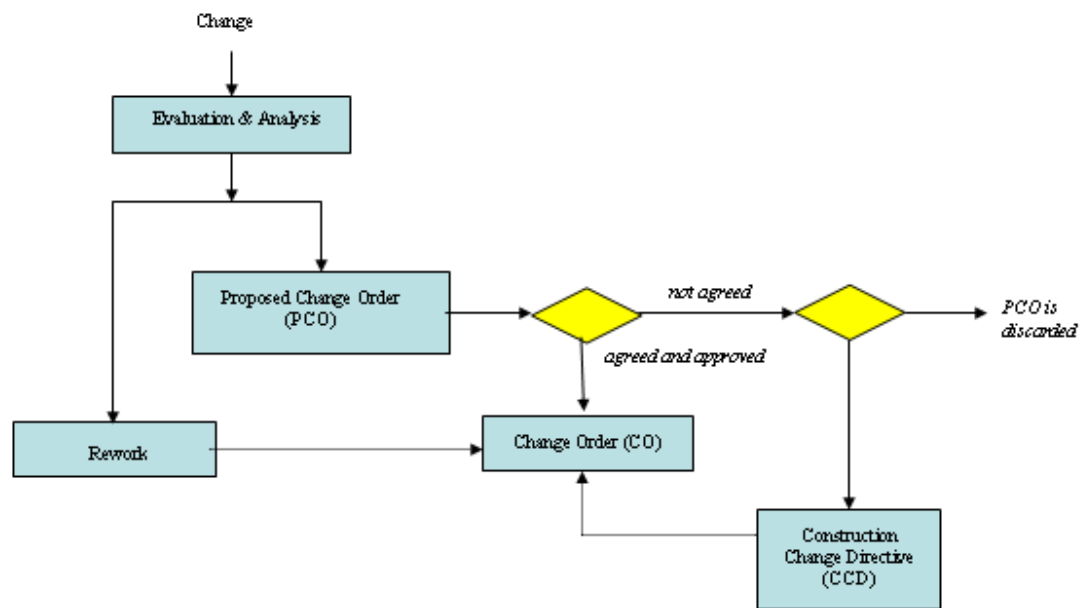Change Order (CO)

Construction
Change Directive
(CCD)

Figure 1: Change orders, reworks, and CCDs

Change order refers to changes that are generated by unanticipated causes, for example, scope changes from the owner, design / technological changes from the architect, and cost and/or time changes caused by supplier problems, design errors, material and operational failures, or by unsatisfactory site conditions. Change orders are common to most projects, and very common with large projects. This type of change has to be negotiated case by case and requires a common (documented) agreement among all the parties involved. The owner or its delegated architect or project manager has the authority to finalize change orders. Once a change orders is submitted and approved, it generally serves to alter the original contract such that the change order now becomes part of the contract. The contractual nature of construction changes is a very distinguished feature of the construction industry.

A CCD is issued by an owner or its designate requesting a change in the contract scope when there is no agreement on cost. CCDs are originated from disputable change orders and could become change orders again, once the dispute can be settled. The process of handling CCD is simpler than that of change orders in that it directly starts from the implementation stage once the CCD is issued (see Figure 2).
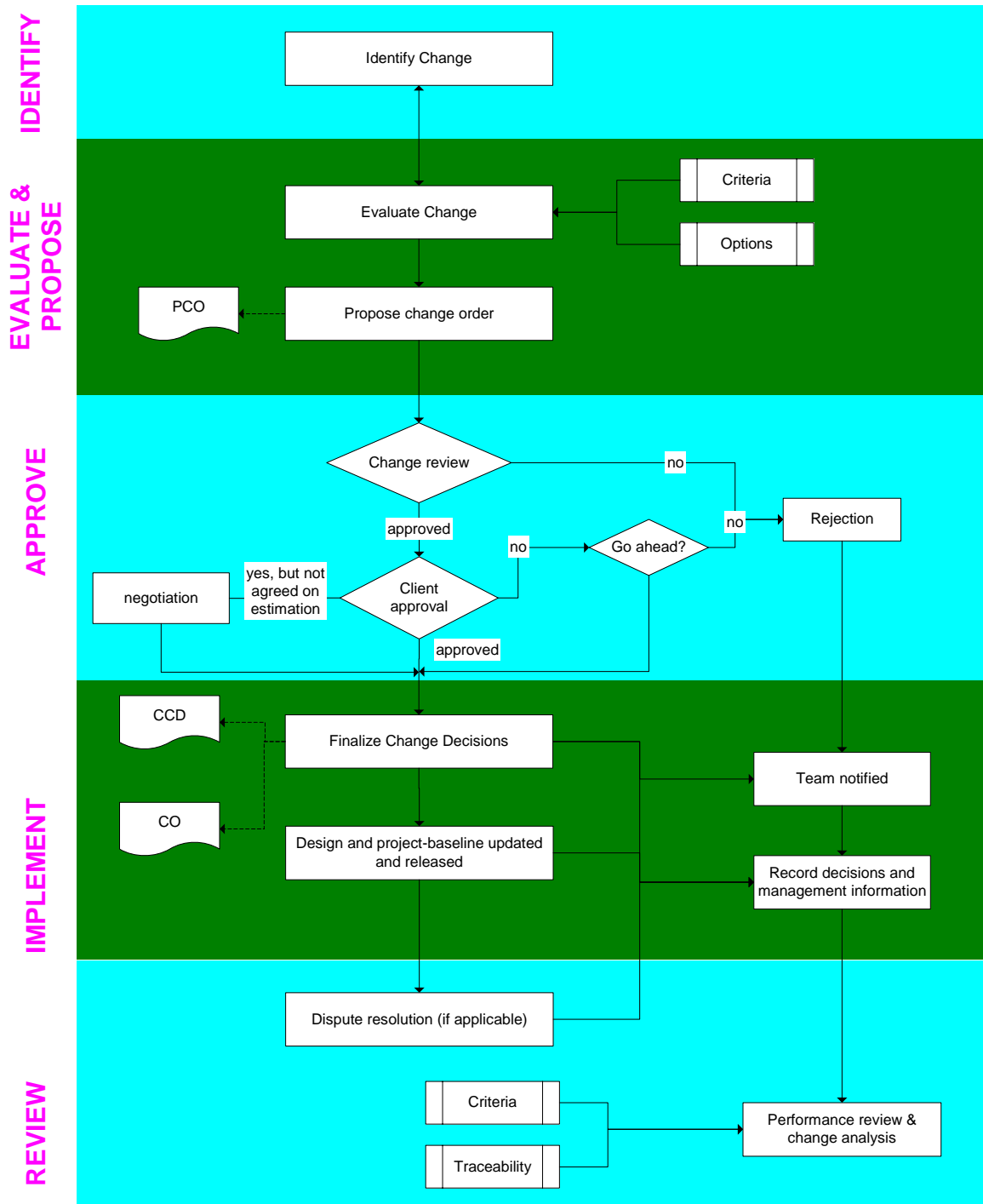
Figure 2: General change process model

Rework refers to re-doing a process or activity that was incorrectly implemented in the first place and is generally caused by quality defects, variance, negligence, and poor design and/or on-site management (Sun et al., 2004). Rework is usually pure waste and should be avoided as much as possible. The only requirement for handling rework is to perform all necessary correction activities to guarantee the conformance of the "as-built" to the "as designed", which is more or less obvious. However, the decision of rework is a difficult one

since rework is normally accompanied by the demolition of what has already built. In most cases, reworks become change orders by minor adjustments in design, construction processes or use of alternative materials as long as the baseline requirements can be still satisfied by the new alternative.

A number of organization and associations produce standard contract forms. These include the American Institute of Architects (AIA), the Association of General Contractors (AGC), the Construction Management Association of America, and in Canada, the Canadian Construction Association (CCA) and Canadian Construction Documents Committee (CCDC). A construction project management authority can choose to use any combination of these standard documents directly or develop their own documents ether as modified standard documents or proprietary in-house contracts. As change orders are part of the contract, all these standards have articles or clauses to obligate the change management procedure.

5. A GENERAL CHANGE PROCESS MODEL

Change management seeks to forecast possible changes; identify changes that have already occurred; plan preventive measures; and coordinate changes across the entire project [8]. Small reworks with minor impacts do not need to go through a formal change process. However, changes with noticeable impacts, either reworks or change orders, all require following a formal process in change management.

A generic change process model is considered to have five stages in a sequence: identify, evaluate & propose, approve, implement and review (Figure 2). The process model is conceptualized based on a synthesis of the change process models reviewed in the literature and the characteristics of computational environments.
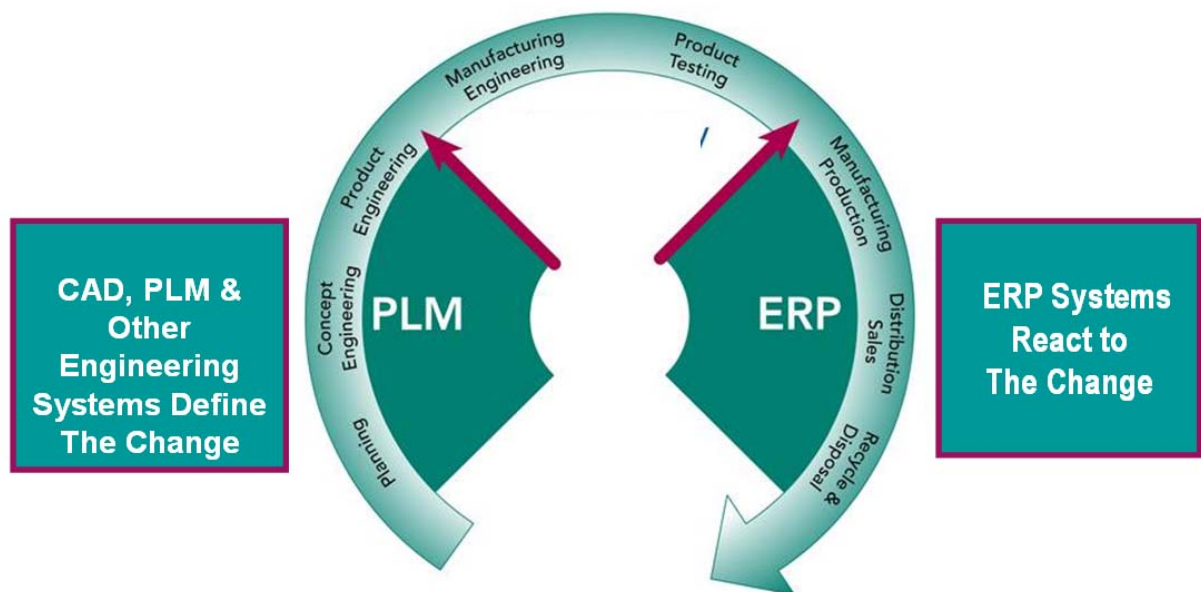

Figure 3: Engineering change in manufacturing

1. Identify changes. This requires an effective change management system to build up the relationships of the requirements, symptoms, malfunctions, and various other aspects of changes. It is common for a typical change management system to exclude the identification stage and start with the change evaluation and proposal processes. This is because the initiating role of a change is hard to be taken automatically by the system, or at the least, a computational system is far less "smart" or "intelligent" than people thought. However, from academic or innovative viewpoint, reaching the "intelligence" of such pro-activeness in change management needs a lot of R&D efforts.

2. Evaluate and propose changes. Based on criteria and options, the evaluation module calculates all possible impacts that an identified change can have on other processes and team members, in terms of time and cost. Analysis and (if possible) optimization of change options is required for decision-making – whether to go ahead with any of the change options or to undertake further investigations. This stage, again, requires heavy efforts in modeling intelligent behaviors involved in the decision-making processes. The outcome of the evaluation is a proposal change order (PCO) which summarizes the change itself and the impacts of the change – a new updated action plan, cost, schedule, etc.

3. Approve changes. Each identified change needs to go through a formal approval process. There are a set of predefined approval processes for different types of changes and construction contracts. Firstly, all the parties involved must agree on the proposed change of work described in the PCO. This is done through a change review process. Next, the approval of the client is required for the PCO to be finalized. This may involve decision making on acceptance, improvement, or rejection of changes. An accepted change modifies the contract while a rejected change may either become a permanently rejected change, or it might still be enforced in the form of a CCD.

4. Implement changes. The change management process model requires all the parties involved to keep records of all relevant information on change cases to build a case base for future use. Unlike previous stages, no major decision is expected during the change implementation stage. An operational system is needed to make sure that all aspects are updated, all parties are notified, and all activities are done properly and coordinated well. Everything recorded is linked with each other and to the change cases as well in order to facilitate the change analysis procedures afterwards.

5. Analyse changes. Change analysis and system performance is reviewed based on the data collected during the change implementation phase.

6. CHALLENGES TOWARDS INTEGRATED CHANGE MANAGEMENT

Developing an effective construction change management process is a challenging task because it requires an integrated solution for coordinating everything involved for the purpose of the change management in question (see Figure 4). While one may find a couple of project management or construction enterprise management software on the market, change management in construction is a topic that one can hardly get through any resources. The existing change management module, that some software claimed to have, is mostly a feature for change information recording and document approval. Change estimation, impact analysis, post-change analysis, statistics, and more importantly, change traceability are not implemented in most of these solutions.
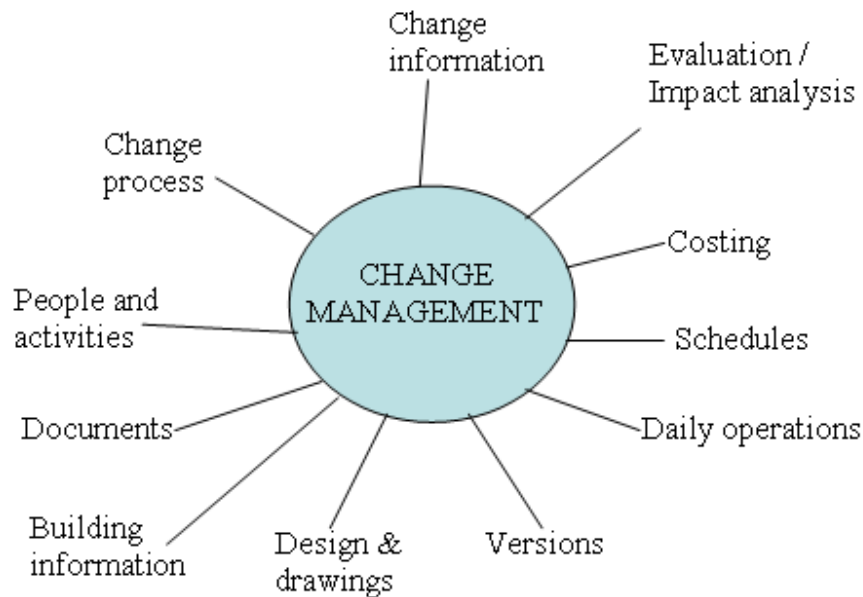
Figure 4: Requirements of an integrated change management system

An effective construction change management system will have the following requirements:
- Consolidating all aspects of change information, including causes, symptoms, sources, impacts, actions, and processes of changes and their linkages
- Evaluating all elements affected by a change, across all design and construction phases
- Automating workflow processes for change review, approval and implementation
- Coordinating changes into operational systems of different parties
- Coordinating changes into a shared project management system
- Coordinating people's activities (including notification, reminding, monitoring, etc.)
- Coordinating the distribution and management of documents and drawings in latest versions
- Day-to-day process and cost recording
- Dispute resolution procedure
- Change traceability and post-change analysis

Change management is a part of project management and enterprise management systems, but it can also stand alone as an independent system or as part of an integrated system with its focus on the construction change itself.

An integrated change management system requires technical supports from different technologies, including Collaborative Workflow, System Integration and Collaboration Technologies, nD Modeling, Web-Based Collaborative Project Management Tools, and Online Document Management Tools.

We have other projects focusing some of these technologies. Shen et al. [18] provides a comprehensive survey on system integration and collaboration technologies in the construction sector. Hao and Shen (2006b) has done a comprehensive literature review of adaptive workflow and distributed workflow technologies. We strongly share the vision that the integration agent, web services, and workflow technologies provides a promising solution for effective coordination of product design, engineering and manufacturing activities across or within enterprise boundaries. Sharing similar ideas, Boddy et al. (2007) proposed an outline architecture for the process driven integration in construction based on the use of agent technologies, Web services / composition, Semantic Web, and higher level protocols in web services stack. Another report by our group (Neelamkavil et al., 2008) is focused on the need for intelligent system in construction process automation. Based on the FIATECH's Capital Projects Technology Roadmap Vision (http://www.fiatech.org/projects/ roadmap/cptri.htm), this report covers related technologies such as 3D/4D modeling in automated design and engineering; intelligent material management and control for automated

construction supply chains; robotics, mobile devices and RFID, etc. for construction process automation, and project management and enterprise management systems.

7. CONCLUSION

Changes are inevitable in construction projects. And, during a construction project, many decisions have to be made, often based on incomplete information, assumptions and personal experience of the construction professionals. Change is a common denominator in all construction projects, though the size, scope, and complexity of projects may vary significantly from case to case. Change management is a critical problem faced by the construction industry. The effort of managing change orders has imposed a huge burden on project management. Changes are identified as the major cause of project delay, cost overruns, defects, or even project failure. More seriously, playing games on changes cause serious ethical problems and disputes in the industry.

Changes in construction projects are very common and likely to occur from different sources, by various causes, at any stage of a project, and may have considerable negative impacts. This paper addresses the types the changes, as well as their stakeholders, causes, impacts and correction actions in the context of typical stages/phases in a construction project. Effectively managing change orders in construction processes is not trivial because change orders are a part of contract and they need to be strictly traced in terms of contracts, documents, approval process, payment claim, etc.

Based on a synthesis of several change process models reviewed in the literature and the characteristics of computational environments, a generic change process model is proposed having five stages in a sequence: identify, evaluate & propose, approve, implement and review. Building an effective construction change management system is very challenging, and one can hardly find a mature software tool on the market, that deals with this issue. Existing change management module, that some software claimed to have, is mostly a feature for change information recording and document approval. Change estimation, impact analysis, post-change analysis, statistics, and more importantly, change traceability are lacking in these solutions. An integrated change management system requires technical supports from different technologies, including collaborative workflow, system integration and collaboration technologies, nD modeling, web-based collaborative project management tools, and online document management tools. We have not arrived at a full solution for construction change management yet. More work will have to be undertaken to develop innovative and practical solutions that are adoptable by the industry.

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