Causes of Discrepancies between Design and Construction in Pakistan Construction Industry

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Abstract: In the building construction, discrepancies frequently occur between the design and construction pertaining to architectural details, structural details, materials and quality of construction. The objective of this paper is to identify the major causes of discrepancies in building construction from the viewpoint of the project stakeholders. A questionnaire is utilized that contains sixty-five potential causes of discrepancies, classified into four categories including the design, tendering, construction and overall project phases. Data were obtained from Pakistan and the response rate was excellent (80.6%). Collected data are analysed and important causes of discrepancies are identified. Results indicate that the provision of incomplete data to designers, lack of interest by approving authorities to carefully check the design, and owner-proposed changes due to financial problems, are the top three important causes of discrepancies. Insights and discussion are provided in the paper. This work provides a basis to minimize discrepancies in the construction industry and consequently helps in reducing rework, delays, and defects in construction.

Keywords: Building construction; Design errors; Construction discrepancies; Relative importance index.

Introduction

Construction and engineering practitioners have found it increasingly difficult to learn from their mistakes, particularly with regard to design errors and discrepancies (Lopez et al., 2010). Evidence in support of this is present within reports of "high profile" repeated errors and discrepancies incidents that have contributed to the failure of buildings and engineering infrastructure (e.g. Hauck, 1983). Design discrepancies continue to be a major contributor to building and engineering infrastructure failures as well as project time and cost overruns (Sun and Meng, 2009; Love et al., 2009). Han et al. (2013) describe that design errors and discrepancies leading to rework and/or design changes are considered to be the primary contributor to schedule delays and cost overruns in design and construction projects. Non-value-adding-effort (NVAE) from errors and changes in design and construction are identified by Han et al. (2012). They show that NVAE or wasted effort can be avoided if the project is carefully planned and executed.

Discrepancies and changes can have harmful effects on project performance, most often producing a ripple effect among the different activities needed to accomplish the completion of a project (Lee et al., 2006a). Discrepancies, errors and changes in one activity can easily propagate to other activities due to their physical and procedural relationships (Lee et al., 2006b). Lopez and Love (2012) reveal that design errors and discrepancies can adversely influence project performance and can contribute to failures, accidents, and loss of life. Wang et al. (2016) reveal that design management is critical to project performance. Andi and Minato (2003) reveal that defective design has an adverse impact on project performance and the participants and this issue need to be addressed carefully.

Nonetheless, every building construction project starts with the objectives of completing it in accordance with the details set in the contract. The client, the consultant and the contractor contribute their share to fulfil the requirements set at the start of a project. When a project progresses and enters into the construction phase, the requirements and quality standards defined during the design phase start changing (Alarcon and Mardones, 1998). The problem is that a discrepancy in design and construction can be small but it is usually significant. In building construction, discrepancies mostly occur in various phases, for example, design phase and construction phase. These discrepancies include changes in the sizes of rooms, false ceiling heights, locations and thicknesses of walls, locations and sizes of doors and windows, locations of underground and overhead water tanks, plinth levels from the ground surface, locations of beams and columns, sizes of beams, foundation types and sizes, reinforcement details, quality of concrete, changes in bricks and tiles, changes in paints and finishes, quality of workmanship, insulating materials, changes in plumbing pipes and accessories, changes in electric cables and accessories.

Pakistan is a developing country and has experienced rapid expansion in construction activities in recent years with economic growth 4.24 percent in 2014-15 (Ministry of Finance, 2015). According to the Ministry of Finance (2015), the share of construction is 12 percent and is one of the potential components of industries. The construction industry has registered a growth of 7.05 percent in 2014-15 (Ministry of Finance, 2015). Large and complex projects, for example the China-Pakistan economic corridor (CPEC), are being built which can lead to inadequate design resulting in changes to plans, specifications, and conditions of contracts. Additionally, large and complex building project are being built due to the demand of both the public and private sectors. A chief executive officer (CEO) of a consulting company in the country revealed that design firms omit to undertake design audits, reviews, and verifications to maximize their fee and profit. Discrepancies, errors, and defects can occur during the design and construction stages of projects due to these oversights. In order to detect incompatibilities and to increase the service life of projects, it is essential that important causes of errors and discrepancies are identified and eliminated or their adverse effect is reduced. A research study is conducted in the country and specifically, the following objectives are considered:

1. Identify causes of discrepancies between the design and construction pertaining to building projects and investigate their relative importance;
2. Ascertain the ranking of the causes to determine the differences in the

perceptions of clients, consultants and contractors;

3. Investigate any agreement on the categories of discrepancies between clients, consultants and contractors.

This research is carried out to gain insights for causes of discrepancies and errors in the design and construction in the building industry in the country, a topic that is largely ignored by researchers until recently. The importance of this work is evident from the fact that it provides viewpoints of all three key stakeholders in building projects namely the client, the consultant and the contractor. Nonetheless, this paper is more focused on the traditional design-bid-build construction.

Literature Review

Every individual makes errors from time to time. Technical errors occur when a person fails to correctly carry out a procedure (Wantanakorn et al., 1999) and are relatively easy to identify. For example, if someone added 3 and 4, and then arrived at an answer of 6.5, this would be easily identified as an error and corrected. Nonetheless, design discrepancies and changes are more complicated and diverse in nature. According to Mohamad et al. (2012) design changes are common in building projects. Any change in the design or construction of a project after the contract is awarded and signed is defined as a design change. Variations and changes occur in all types of construction projects (Thomas et al., 2002). Even if cautiously planned, changes are still inevitable in the contract as work progresses (Al-Hammad, 2000). These changes in the design phase and ultimately in the construction phase create problems between the contracting parties.

Mendelsohn (1997) found that 75 percent of the problems faced on site are caused at the design phase. Many design defects are detected during the execution phase of the projects, which consequently lead to rework (Oyewobi et al., 2011). Mohammed et al. (2010) postulate that changes in the plans by the owner, substitutions of materials by the owner or the contractor, and changes in the design by the consultant are the main causes of variations on building projects in Selangor Malaysia. Grau et al. (2012) reveal that conflicts between designers and contractors are attributed to poor planning of design, inaccuracy of design documents, high build cost of design options, delay of drawing supply, and unreasonable design fees. Tribelsky and Sacks (2010) measured the flow of information in the process of detailed design where construction documents are prepared. Tenah (2001) pointed out that what appears good on drawings or on the computer screen is sometimes difficult to build, and designers seek resulting modifications in the plans during the construction stage. These discrepancies result in rework, changes in quantities, delays and defects in construction. Kong and Gray (2006) indicate that the most prominent source of delays and consequent disputes on construction projects in Malaysia was variations between the contracting parties. These variations and the consequent delays result in the lack of investment by the investors. This generally reduces the overall growth of building construction which sometimes results in unemployment.

Wang (2000) reveals that conflicts between the stakeholders were frequent in projects marked by poor management. These can include authorization requests granting approvals, reporting procedures, and inspections. Mohamed et al. (2012) indicate that almost all projects undergo various changes, not only at the design stage but also during construction. Discrepancies in design and construction can either result in delays in project durations, compromise in quality, or increase in cost. Eliminating discrepancies that exist can enable the project management team to complete project successfully (Arian et al., 2006). It is important to evaluate the potential causes of discrepancies in the project life-cycle.

Research Method

This section describes the research method, questionnaire development and data collection. A questionnaire is initially designed and subsequently modified to evaluate the importance of the identified causes. The literature review provided the foundation for developing a questionnaire which is used as the research instrument. Data were collected by distributing the questionnaire to clients, consultants and contractors. Responses to the questionnaire are then received and analysed. In this paper, the client is the owner or employer of the project. The contractor is the constructor or builder of the project with whom the owner entered into a construction contract. The consultant is the designer or engineer of the project with whom the owner entered into a contract for providing professional services.

Questionnaire

Guidance for designing the questionnaire is obtained via the literature review. The questionnaire consists of 65 causes of discrepancies, grouped into 3 categories. The researchers performed a pilot-test on the questionnaire with 2 clients, 6 consultants and 7 contractors and then conducted interviews with each participant. Every respondent possesses more than 10 years of experience in the building construction industry. The questionnaire is modified in accordance to the feedback from these experts to make it suitable for the building construction in the country. The researchers issued a cover letter and survey instructions for the participants to give them assurance that their responses would be anonymous. The final questionnaire solicited information about the respondents covering their qualification, designation, working experience in the building construction, and the category whether they represent clients, consultants or contractors. The questionnaire covers four sections including design phase, tendering phase, construction phase, and overall project phase. In the design phase, 20 incompatibility causes are listed, of which 5 are adopted from Arain et al. (2006) and the rest are developed from the input of experts from the pilot study. The tendering phase is a newly added portion to the questionnaire comprising of 7 causes. In the construction phase, 24 causes are identified, from which 6 are adopted from Arain et al. (2006) and the rest are developed from the input of the experts. In the overall project phase, 14 causes are identified, of which 8 are adopted from Arain et al. (2006) and the rest are developed from the input of the experts. From the 65 items questionnaire, 19 were adopted from Arain el al. (2006). Finally, the questionnaire comprised on a 5-point Likert-type scale (5 = extremely important, 4 = very important, 3 = moderately important, 2 = slightly important, and 1 = not important) facilitating statistical analysis of the responses.

Sample

Surveys are administered to clients, consultants and contractors. There are altogether 41,025 registered companies of consultants, clients and contractors registered with the Pakistan Engineering Council (Pakistan Engineering Council, 2014). The sample size that represents the target population is determined from an equation that is widely used by researchers (Arain and Pheng, 2005; Kish, 1995):

$$n = \frac{n'}{(1 + n' / N)} \qquad \text{Eq. 1}$$

Where:
n' = Sample size from infinite population = S^2 / V^2
n = Sample size from finite population
N = Total population (41,025)
V = Standard error of sample population equal to 0.05 for the confidence interval 95%
S^2 = Standard error variance of population, $S^2 = P (1 – P)$; Maximum $P = 0.5$
The sample size for the target population was calculated as follows:

$$n' = S^2 / V^2 \qquad \text{Eq. 2}$$
$$n' = (0.5)^2 / (0.05)^2 = 100$$
$$n = 100/ (1+100/41,025) = 100$$

In total, 165 hard copy questionnaires are distributed and the response rate was 80.6%, resulting in 135 questionnaires are collected. Respondents include 19 clients, 75 consultants and 41 contractors. Two incomplete questionnaires are received and were discarded. These discarded surveys are considered invalid as their use would distort the results. The sample is thus reduced to 133 for the data analysis. Of the 133 respondents hereinafter called the sample, in terms of building projects experience, 42% (8 clients, 33 consultants and 15 contractors) had experience 0 to 10 years, 32% had experience 11 to 20 years, 15% had experience 21 to 30 years and the remaining 11% had more than 30 years' experience (see Figure 1). Considering education, 48% of the respondents had engineering degrees, 24% had earned technical certificates (diploma), 18% had non-engineering bachelor's degrees and the remaining 10% had secondary education.

Figure 1

Reliability Analysis

Reliability of the collected data is assessed using statistical package for social sciences (SPSS) version 19.0. The reliability test is conducted to check whether each item in the scale is free from error of measurement (Leech et al., 2005). If a questionnaire is examined at different times and across different populations, and it produces the same results, the questionnaire is a 'reliable one' (Hinton et al., 2004). In this test, Cronbach's Alpha values range from 0 (un-reliable) to 1 (reliable) with

0.75 being considered a relatively strong value of reliability. In SPSS, widely-used methods for assessing reliability are Cohen's Kappa Coefficient for categorical data and Cronbach's Alpha for continuous data (Likert-type scale). Since the data are based on a Likert-scale, Cronbach's Alpha method is used to check the reliability.

Relative Importance Index

The relative importance index (RII) is computed for each cause, and the ranking of the causes is ascertained for clients, consultants and contractors. Chan and Kumaraswamy (1997) used RII to decide the relative importance of attributes. In the current research, the respondents' input on five-point scale in the questionnaire is transformed to a relative importance index for each cause of incompatibility to determine the rank of that cause for each stakeholder. The formula for the RII (Chan and Kumaraswamy, 1997) is:

$$RII = \sum w/(A \times N) \qquad \text{Eq. 3}$$

Where;
w = Weighting as assigned by each respondent in a range from 1 to 5, where (1 implies not important, 5 implies extremely important);
A = The highest weight, e.g. '5';
N = The total responses in the sample.

Rank Agreement Factors

The rank agreement factors (RAF) are calculated using the formula and method revealed by Okpala and Aniekwu (1988) and used by several researchers, including Chan and Kumaraswamy (1997) to quantitatively quantify the agreement in ranking between groups, namely client, consultant and contractor. The RAF potentially varies from 0, which indicates perfect agreement, to a higher value representing increased disagreement. The researchers calculated the percentage disagreement (PD) and percentage agreement (PA). RAF, PD and PA for any two groups of respondents are calculated as described by Chan and Kumaraswamy (1997):

Absolute Difference (Di) = $| Ri_1 - Ri_2 |$ Eq. 4
Where Ri_1 = Ranking of First Group; Ri_2 = Ranking of Second Group
Maximum Absolute Difference (D_{max}) = $| Ri_1 - Rj_2 |$
Where Ri_1 = Ranking; Rj_2 = Ranking with absolute maximum difference
Rank Agreement Factor (RAF) = $\sum D / N$ Eq. 5
Where D = Absolute difference; N = Number of Categories, j = N – i + 1
Percentage Disagreement (PD) = RAF/RAF_{max} or (Di / N) / (D_{max}/N)
Percentage Agreement (PA) = 100% - PD

Analysis and Results

This section provides the results of the reliability analysis, relative importance index (RII), rank agreement factor (RAF) and percentage agreement (PA). The reliability results are given in Table 1. The results indicated that Cronbach's Alpha values for respondents are above 0.75, thus all the causes in each category are retained.

Table 1

Using the relative importance index (RII), the causes and the categories of causes are ranked from the perspective of the clients, the consultants and the contractors. The ranking of causes and categories are discussed in the following sections:

Design Phase

The design phase category contains 20 causes. The RII and ranking for each cause is shown in Table 2. From this category, it is observed that "data provided to designer are incomplete" is ranked in the 1st position within this category (RII = 0.72). On the basis of the overall ranking (or in all the different phases) of each respondent, it was ranked 1st by clients and consultants and 3rd by contractors. This cause is ranked in the 1st position in terms of the overall ranking or in all the different phases. "Approving authorities do not check carefully that the structure is designed according to the building bye-laws, codes and government rules" is ranked in the 2nd position in this group (RII = 0.70). It is ranked 10th by clients, 3rd by consultants and 1st by contractors. This cause is ranked in the 2nd position in terms of the overall ranking. "Too little time is given to the designer for completion of the design documents" is ranked in the 3rd position in this design phase category (RII = 0.68). It is ranked 7th by clients, 2nd by consultants and 14th by contractors. This cause is ranked in the 5th position in terms of all the different phases.

Table 2

Tendering Phase

This tendering phase contains 7 causes. The RII and ranking for each cause is shown in Table 3. All causes in this category received low ranking ranging from 23rd to 53rd with the RII = ranging from 0.60 to 0.47. The results reveal that clients, consultants and contractors are successful in addressing these cause factors, and this resulted in no major issues of incompatibility.

Table 3

Construction Phase

The construction phase category contains 24 causes. The RII and ranking for each cause are shown in Table 4. For this category, it is observed that "owner proposes changes due to financial problems" is ranked in the 1st position in this category (RII = 0.69). This cause factor is ranked 10th by clients, 9th by consultants and 2nd by contractors. It is ranked in the 3rd position in terms of the overall ranking or in all the different phases. "Approving authorities do not check carefully that the structure is constructed according to the approved building plans" is ranked in the 2nd position in this category (RII = 0.68). This cause factor is ranked 3rd by clients, 6th by consultants and 4th by contractors. It is ranked in the 4th position in terms of the overall ranking. "Contractor's lack in skilled manpower" is ranked in the 3rd position in this category (RII = 0.67). This cause factor is ranked 14th by clients, 4th by consultants and 12th by contractors. This cause is ranked in the 6th position in terms of the overall ranking.

Table 4

Overall Project Phase

The overall project phase category contains 14 causes. All causes in this category received low ranking, ranging from 9th to 65th with RII = ranging from 0.66 to 0.37. The results reveal that clients, consultants and contractors have adequately addressed these concerns so they are not a source of major discrepancies.

The design phase is ranked in the 1st position among the overall categories (RII = 0.58), which emphasizes the importance of this category with reference to discrepancies. This category is ranked 1st by clients and consultants and 2nd by contractors. The construction phase is ranked in the 2nd position among the overall categories (RII = 0.57). This category is ranked 2nd by clients and consultants and 1st by contractors. The tendering phase is ranked in the 3rd among the overall categories (RII = 0.54). This category is ranked 3rd by clients, consultants and contractors. The overall project phase is ranked in the 4th among the overall categories (RII = 0.51). This category is ranked 4th by clients, consultants as well as by contractors. The RII and ranking of the categories are listed in Table 5.

Table 5

Results for the rank agreement factor (RAF) and percentage agreement (PA) reveal that the clients and the consultants have high agreement (100%) in the ranking of the categories of discrepancies. The results also indicate that the clients and the contractors, and the consultants and the contractors have 75% agreement in the ranking of categories of discrepancies (see Figure 2).

Figure 2

Discussion

The data analysis and results of this research are given in the previous sections. Here, the results are discussed to consider their implications for the construction industry. "Data provided to the designer are incomplete" is ranked in the 1st position in overall causes. This factor is ranked 1st by clients and consultants and 3rd by contractors. The results show that all parties are in agreement concerning the importance of this cause in the creation of discrepancies. The provision of incomplete data to the designer is attributed to a deficiency of the organization on part of the consultants, as indicated in the interviews. The consultants make unrealistic commitments to the clients regarding the time required for the completion of the design documents. Once they realize that the commitment cannot be fulfilled, designers respond by taking shortcuts. This is where they ask the design team to complete the design on the basis of incomplete data. Once the construction starts, problems begin to surface due to differences in the design and the actual site conditions. A lack of data can result in misinterpretation of the actual requirements of a project (Assaf et al., 1996). With insufficient data, designers are compelled to develop design based on their own perceptions, which may not be what the owner wants.

"Approving authorities do not check carefully that the structure is designed according to the building bye-laws, codes and government rules" is ranked in the 2nd position among overall causes. It is ranked 10th by clients, 3rd by consultants and 1st by contractors. The consultants and the contractors are in agreement that the 'not to check the design in accordance to standards' is an important cause of discrepancy for designs. On the contrary, clients gave this aspect less importance as they are obligated to enforce building code bye-laws. Interviews indicated that the approving authorities in urban areas and towns are obligated to check the designs of building structures according to the building bye-laws. Periodical checking by the authorities requires project owners and others involved in building construction to follow the updated building bye-laws. One interviewee indicated that the overseas designer follows standards of their own countries which sometimes differ from the local building codes of Pakistan.

"Owner proposes changes due to financial problems" is identified as the 3rd significant cause of incompatibility among the overall causes. It is ranked 10th by clients, 9th by consultants and 2nd by contractors. The results show that contractors find financial problems of clients are a major source of discrepancies. On the contrary, clients and consultants give this aspect less importance. For a successful project, client and consultant need to decide on the exact scope of the project in light of the available funds. Interviews revealed that the clients habitually ask for changes when funds and other resources are available. This result is consistent with the findings of other researchers (Arain and Pheng, 2005; Clough et al., 2015). This research concludes that a change in scope of the project by the owner is an important cause for changes when resources (e.g. funds) are available with the client. Al-Hammad (2000) revealed that owners underestimate construction costs of projects but demand higher quality from the contractors. Mohamad et al. (2012) recognize that owners are a major source of design changes due to modifications to the design, scope changes, and unclear initial design briefs.

"Approving authorities do not check carefully that the structure is constructed according to the approved building plans" is identified as the 4th important cause of discrepancies among the overall causes. It is ranked 3rd by clients, 6th by consultants and 4th by contractors. The three parties are in agreement that checking of design in construction is an important cause of discrepancies. Approving authorities are obligated to approve project design within their jurisdiction in accordance with the bye-laws that they have to enforce. Oversight by the architect or engineer encourages contractors to incorporate additional changes during construction. Mohamad et al. (2012) indicated that insufficient details of the existing site condition are the common cause of design changes. They also revealed that contractors tend to use available materials and alternate construction methods to save money.

"Too little time is given to the designer for completion of the design documents" is ranked as the 5th important factor of discrepancies among the overall causes. It is ranked 7th by clients, 2nd by consultants and 14th by contractors. Design cannot be developed in a proper manner if too little time is given, and it can force the designer to wrap up the necessary design at a lower quality. "Unrealistic design period" is ranked 3rd and 7th by contractors and overall respondents respectively as a cause of change orders (Alnuaimi et al., 2010). The results show that clients and consultants are in agreement concerning the level of importance of providing adequate time for the designers to complete the design documents. On the contrary, contractors give less importance to this cause.

"Contractor lacks in skilled manpower" is ranked as the 6th important factor of discrepancies among the overall causes. It is ranked 14th by clients, 4th by consultants and 12th by contractors. A study conducted by Mohammed et al. (2010) ranked 14th the "contractor lacks in skilled manpower" as the cause of variation in the construction of building projects. The consultants are of the view that this is an important cause of discrepancies.

The least important causes of discrepancies identified in this study is "appointment of designer as consultant" ranked in the 60th position among the overall project phase. Appointment of designer as consultant may attempt to put the blame for design errors on the contractor. "Withdrawal of licenses and permits" is ranked 61st in the overall, "design firm or contractor goes bankrupt and blacklisted" are ranked 62nd. "Appointment of contractor as consultant" is ranked 63rd in the overall. This result indicates that contractors are rarely appointed as consultants in the construction industry. "Owner proposes changes to assert their authority and make undue interference in construction" is ranked 64th position in the overall. "Nationality of participants" is ranked as the 65th factor of discrepancies among the overall causes. Assaf and Al-Hammad (1988) revealed that oversees designers, sometimes do not have sufficient knowledge of the local design regulations in a country, and international contractors are not sometimes familiar with the availability of resources, and these issues causes design and construction interface problems. Interviews revealed that international companies need to vigilant about discrepancies or errors in design and construction, and related risks while delivering building construction services. The stakeholders need to be aware of the need to improve the integration, planning and control of their designs and production processes. The owners, consultants and contractors need to be closely involved to eliminate discrepancies in the design and construction.

Conclusions

This study identified the causes of discrepancies and errors between design and construction pertaining to building projects. It investigated the relative importance of various factors in influencing discrepancies in designs and construction. Further ranking of these causes are ascertained to determine the differences in the perceptions of contracting parties i.e. clients, consultants and contractors. The results indicate that "data provided to the designer are incomplete" is ranked in the 1st position in overall causes, and this factor is ranked 1st by clients and consultants and 3rd by contractors. Further results indicate that "Approving authorities do not check carefully that the structure is designed according to the building bye-laws, codes and government rules" is ranked in the 2nd position among overall causes, and it is ranked 10th by clients, 3rd by consultants and 1st by contractors. "owner proposes changes due to financial problems" is identified as the 3rd significant cause of discrepancies among the overall causes, and it is ranked 10th by clients, 9th by consultants and 2nd by contractors. "Approving authorities do not check carefully that the structure is constructed according to the approved building plans" is identified as the 4th important cause of discrepancies among the overall causes, and it is ranked 3rd by clients, 6th by consultants and 4th by contractors. "Too little time is given to the designer for completion of the design documents" is ranked as the 5th important factor of discrepancies among the overall causes, and it is ranked 7th by clients, 2nd by consultants and 14th by contractors. "Contractor lacks in skilled manpower" is ranked as the 6th important factor of discrepancies among the overall causes, and it is ranked 14th by clients, 4th by consultants and 12th by contractors. These six most important causes, on the basis of the overall ranking are in the design and construction phases. These six causes are primary to improve the design-construction interface by minimizing and controlling discrepancies and are summarized in terms of the recommendations:

1. The data required by the design team need to be provided at the initial stage to enable designers to prepare the design drawings and specifications according to established criteria that are not likely to change drastically;
2. The designer and consultant need to check that all drawings and specifications used for construction are carefully inspected for on-site construction activities. Managing design changes can help the stakeholders to achieve optimum satisfaction on a project. A vigilant role played by the approving authorities ensures that discrepancies are minimized;
3. All the stakeholders especially the owner, needs to pay careful attention to the availability of funds for the project to manage risks that arise during its execution;
4. Approving authorities need to make sure that all structures are built according to the approved building plans during construction;
5. Designers are to be given sufficient time to prepare the drawings and specifications by following the updated building codes. They are to be paid a fee that is commensurate with their efforts.
6. Contractors need to make sure that they are working with skilled manpower as well as maintaining the high quality of workmanship.

Nationality of participants, the appointment of a designer as consultant, and the appointment of a contractor as the designer, are some of the least important identified causes of discrepancies. Additionally, the categories of discrepancies are also ranked on the basis of ranking and the results indicate "design phase" ranked at number 1; "construction phase" at number 2; "tendering phase" at number 3 and "overall phase" at number 4 in the overall. Finally, clients, consultants and contractors are in agreement on the need to minimize and control discrepancies in building construction. Useful findings related to the causes of discrepancies in the construction industry are documented. Similar studies can be undertaken elsewhere to investigate how regional and cultural factors influence the findings of this research. Further research is required to determine the strategies and to suggest solutions to eliminate the causes of discrepancies between design and construction on construction projects.

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Table 1. Cronbach's Alpha of Categories of Incompatibilities

Category	**Client**	**Consultant**	**Contractor**
Design phase	0.922	0.903	0.933
Tendering phase	0.862	0.756	0.870
Construction phase	0.938	0.929	0.970
Overall project phase	0.941	0.904	0.957

Table 2. Ranking of Causes for Design Phase

Cause	**Client**		**Consultant**		**Contractor**		**Overall**		**RC**
	RII	Rank	RII	Rank	RII	Rank	RII	Rank	
Contractor is not involved in the conceptual phase of design.	0.46	56	0.43	61	0.52	30	0.46	56	20
Contractor is not involved in the development phase of design.	0.52	47	0.45	58	0.50	36	0.48	51	18
Data provided to designer are incomplete.	0.75	1	0.74	1	0.66	3	0.72	1	1
Data provided to designer is incorrect.	0.66	16	0.62	22	0.45	49	0.58	26	9
Data is provided late to designer.	0.64	25	0.64	17	0.57	17	0.62	17	7
Lack of human resources with designer.	0.69	10	0.65	14	0.60	6	0.64	12	6
Designer busy in too many assignments.	0.62	29	0.59	28	0.49	43	0.56	29	10
Designer's knowledge is lacking in building bye-laws, codes and government rules.	0.56	41	0.58	30	0.40	62	0.52	43	14
Designer's knowledge is lacking in constructability of design.	0.43	61	0.54	43	0.52	28	0.52	44	15

Designer's knowledge is lacking on availability of materials.	0.60	34	0.57	34	0.52	30	0.56	32	11
Designer's knowledge is lacking on engineering design technique and software.	0.54	44	0.51	45	0.43	55	0.49	48	17
Lack of designer's knowledge concerning engineering drafting.	0.49	51	0.51	47	0.47	46	0.49	46	16
Lack of designer's knowledge for suitability of materials.	0.60	34	0.55	41	0.51	34	0.54	39	13
Frequent replacement of designer by the owner.	0.56	41	0.58	30	0.51	34	0.55	34	12
Personal and social problems of designer.	0.47	55	0.48	51	0.47	46	0.48	51	19
Lack of reward, delayed payment or less payment to designer by owner.	0.72	3	0.67	13	0.58	14	0.65	10	5
Too little time is given to designer for completion of the design documents.	0.71	7	0.73	2	0.58	14	0.68	5	3
Lack of project planning and analysis by owner at the project start.	0.73	2	0.67	10	0.60	6	0.66	8	4
Frequent changes in the design due to owner dis-satisfaction.	0.72	3	0.65	14	0.50	38	0.62	18	8
Approving authorities do not check carefully that the structure is designed according to the building bye-laws, codes and government rules.	0.69	10	0.72	3	0.69	1	0.70	2	2

RC = Rank within this category

Table 3. Ranking of Causes for Tendering Phase

Cause	Client		Consultant		Contractor		Overall		RC
	RII	Rank	RII	Rank	RII	Rank	RII	Rank	
Incomplete or inaccurate design documents un-intentionally provided with bidding documents.	0.59	38	0.46	55	0.45	49	0.47	53	7
Incomplete or inaccurate design documents intentionally provided with bidding documents.	0.61	32	0.56	37	0.50	38	0.55	36	5
Type of construction contract in use.	0.59	38	0.50	49	0.39	63	0.48	50	6

Contractor did not consider that the design is exotic, complex or difficult to build, and he does not have the required expertise.	0.60	34	0.60	27	0.52	30	0.57	27	2
Selection of contractor on the basis of lowest bid.	0.51	48	0.62	24	0.61	5	0.60	23	1
Amount of performance security and retention money.	0.62	29	0.58	29	0.51	33	0.57	28	3
Absence of third party validation during defect liability period.	0.56	41	0.58	32	0.53	26	0.56	31	4

RC = Rank within this category

Table 4. Ranking of Causes for Construction Phase

Cause	**Client**		**Consultant**		**Contractor**		**Overall**		**RC**
	RII	Rank	RII	Rank	RII	Rank	RII	Rank	
Owner proposes changes because he had planned to make changes during construction.	0.44	59	0.57	33	0.60	6	0.56	29	13
Owner proposes changes during construction due to sudden changes in his requirements / expectations.	0.45	57	0.56	37	0.48	45	0.52	42	18
Owner proposes changes during construction due to change in ownership.	0.40	62	0.44	60	0.56	20	0.47	54	20
Owner proposes changes to assert his authority and make undue interference in construction.	0.26	65	0.38	64	0.50	36	0.40	64	24
Owner proposes changes due to financial problems.	0.69	10	0.68	9	0.69	2	0.69	3	1
Slowness in decision making process by owner.	0.64	25	0.69	7	0.53	26	0.63	13	5
Changes in building codes, bye-laws and govt. rules.	0.48	53	0.47	54	0.41	59	0.45	59	23
Delayed revision of drawings by designer.	0.69	10	0.62	23	0.56	19	0.61	20	9
Drawings not properly stamped or certified by designer.	0.51	48	0.45	56	0.45	49	0.46	56	22
Custody and supply of drawings at site.	0.45	57	0.48	52	0.45	52	0.46	55	21
Delayed approval of drawings by owner or consultant.	0.67	15	0.55	42	0.49	40	0.55	38	15
Material changes due to shortage of particular material in the market.	0.66	16	0.63	21	0.59	12	0.62	16	8

Material changes due to procurement delays by contractor.	0.66	16	0.63	20	0.56	20	0.61	21	10
Contractor does not follow recommended construction methods and reluctant to use proper construction equipment.	0.65	21	0.69	8	0.49	40	0.62	15	7
Contractor lacks in skilled manpower.	0.68	14	0.72	4	0.59	12	0.67	6	3
Contractor lacks in comprehension of drawing details.	0.71	7	0.70	5	0.60	10	0.67	7	4
Contractor lacks in coordination and management during construction.	0.66	16	0.56	40	0.40	61	0.53	41	17
Contractor's staff facing shortage of tools and or equipment for measurement, alignment and or for adjustment at corners.	0.65	21	0.65	16	0.58	14	0.63	14	6
Contractor and his staff focusing on other projects.	0.64	25	0.57	34	0.47	46	0.55	36	14
Lack of awareness of the designer about the ongoing construction process.	0.61	32	0.64	18	0.55	22	0.61	22	11
Unanticipated weather conditions.	0.51	48	0.51	45	0.44	54	0.49	49	19
Unforeseen problems and differing site conditions.	0.63	28	0.61	26	0.54	23	0.59	24	12
Timing of proposed changes, i.e. whether at the start or at the end of construction.	0.62	29	0.52	44	0.54	24	0.54	40	16
Approving authorities do not check carefully that the structure is constructed according to the approved building plans.	0.72	3	0.69	6	0.65	4	0.68	4	2

RC = Rank within this category

Table 5. Ranking of Categories of Incompatibilities

Category	**Client**		**Consultant**		**Contractor**		**Overall**	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Design phase	0.608	1	0.595	1	0.526	2	0.576	1
Tendering phase	0.582	3	0.556	3	0.499	3	0.543	3
Construction phase	0.588	2	0.584	2	0.528	1	0.567	2
Overall project phase	0.558	4	0.523	4	0.476	4	0.514	4

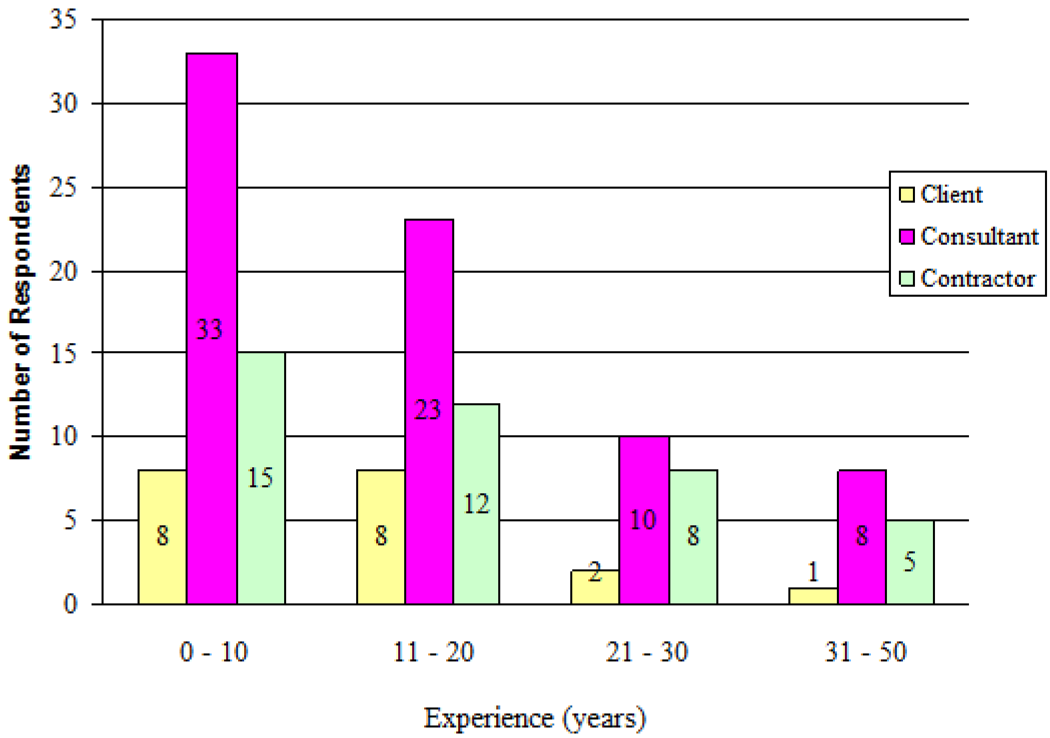

Figure 1. Experience of the Respondents

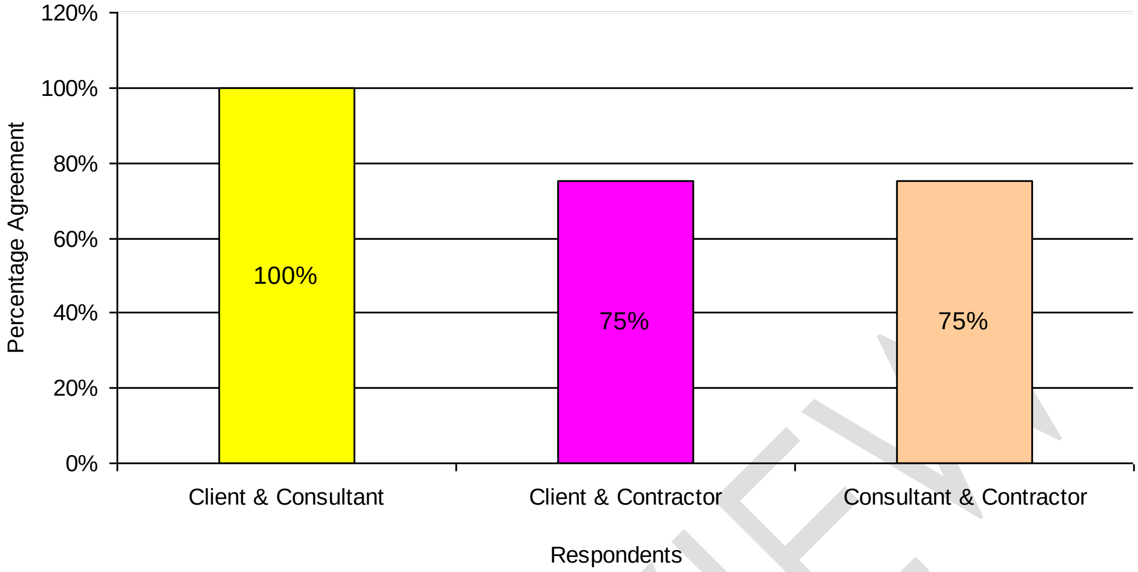

Figure 2. Percentage Agreement between the Respondents