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CONSTRUCTION ERROR TYPES – THE EXECUTION STAGE OF DUBAI PROJECTS

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Abstract: Construction errors can have significant effects on project performance. Yet, any attempt to tackle error should be driven by the ability to understand its archetypal nature. This study aims to analyze a variety of construction errors at the execution stage, in order to develop a comprehensive set of categories that shall provide insights about the effect of different error types on the industry. We investigate a database provided by an authoritative source, which includes a number of 256 construction errors that occurred in the year 2009 in Dubai construction industry. Results from this study reveal that the most common error arose from 'poor workmanship' which accounted for 21% of the total encountered faults. The next most common types arose from the 'usage of impaired materials', followed by the 'deviation from an intended dimension'. These observations infer that the majority of construction errors are driven by workers' lack of skill or competence. Moreover, it suggests that execution-oriented errors are the major cause of faults and accidents rather than design errors.

Keywords: Error, Rework, Failure

INTRODUCTION

Errors have a significant impact on construction projects. They often lead to rework (Burati, Farrington & Ledbetter 1992; Love et al. 2009; Wills & Willis 1996), delays (Chan & Kumaraswamy 1997), claims and disputes (Love et al. 2010a), accidents and cost and schedule overruns (Chan & Kumaraswamy 1997; Love et al. 2009). Moreover, they create unsafe environments (Ortega & Bisgaard 2000) and have an impact on people's morale (Love et al. 2010c). They are therefore as threatening as any other risks that may hamper project success.

For instance, a study reports that costs of defects in residential, Industrial and commercial construction projects range from 2% to 6% of their total contract value (Josephson & Hammarlund 1999). Another study confirms these results and reports that defect rectifications in the residential construction industry cost 4% of the contract value (Mills, Love & Williams 2009). Furthermore, the construction industry development board in Singapore (CIDB 1989) recently estimated that contractors spend 5% to 10% of the total project cost doing things wrong and rectifying them. Moreover, Love (2002) reveals that the indirect costs, that are sequentially incurred by errors, are five times their direct costs. In particular, omissions errors accounts for as much as 38% of the total rework cost (Love et al. 2009). These illustrations of errors are, however, deemed to be expected and usual for construction projects (Love et al. 2010c). Consequences of errors may be more catastrophic, whilst in extreme cases they may escalate to causing life losses.

In general, errors were regarded as "being events in which the outcome was appreciably worse than the expectation, could not be put down entirely to chance or circumstances, and involved some element of surprise" (Busby & Hughes 2004). Human error in particular occur due to physiological or cognitive limitations (Love, Edwards & Han 2010); and they involve a sort of a deviation: weather from an intended course of action, from a route of actions planned toward a desired goal or a deviation from the "right" behavior at work (Busby & Hughes 2004). Any effort to eliminate error shall primarily begin with developing the ability to understand and discover it. Two main perspectives were adopted throughout literature with regards to the variables contributing to error occurrence. These are: human related errors (e.g. Reason 1990) and system related errors (Busby & Hughes 2004).

There is a considerable amount of research that considers both, systems and human perspectives of design errors (Lopez et al. 2010; Love et al. 2010b). Though, studies handling construction errors (which occur at the execution stage of the project) are yet few. Rather, information about construction errors are scattered throughout literature. Using data provided by an authoritative source (Dubai Municipality), which includes 102 cases of disputes triggered by 256 technical errors of the year 2009 in Dubai construction industry, we develop a framework which comprehends the encountered error types. The recurrence of each error type will be presented statically. From these findings, the nature and patterns of errors which the industry most suffers from will be discussed.

THE CONSTRUCTION INDUSTRY

Several factors make construction projects highly prone to errors. The most identifiable issue is the repetitive economic or schedule pressures imposed on firms and individuals (Love et al. 2009, pp. 426-427). These pressures may be imposed by clients who themselves are driven by several needs such as: their need to cope with: increasing capital costs, increasing expectations of shareholders towards return on investment, increasing competitions in markets, environmental concerns and the increasing population which requires physical infrastructure (Love et al. 2009). Other pressures imposed on firms may include the scarcity of resources such as skilled labor (Love et al. 2010c) and liquidity.

No matter what accounts as pressures for firms and individuals, the result is a turbulent environment which thus leads to more errors. For instance, Tilley & McFallen (2000) showed that where clients demanded earlier completion of projects, designers produced erroneous contract documentation. Moreover, Love et al., (2009) suggested that it has become a norm for designers to eschew audits, checks, verifications and reviews due to financial and time pressures imposed by clients. Today, it is not anomalous that firms commence construction with uncompleted design-related documentation in order to stretch the whole schedule (Waldron 2006). Such shortcuts increase the probability of an error to occur in construction projects.

Furthermore, the complex nature of construction and engineering projects makes it more prone to errors. Current project management obviates conventional top-down command and leadership hierarchies. Rather, complex and overlapping-tasks-oriented systems are adopted to insure the success of delivering projects within optimized schedules (Love et al. 2010c). The drawback is, however, that decision-makers and managers have less control upon information-flows and upon consequences of people's actions (Aram & Noble 1999). Project elements become complexly interdependent whereas a decision made on one part of the project triggers events that may be unpredictable in other parts of it (Perrow 1984; Williams 2002). Moreover, individuals are often compelled to perform their tasks or at least some of its aspects on the basis of tentative information (Love et al. 2009). Besides, project goals and objectives in many occasions may be unclear or missing (Williams 2002). All these circumstances make construction and engineering projects more prone to errors.

Describing the turbulent environment of which an error has occurred does not essentially give insights to their actual mechanics. Rather, more detailed observations of project systems and people's behavior are needed; whereas any attempt to eliminate errors shall primarily begin with developing the ability of their discovery (Cooper 1993; Love et al. 2009; Rodrigues & Bowers 1996). Cooper (1993) suggests that, in order to solve fundamental problems, the reduction of number of errors or at least the reduction of time for their discovery is vital and is more important than pumping projects with additional resources. Such discoveries must be accompanied with the determination of the various error types and causes. Once these have been understood, project practitioners shall thereafter have a platform to decide what sort of actions are required to avoid different sorts of errors (Love et al. 2009).

HUMAN ERRORS

Understanding human errors is significantly vital whilst failures are often, either rightfully or wrongfully, attributed to individuals. Regardless their skills, knowledge or experience, the possibility of errors and omissions are inevitable (Atkinson 1998; Orndoff 1986; Wantanakorn & Mawdesley 1999). Even people with highest competencies commit mistakes that are often most severe (Reason 2000). On the other hand, it is arguable weather blame to individuals should be resigned under the justification that making mistakes is among the characteristics of human nature (Reason 1990). However, individuals are mostly deemed to have the choice between the adoptions of error-free or erroneous-based behavior (Love et al. 2009).

Numerous studies have tackled the nature of human errors as well as their types and causes. Rasmussen (1983) for example assorted different kinds of human error, where he argues that each is performed at a different level: *skill-based*, *rule-base* and *knowledge-based*. These assortments are based on the intention adjustments against executions. At the *skill-based* level, slips and lapses occur where the intention is correct but the execution is wrong. At the *knowledge-based* level, which Kletz (1985) refer to as mismatches, intentions are rather wrong but executions are correct. Skill-based errors involves behavior were work is routine and relatively automatic; whereas knowledge-based errors involves behavior that requires some thought and consciousness. Knowledge-based errors occur when practitioner's intention is initially wrong and thus commit an error in execution. The third kind of human errors is the *rule-based*. Herein individuals execute tasks on the basis of inapplicable rules, in which they have a false analogy between situations where such rules were applicable and the current attended ones. However, Rasmussen's (1983) assortments has been criticized that it confuses errors caused by limitations of individuals' minds with other inferential mental causes (Hollnagel 1993). Reason (1990) thereafter built on Rasmussen's (1983) research and added the behavior of *violation*: which stands for the practice of deliberately having a wrong intention. This may be for example to knowingly skip some required procedures for the sake of taking shortcuts.

Human errors has also been ascribed to cognitive failures (Broadbent et al. 1982; Busby 2001). That is, mistakes that involve problems with the memory and the attention (Simpson et al. 2005). Love, Edwards & Han (2010) argue that cognitive failures are driven by boredom, which arise when an individual is either forced to do what he does not want, or is prevented from doing what he prefers. In addition, Bea (1995) argues that humans commit errors due to stress, time constraints, task unfamiliarity, distractions and impairments. Generally, previous research on human error has traditionally focused on the psychology of individuals (Busby & Hughes 2004). Love et al. (2009, pp. 426-427) summarize that human errors can arise due to the following reasons:

- Mistakes- where errors occur as a result of ignorance of the correct task or the correct way of performing it. According to Rasmussen (1983), a mistake is either rule-based or knowledge-based. This happens usually when individuals encounter a novel situation that involves thoughtful ideas lying beyond the range of their learnt problem solving routines.
- Violations- where errors occur as a result of individuals' own decision to not carry out a task or not to perform it the correct way. They may occur due to motivational problems such as low morale, poor supervision etc.
- Slips and lapses of attention- where errors occur as a result of forgetfulness, habit, or similar psychological issues. Error herein is purely encountered at the level of execution, whilst it generally occurs where tasks are routine and the surroundings are familiar.

Love et al. (2009) further suggest that, because human faults are associated with some form of attention capture, an omission error must have arose at a mental stage of action control. Action controls at least involve four stages: planning, intention, storage, execution and monitoring (Love et al. 2009). However, it is often hard to identify the exact mental process at which the error occurred (Reason 2002), since the error maker himself finds it hard to distinguish such details (Love et al. 2009). Thus Reason (2002) suggests that, instead of determining the cognitive stage, an easier approach is to analyze task characteristics and its elements that are more likely to provoke errors.

SYSTEM ERRORS

Other studies focused on project and system-related aspects of error. Although these studies were predominantly examining determinants of project failures rather than mechanisms of certain errors occasions (Busby & Hughes 2004), they have an advantage that they broaden the focus from merely individuals-oriented into a broader context concerning systems. For example, Sauser, Reillya & Shenhar (2009) examined NASA failed projects and argued that their root failing causes were mostly managerial rather than technical. The authors specifically emphasize that success shall be accompanied with finding a better fit between project characteristics and the adopted project management style. Another research suggests that it is project selection rather than project management that counts among the major success factors (Munns & Bjeirmi 1996). Furthermore, Eriksson & Westerberg (2011) propose that project performance is positively influenced by cooperative procurement procedures such as joint specification, selected tendering, soft parameters in bid evaluation, joint subcontractor selection, incentive-based payment, collaborative tools, and contractor self-control.

Organizational behavior factors with respect to project success/failures have also taken a reasonable consideration throughout literature. For instance, Belout & Gauvreau (2004) attempted to identify the impact of human resource management on projects whilst they found a link, although not significant, between the personnel factor and project success. Furthermore, it has been suggested that project performance is negatively affected by models that underestimate the complexity and the dynamics of projects (Munns & Bjeirmi 1996). Belassi & Tukel (1996) proposed schemes that classify the critical success/failure factors and their impact on project performance; these include: team members' commitment and technical background, project managers' managerial abilities, project attributes and environmental issues (Busby & Hughes 2004). A similar study adds that effective coordination, communication and consultation are the most significant factors of success in the construction phase particularly (Carlos & Khang 2009). To sum up, efforts on identifying success/failures factors of projects did not essentially concern exhibiting mechanisms that produce specific errors (Busby & Hughes 2004). It rather gives an allusion that, as significant as individual-related, project and system-related drivers yield errors and failures.

APPROACH

Any attempt to respond to error shall be driven by apprehending their archetypal nature. After establishing the appropriate methods and techniques for understanding error, only then could project managers implement error containment (enhancing error discovery and minimizing its adverse consequences) and error reduction (limiting its occurrence) strategies (Love et al. 2009). Categorizing error gives significant illuminations towards the various roots and qualities of which it involves, and thus shall ease its containment.

Few past studies attempted to categories error from different perspectives (e.g.,Busby & Hughes 2004; Hurst et al. 1991; Minato & Andi 2003; Reason 1990). Reason (1990) for instance categorized active failure types and also the cognitive stages at which they occurred. Busby and Hughes (2004) also categorized pathogens and incubation periods within engineering and construction projects. However, there is no one error taxonomy that could be fully accurate, and serve different circumstances and needs (Reason 2000). Though, attempts to identify generic categories are beneficial in a sense that they provide a structured pattern of assessing vulnerability (Busby & Hughes 2004); and practically speaking, these are deemed useful for the assessment of potential risks (Love et al. 2009). These could, for example, provide project practitioners with a checklist that alerts for a possibility of error occurrence prior to construction, based on certain underlying conditions (Love et al. 2009). In the following sections the development of errors categories will be discussed.

For the purposes of categorizing construction error types, we elect a database obtained from Dubai Municipality (a government authority which controls the local construction industry). The database includes a number of 670 claims and disputes which occurred within the period of 2006 till recent 2010, between the three main project parties: contractor, consultant and client. This database solely includes technical disputes. That is, disputes occurring due to technical errors found at the execution stage of a construction project. Tentative results of an ongoing research will be presented in this paper which involved the analysis of 102 dispute cases triggered by 256 technical errors. We conceive that Dubai Municipality's database has the ability of addressing a significant number of errors that encompass a variety of determinants in order to develop a reliable set of construction error type categories. As a basis for formulating the error types, Bea's definition of error will be adopted. That is, an error is "a departure from acceptable or desired practice on part of an individual that can result in unacceptable or undesired results…" (Bea cited in Atkinson 1998, p. 340).

CONSTRUCTION ERRORS

Figure 1 presents the types of errors and their recurrence among Dubai construction projects. The analysis of the 256 incidences revealed that 53 (21%) of errors were *poor workmanships*, 48 (19%) *impaired material usages*, 35 (14%) *deviations from an intended dimension*, 28 (11%) *task sequence omissions*, 27 (10%) *instruction contraventions*, 19 (7%) *professional principles/conventions noncompliance*, 18 (7%) *official rule noncompliance*, 9 (4%) *items interdependence disregards*, 8 (3%) *site environment mismanagements*, 6 (2%) *adoptions of misguiding instructions*, 5 (2%) *aesthetic disregards*. The underlying factors and conditions that lie behind the aforementioned analyzed errors are various. Although our focus in this study is to identify and categorize error incidences rather than their triggers, some underling factors will reviewed, as these support the simulation of insights regarding the nature of errors. Detailed identifications of the error type categories will be discussed below.

A. Adoption of misguiding instructions

Instructions are considered any sort of information of which builders are supposed to base execution upon. They can take different forms such as drawn, vocal or written guidelines and can vary in scope such as illustrating a major design concept or be as minor as providing a window dimension. Multiple bodies get involved in guiding construction, but design firms are in theory the main instructors since the majority, if not all, construction documents are provided by them. However, instruction faults passed by any of these external bodies are not considered construction errors since they were committed by people other than those responsible for execution. Therefore, by establishing this category, we draw a separation line between errors committed by 'instructors' and those committed by 'executors'. For example, design errors or drafting omissions are misguiding instructions that yield to errors in execution. Though, for the context of construction, we consider the adoption of these faulty designs by itself an error.

B. Instructions contravention

In contrary to the adoption of misguiding instructions where executors commit to follow construction documents exactly as provided, contraventions herein refer to omitting an instruction which is presumed to guide to an error-free construction. Again, an instruction may be any detail which is included within an architectural drawing, structural drawing, MEP drawing, surveying report, lab recommendation, or any other source of construction guidance. The contravention of these Instructions include, for example, neglecting a drawn detail, not using the intended building material, or placing an element in a position different from what instructed in drawings.

C. Deviation from an intended dimension

While builders intend to fully comply with the provided construction drawings, errors in meeting the exact dimensions repetitively occur. Although such errors do not often seem highly severe, they may result to fatal consequences. For example, a slight deviation in a column's verticality will escalate to a sharper inclination. Further, a mistake in matching the intended slab thickness will decrease its strength and will thus cause it to deflect, or even collapse. An obvious trigger to this error is the inaccuracy of people responsible for execution.

D. Task sequence omission

According to Reason (1998), the most common human error is the failure to carry out compulsory steps in the performance of a task. Results from this study reveal that these failures constantly recur within construction projects in Dubai (11% of the encountered failures). Similar to most other error types, task omissions may occur due to slips, lapses, mistakes or violations of builders. For instance, workers would simply decide to take shortcuts by not curing concrete after casting. In other cases, they may be actually unaware weather the neglected procedure was necessary or not. This phenomenon appears for example where electricity ducts are unwittingly left uncovered and thereafter rain water infiltrates through it. Thus, no matter how minor would a step seem to be, leaving it behind may yield to unexpected injuries in the constructed building element.

Regardless of the factors that drive people into the omissions of procedures, some tasks by their nature easily trap builders into omissions. Reason (2002) suggests that instead of determining the exact cognitive processes that were involved in omitting a crucial task, there needs to be a shift towards examining those characteristics most likely to afford them. For example, several authors identified the task properties that could make it prone to errors as following (Love et al. 2009): The greater the information loaded on the short-term memories as requirements of a particular task (Norman 1988); 2) Procedural steps that are isolated functionally i.e. do not obviously appear to be required within a cue of task proceedings (Reason 2002); 3) Steps that are repetitive or recursive (Herrman, Weigartner & Searleman 1992); 4) Steps of which the items required for action is concealed (Reason 2002); 5) Steps that are located in the final stages or the end of a task sequence (Reason 1998); And 6) steps that require breaking a routine or a departure from habitual actions sequences or from a familiar operating procedures (Reason 2002). However, in spite of the traps accompanied by these characteristics, most task sequence omissions occur due to, simply, the violations of people responsible of it (Busby & Hughes 2004; Love et al. 2009).

E. Items interdependence disregard

Construction is a highly complex industry which necessitates the coordination between the interdependencies of tasks, parts and units involved within its processes (Bankvall et al. 2010; Gidado 1996; Winch 2003). Such interrelations exist internally, at many levels of the construction organization (Shirazi, Langford & Rowlinson 1996), and also exist externally throughout different subsystems within the supply chain (Bankvall et al. 2010). Normally changes in one item affect the state of others. That is, if these interdependencies were disregarded, unexpected faults may occur. According to Thomson (1967), there are three types of interdependencies:

- Pooled - where "each part renders a discrete contribution to the whole and each is supported by the whole" (Thompson 1967, p. 54). This type manifests when a common part serves all players (Shirazi, Langford & Rowlinson 1996) such as a crane, or any major construction equipment, of which multiple specialists benefit from (Bankvall et al. 2010). It has been argued that In this type of interdependence, although parts are not necessarily being in a direct operational dependence, the failure of one can threaten others (Bankvall et al. 2010).
- Sequential - where the output of a part becomes the input of the next. Shirazi et al. (1996) exemplified it as when a steel blender bends bars which are then fixed into a form provided by the carpenter; and as another example, when a bricklayer builds a wall (output) and the wall then becomes the surface (input) for the plasterer.
- Reciprocal - where inputs become outputs for others in a manner that work moves backward and forward between parts (Shirazi, Langford & Rowlinson 1996). Reciprocal interrelates also has pooled and sequential aspects to it (Bankvall et al. 2010). An example provided by Shirazi et al. (1996) is the way heating, ventilating and electrical control systems depends on, and requires adjustments, to each other (Bankvall et al. 2010).

A disregard of the interdependencies which exist among items, especially those found in sequential and reciprocal types, will ultimately clutter a construction sequence at any contingent stage, and will perhaps yield to an unacceptable final result.

F. Impaired material usage

The use of damaged, unfitting or unsuitable materials irritates the functionality of the constructed elements, which thus leads to undesired consequences. For example, Pandey et al. (2008) discuss the initiatives of housing safety in Indonesia, Nepal, Pakistan and Turky; and they report that in all countries, poor construction material was found to be the major factor for weak houses. Similarly, Dubai construction industry suffers from such errors. Using impaired materials may exist due to misjudgments of contractors upon the selection of right materials, or in many situations, due to contractors tending to save costs through utilizing lower quality materials. However, contractors often require rectifications at further stages and end up incurring even more costs. Also, in cases where materials are formed in situ such as concrete, mistakes occur during the mixing process by missing the required proportions of contents. In other cases builders may initially have used the right material but it further got damaged due to mistreatments, and though kept it without rectifying. A typical example is retaining the use of reinforcing steel bars which has rusted due to exposing it for a period of time without protection. Regardless what factors cause damages to materials, the usage of any inappropriate ones may impose negative impacts on construction projects.

G. Poor workmanship

According to the English Oxford Dictionary, workmanship is "the degree of skill which a product is made or a job is done." Love & Josephson (2004) define workmanship errors as those that "can be traced back to the main contractor's workers, normally carpenters and concrete workers". Thus, these are strictly concerned with the level of quality workers employ in performing a certain task. Similarly to the differing opinions among builders and consumers on the severity of problems (Kliger 1991), what quality is considered acceptable may also differ. However, for the purposes of this research, only those workmanship standards resulting to undesired consequences will be considered 'poor'.

Georgiou (2010) reports that in three separate studies concerning house defects in Victoria, poor workmanship was found predominant; whilst it ranged between being 38% to 77% of the overall encountered problems. Another study reported that over one-third of the defects in the Libyan construction industry were caused by poor workmanship (Alsadey, Omran & Pakir 2010) Unsurprisingly, our preliminary results also indicate that poor workmanship was the most recurrent, with it accounting for 21% of execution errors in Dubai. This may be attributed to multiple factors. Commonly, the shortage of skilled labor supply compared with the increasingly high demand (Love et al. 2010c) compels builders to compromise with allocating low skilled workers. Nevertheless, besides the issue of workers, the problem of poor workmanship should also be attributed to managers since quality control and assurance fall within their realm (Georgiou, Love & Smith 2000). For instance, Cross (cited in Georgiou 2010) found that the systems used by builders, trades people and building inspectors have no recognized quality base. He also found that builders could not identify a method of - quantifiably - measuring and ensuring quality. Such triggers made workmanship standards fluctuating among contractors.

H. Aesthetics disregard

Builders were occasionally found disregarding minimal aesthetic requirements. Such errors are not relevant with the ability of the structure to function, neither with the quality of the constructed elements, these are however mistakes concerning the well-being of the buildings' final appearance. Contractors often do not consider the disregard of aesthetics as severe as do consumers. On the contrary, they tend to trade it off when constructability or resource availability pressures are imposed on them. For example, in a case the builder was found painting the wall with unequally toning colors due to a shortage of paints. In other cases these were simply negligence actions, such as leaving electricity wires exposed rather than hidden. Aesthetic errors lead to customer dissatisfaction which often yields a claim or a dispute.

I. Site environment mismanagement

A poorly managed site will give a negative impression about the superintendent, and will have a negative impact on the project performance. For example, It has been argued that "a clean environment will ultimately lead to a higher quality-work" (Levy 2003, p. 196). According to March's (1992) observation, the construction industry's environmental impacts include ecology, land-scape, traffic, water, energy, timber consumption, noise, dust, sewage, and health and safety hazards. Moreover, several cases in this research proves that the consequence of mismanaging the site environment surpass being an atmospheric problem. Rather, it may negatively effect the durability of the structure itself. For example, builders were frequently found casting concrete without evacuating the formwork, which is normally occupied by trash. Concrete therefore loses its coherence due to amalgamating fragments of residues within its mixture. Accordingly, the building element loses its strength.

J. Professional principles/conventions noncompliance

Violating conventions and/or principles refers to performing tasks in a manner that is entirely distinct from the professions' (i.e. construction) established practices. This error type is different from the aforementioned types in a sense that the latter involves deviations from the acceptable professional practices whereas this involves abnormalities in the way the job is initially done. An example of principles violation is to dig into a loaded concrete footing for the sake of planting mechanical cables. Both Intention and execution are wrong herein. Alexander (1992) suggests that the basis for professional practices is necessarily found on the concepts of *knowledge* and *response*; whereas he defines knowledge as what the person knows or should know, and defines response as the following action of being responsible for what is needed. In other words, professionals are expected to hold the *knowledge* required in their area of profession and "are expected to *respond* in accordance with recognized codes of practice" (Alexander 1992, p. 16). Project participant including clients, consultants and authorities presume that contractors work in compliance with principles and conventions. However, since workers often learn by doing or from their more experienced colleagues rather than learn by education or formal training (Gonza´lez 2001, cited in Serpell & Ferrada 2007), there is generally a fluctuant level of professionalism. This is the main factor that makes violating principles and conventions a recurrent problem in Dubai.

K. Official rule noncompliance

Dubai Municipality's building rules and regulations covers a wide extent of aspects involved in the construction stages. These include, for example, legislations and standards concerning structural requirements (i.e. materials and construction methods), MEP requirements, scaffolding and shoring setups, general site arrangements, health and safety provisions, space distributions, design and architectural benchmarks, land demarkation and surveying procedures, etc. All construction projects in Dubai are subject to periodic investigations by the municipality's engineers to confirm its compliance with these rules whereas fines, and sometimes claims, are issued against violators. A traditional philosophy behind enforcing these rules is to standardize the work among construction projects so that accidents and faults are prevented and a higher quality of buildings is achieved among the city. Nevertheless, contractors work for their own interest and violate the rules when they perceive that there is a benefit, or at least no risk, for doing so. Generally, people tend to work at a level of zero perceived risk (Näätän & Summala 1974). However, Clarke (1996) argue that the adaption to risks distorts peoples' risk perceptions which results to automated inconsideration of risks. Consequently, they adapt to violate rules designed to limit risk (e.g. DM rules). Besides the accidents and failures that may be accompanied with violating rules, there is always a chance of incurring overheads caused by fines or claims. For example, Kartam, Flood & Koushki (2000) report that Kuwait Municipality issues thousands of safety rules' violation warnings and around 100 safety tickets annually to contractors. Therefore, rule violations by different means may impose negative impacts on projects.

SUMMARY AND CONCLUDING REMARKS

Understanding error is a vital stage to the elimination of construction errors. Based on this principle, literature attends to two main distinct perspectives of error: human and system related. Studies concerning human related errors are mainly focusing on the physiological or psychological aspects of the incidence. On the other hand, system related studies are rather more comprehensive; they include organizational and project-level factors. However, past efforts were either generic to the whole industry or specific to project stages other than execution (i.e. errors at the design stage). Nevertheless, the execution stage is by nature highly prone to errors since it involves a great deal of complexity and requires a high level of skill and professionalism. This study therefore establishes a set of error types encountered by the construction industry at the execution stage in order to stimulate insights about the errors' nature and pattern of which the industry most suffers from.

The analysis of a sample of 256 incidences suggests that a construction error could be any of the following types: *poor workmanship*, *impaired material usage*, *deviation from an intended dimension*, *task sequence omission*, *instruction contravention*, *professional principles/conventions noncompliance*, *official rule noncompliance*, *items interdependence disregard*, *site environment mismanagement*, *adoption of misguiding instructions* or *aesthetic disregard*. The underlying factors and conditions that trigger these errors are various; whilst some are exclusively human related and others may involve a system aspect. Regardless, the distinctive fact herein is that they all yield to unacceptable or undesired results, including injuries in the constructed component, rework, cost and schedule overruns accidents, customer dissatisfaction, claims and disputes, etc.

The most common kind of errors arose from workers' *poor workmanships* (21%). The next most common types arose from *impaired materials usage* (19%) followed by *deviations from the intended dimensions* (14%). On the other hand, design errors which were categorized as 'adoptions of misguiding instructions' herein, accounted as only 2% of the error incidences. These findings reveal that, contrary to the prevalent view, errors of the execution stage of construction are the major cause of faults and accidents rather than design errors. Furthermore, most of these errors are *skill-based* (according to Rasmussen's (1983) assortment), since they are often driven by the inaccuracy (e.g. deviation from an intended dimension) or the incompetency (e.g. poor workmanship) of workers. We therefore suggest that practitioners of the construction industry should focus on obtaining skill and professionalism among workers who actually perform the task on site.

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