

Design Changes in Construction Projects – Causes and Impact on the Cost

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Abstract

Isolation of design phase from construction has made the design changes inevitable in construction projects. Extensive literature appraisal has acknowledged the detrimental effect of design changes on project performances. However, the impact and causes of design changes have been divided up, either separately or project specific. As a result, the relationship between impact and causes of design changes could not be established for general construction. The primary objective of this paper is to examine the impact of design changes on project cost and identifying actions responsible for these changes. The objectives of the study were achieved through a systematic review of past literature published in well-established journals, and contents analyzed. From the extensive literature review, it was established that the design change is one of the predominant factors to cost overrun, and in some cases, may upshot into cost overrun between 5 and 40% of the project cost. Also, many causes of design changes resulting in cost overrun within the perspective of the owner, consultant, and contractors are explored. Some projects experienced closure as a result of owner induced design changes, although these changes may not be significant in number. Design changes as a result of consultants and contractors in some cases might have reduced impact but are frequent. For each consideration, most events leading to design changes can be eliminated by improving on communication and coordination between stakeholders. The main contribution of this research is to bring together the impact and causes of design changes on cost under one platform for effectively managing the design process.

Keywords: Design Changes; Impact on Cost; Causes of Design Changes.

1. Introduction

The volatility and complex nature of construction have increased the degree of uncertainty involved in the planning and execution stages. Unlike manufacturing, construction has conventionally separated planning and design from construction processes which have resulted in some scope and design related changes during the construction [1]. Separation of design and construction has led to severe problems in which designs are made without concerns for buildability or productive economies thereby impacting the performance of the projects negatively [2, 3]. The effect of these changes has resulted in issues of cost overrun, schedule delays and productivity loss. Combination of aforementioned have a detrimental effect on the overall project cost.

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Even in well-managed projects, the design changes can directly impact the cost in a range from 2.1% to 21.5% of total construction cost [4]. Han et al. (2013) [5] concluded that design errors have led to some reworks in construction projects and resulted into 5 to 20% increase in the project. The phenomena of cost overrun due to design changes are universal. Thus, almost every country is experiencing the unfavorable effect of design changes on cost performances of projects. Many studies have been conducted on identifying the causes associated with design changes, which depends on the type of project and regional demography. Generally, design changes occur due to actions interconnected to owners, consultants and contractors [6, 7]. Few researchers have considered clients as the primary force behind design changes, whereas others have blamed consultants for frequent changes. All the same, contractors have also been identified as the leading players in creating events leading to the design changes.

Building construction is a project-based practice and design is an iterative process where deviations are unavoidable. Researchers are in the constant hunt for doing away with design changes by analyzing causes of the design changes and evaluating its impact on project performances. However, the dilemma of some previous researches is that both the impact of cost overrun due to design changes and its causes are dealt with separately.

In some of the cases, the impact of design changes on cost and its causes are evaluated but restricted inside the specific project domain hence lacking the general relationship between impact and causes of design changes in an overall construction environment. For instance, [8], measured the impact of design changes on cost overrun in a quantifiable term but stopped short of suggesting the causes of the changes which impacted cost.

Similarly, many authors have identified the causes of design changes. However, the impact of design changes on cost is not disclosed [9, 10]. These two domains are predominantly researched separately. There seems to be lack of studies associating causes of design changes and its impact on cost. This paper seeks to contribute by evaluating the impact of design changes on cost in addition to the causes associated with the design changes for general construction practices.

The effort made in this study will help clients, consultants, and contractors in realizing the effect of design changes on project cost, as well as understanding the causes of these design changes. This will enable the critical construction players in developing the strategies which can help them in reducing the damaging effects of design changes and improving the performance of the projects. As discussed above, it is imperative to extend the research on design changes to include the impact of design changes on cost and identification of the causes of these changes. Therefore, the objective of this paper is:

- To quantify the impact of design changes on the project cost;
- To determine the causes of design changes resulted in project cost overruns.

2. Research Methodology

An extensive literature review has been carried out in this study to identify the impact of design changes on the cost performance of construction projects and thereby to determine the causes of design changes. Due to the numerous research already carried out in this field, delimitation for establishing the boundary of this study is carried out using the following criteria:

- Only papers in peer-reviewed English academic journals are considered;
- Only papers in peer-reviewed English conference proceedings are selected for review;
- No books or non-published thesis or dissertations are considered.

Three major academic databases Science Direct, Taylor and Francis and Elsevier were used as the primary source of relevant publications. Other sources such as google search engine was also adopted. Keywords were established for literature research and were used in combination with each other logically with the keyword of the construction industry in all the combinations. The three-stage approach was adopted in the study conducted by Mok et al. (2015) [11]. According to this approach, in stage 1, papers containing keywords in the title are reviewed for further consideration. Due to a large number of papers gathered in stage 1, first filtration process was applied in stage 2 in which only those papers retained containing keywords in individual abstracts. In the last stage, the complete content of each paper was critically reviewed for relevancy, whereas extraneous papers were excluded. Finally, 16 papers within the context of the cost impact of design changes and 40 papers within the context of causes of the design changes impacting the cost overrun were well-thought-out for final review in this paper. The systematic review process is summarized in Figure 1.

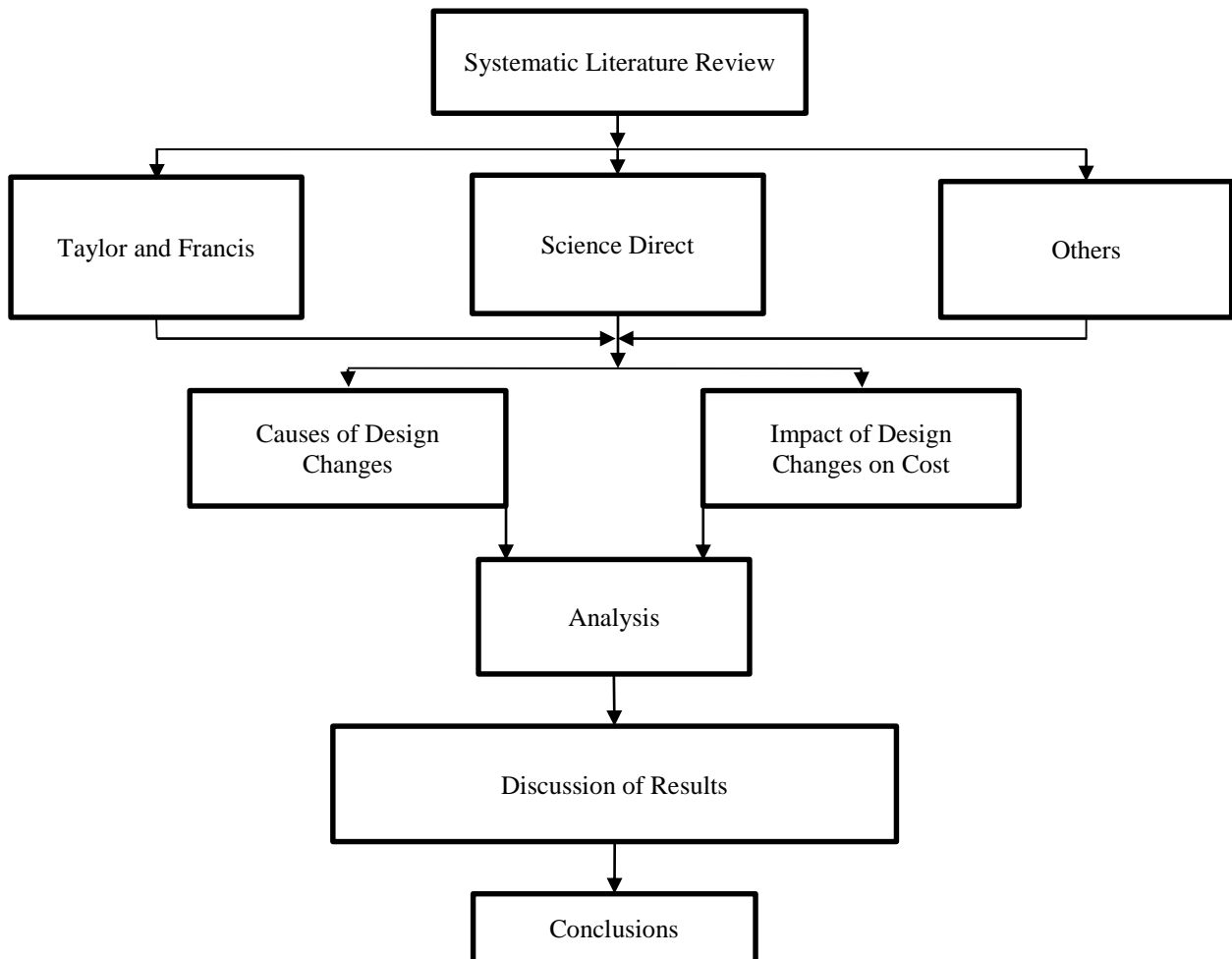


Figure 1. Systematic Literature Review Process

3. Design Changes Impact on Cost

The impact of design changes on cost in construction projects has been studied and evaluated. It has now become a well-known fact that design changes are inevitably the cause of cost overrun. In a research conducted by Ikediashi et al. (2014) [12], on construction projects, they concluded that design discrepancies and frequent design changes are the most important factors resulting into cost overrun, and ultimately leads to complete failure of projects in Saudi Arabia. In another study, Cheng (2014) [13], asserted that most significant factors for cost overrun include the unclear and poorly defined scope of the project, numerous modifications to the scope, and unclear drawings/guidelines/regulations. These factors lead to design changes at any stage of a project thereby resulting in some reworks and do affect not only the cost but also have a diminishing return effect on the morale of workers. Also, Ibbs (2005) [14], emphasized the substantial loss of labor productivity due to design changes and eventually resulting in cost overrun and delay. The conclusion was based on the author's evaluation of 162 construction projects in the USA.

Similarly in another study conducted by Hanna (2004) [15], in USA, frequent design changes in electrical and mechanical construction component also resulted into loss of labor productivity. Apart from productivity issues, design changes also increase indirect cost due to the later events of claims and disputes during the projects [16, 17]. In a study conducted by Ayininuola and Olalusi (2005) [18], the frequent changes in the design were associated with a change in scope of work by owners. This resulted in significant causes of the high incidents of building failures in Nigeria.

Kazaz et al. (2012) [19] used the questionnaire survey technique in Turkey and determined that design and material changes are the most predominant factor which is negatively impacting the project performance and needs to be effectively managed at the start of the project. Most common factors that inhibit cost controls in construction projects as concluded by Olawale and Sun (2010) [20], in a research conducted in the United Kingdom revolves around design changes, uncertainties within construction not pre-assessed, complexities in the project, inaccurate determination of project cost, time, and nonperformance of the contractors. In countries like China, Indonesia, Malaysia, India and Pakistan, extensive research has also been carried to identify the factors contributing the cost overrun in construction

projects with results clearly demonstrating the design changes as the predominant factor in overall impacting the cost of the project [6, 21-24].

It is a well-established fact that design changes are the major contributor to cost overrun in construction projects. The adverse effect of design changes is not specific to a country or a project.

3.1. Quantification of Cost Overrun

It has been established that nearly all projects have to change from the design stage through to the construction. The impact of the design changes on cost is different and vary from project to project, as well as country to country. Determining the exact impact of design changes on the cost is very difficult to quantify at the beginning of the project. However, the trend of the impact on cost can invariably be judged throughout the world. Extensive research has been carried out to collect the impact of design changes on the cost globally in a quantifiable term so as highlight the detrimental effect of design changes to projects.

Yap and Skitmore (2017) [6], conducted a questionnaire survey to establish cost overrun due to design changes and concluded that cost overrun ranges between 5 – 20% of the overall project cost in Malaysia. Cox et al. (1999) [25], analyzed four successfully executed building projects in the United Kingdom to establish the cost overrun associated with a design change. They established the cost overrun to be between 5 and 8%. However, Chang (2002) [4] and Hwang et al. (2009) [26], computed the cost overrun as 24% and 5% respectively due to design changes on projected evaluated in United States America (USA). As stated by Hwang et al. (2009) [26], almost \$75 billion was wasted on direct cost as a result of rework in 2004 alone, thereby imposing a heavy burden on the construction industry in the USA. In order to establish that cost overrun associated with design changes, Burati Jr. et al. (1992) [27], analyzed nine industrial projects in the USA and found an overall increase in project cost to be 12.4%, of which 79% was due to the contribution from design related changes. A cost overrun of 5 to 8% occurred due to designer's omission in tender documents, coordination defects and errors in construction projects in the UK [25]. In another research conducted in Singapore on the analysis of data collected from 381 projects, the average cost overrun was determined to be 7.1%. These mostly related directly to owner induced changes which resulted in rework [8]. Also, Love (2002) [28], conducted a questionnaire survey on 161 Australian construction projects. The author concluded that out of total 52% of cost overrun, 26% were directly related to sudden changes in design. The overall summary of the cost impact in different countries are shown in Table 1.

Table 1. Cost Overrun due to Design change

Researchers	Project Type	Research Type	Cost Impact (%)	Country
Yap and Skitmore 2017 [6]	N.A.	Questionnaire	5 to 20	Malaysia
Cox et al. 1999 [25]	Building projects	Case Study	5 to 8	UK
Chang 2002 [4]	Environmental and engineering design for Roadway construction	Case Study	24.8	USA
Chang et al. 2011 [29]	Highway widening, a new highway, landscape bridge, Sewer	Questionnaire, interviews and data analysis	10	Taiwan
Burati Jr et al. 1992 [27]	New construction, Retrofit construction, upgrade construction	Data collection and analysis from documents	12.4	USA
Li and Taylor 2014 [30]	Development of model and testing on Roadwork project	Analysis of model results	13	USA
Kakitahi et al. 2016 [31]	Building Project	Analysis of data	4.5	Uganda
Hwang et al. 2014 [8]	NA	Questionnaire	7.1	Singapore
Hwang et al. 2009 [26]	Data from 359 projects including buildings, heavy and Light industries, infrastructure	Analysis of data	5	USA
Oladapo 2007 [32]	Data collected from 30 completed projects	Questionnaire and data analysis	79	Nigeria
Li and Xu 2013 [21]	Road and Bridge	Data analysis	23	China
Han et al. 2013 [5]	Building project	Model preparation and testing	5-20	USA
Senaratne and Sexton 2009 [33]	NA	Case study	10-15	UK
Hanif et al. 2016 [34]	Hydropower project	Data analysis	31	Pakistan
Love 2002 [28]	161 construction projects	Questionnaire	26	Australia
Moura et al. 2007 [35]	Motorways projects	Data results	39	Portuguese
	Underground projects	Data results	311	
	The building, Environmental, Maritime/Dam	Data results	41	

3.2. Causes of Design Changes Impacting the Cost Overrun

As discussed earlier, design changes are invariably causing substantial cost overrun of construction projects. Construction Industry is in continues hunt towards achieving efficient construction management techniques that can rid of the wastage and non-value adding activities. The primary focus of researchers is to evaluate the causes of the issues which are detrimental to the construction to develop the methods which can rectify the malfunctions present in the process. With this in mind, significant causes of cost overrun due to design changes are explored so that constructors can better be sensitized to overcome design related issues in construction.

Many researchers have evaluated the causes of design changes based on the construction stages like pre-planning, planning, design and construction [34, 36, 37] whereas few researchers have categorized the sources of design change from the perspective of Clients, consultants and contractors [6, 9, 29]. The dynamics can be classified into internal and external factors which are adopted in this paper. The internal factors relate to clients, consultants, and contractors whereas all other factors are considered as external.

Clients, Consultants, and Contractors are considered to be the critical players in a construction project. Most of the times, design changes impacting the cost overrun occur due to intentional, unintentional or negligence of either one or a combination of some of the top players. The researchers have different arguments on identifying the key players contributing towards the design changes. Table 2 represents the leading players contributing towards the design changes as identified by the researchers. The influence of clients on triggering design changes is more compared to other factors, yet the role of consultants and contractors can never be underestimated in promoting events causing the changes in design. There is ample research carried out on identifying the events which caused Clients, Consultants, and Contractors to endorse the design changes. The causes of the client, Consultant and Contractor related design changes impacting the cost overrun are tabulated in Table 3.

Table 2. Key players contributing towards project cost overrun

Top Players Contributing the Design Changes	References
Client	(Cheng 2014, Chang et al. 2011, Hwang et al. 2014) [13, 29, 8]
Consultant	(Muhwezi, Acai and Otim 2014, Moura et al. 2007) [38, 35]
Contractor	(Tawil et al. 2013) [39]
External	(Kaliba, Muya and Mumba 2009, Kaming et al. 1997) [40, 22]

Table 3. Causes of design changes [2, 10, 13, 29, 32, 34, 37, 36, 40, 41]

Factors	Causes
Clients Related	Lack of technical knowledge to comprehend and visualize the project
	Lesser guidance and support available to Clients by technical persons
	Frequent scope change by the Clients
	Long time taken by the client for giving decision
	Clients changing financial and business conditions necessitates the scope changes
	Inappropriate choice of project contract type (unit price, lump sum, etc.)
Designer-Related	Designers lacked the awareness of design to provide commercially focused solutions and constructability
	a lack of confidence in preplanning for design work
	Designers have difficulties both in capturing clients' needs and conveying conceptual design options to them
	Deficient resources in quality or quantity (e.g. tools, equipment, staff, or financial)
	Poor coordination and communication between Client and designer as well as designer and contractor
	Lack of information flow among parties
	Unstructured Design process
	No Design checking or 2nd or 3rd party reviews, No system of design checking
	Unreasonable Client and End User Expectations
	Ineffective utilization of automation
	Time Constraints
	Designer noninvolvement/unavailability during construction phase
	Inadequate information provided to Designer
	Short-term conflict of interests of resource allocation between productivity (production) and quality.
Inadequate training/ inexperience, lack of knowledge in (building bye laws, codes etc, constructability, availability and suitability of materials, engineering design techniques	

Factors	Causes
Contractor- Related	Change of designers
	Lack of awareness about governmental regulations, municipality requirements, statutes and their modifications
	Lack of Design Standards.
	No involvement of contractor during design phase
	Lack of adequate documentation
	Late approvals of design
	Several groups visit project late and give late their points too late
	Discrepancies between contract documents
	Inadequate pre-construction study and review of design documents by contractors considering the exotic and complex nature of design
	Awarding contract to the lowest price regardless of the quality of services
	Lack of experience about new construction technologies
	Lack of communication and coordination between various project team
	Information problems
	Poor project organizational structure
	Adversarial/Oblivious relationship between consultant and contractor
External causes	Shop drawings' submission, approval and adequacy
	Long period between time of bidding and awarding
	Incomplete plans and specifications
	Insufficient working drawing details
	Contractors request on improving the buildability by suggesting alternate construction method and material used
	Strict quality tolerances mentioned in the specification results frequent rework
	Differing site conditions
	Poor economic conditions
	Severe Weather
	Unexpected changes in material availability
Military actions	
Governmental issue	
Shortages of labor	
Undetected underground utilities	

4. Discussion

No matter how well a project is managed, design changes are considered to be inevitable in the construction. The effect of design changes on the project performance is very detrimental.

Construction projects are suffering from the dilemma of cost overrun, schedule delays and loss of productivity due to changes in the design at later stages. Researchers have evaluated the significant causes of cost overrun and considered design changes as one of the predominant reasons behind the cost overrun. The design changes are the primary cause of rework which affected the costs disproportionately. Another indirect detrimental effect of the design changes in the form of claims, disputes and moral of the construction teams is hampering the performance of construction tremendously and in turn causing the considerable amount of financial burden on the owners and consultants.

The phenomena of cost overrun associated with design changes is a worldwide reality. Construction projects in developed, as well as underdeveloped countries, are suffering from the harmful effects of these unplanned changes. However, the impact on cost due to design changes varies for different projects and geographical regions. Two of the many research reviews have established the higher values of cost overrun to be 79% and 311% as indicated in Table 1. Although, most studies have cost overrun within the range of 5% to 40%, assumed to be a reasonable quantifiable representation of the cost overrun due to design changes. From the analysis, design changes are related to client, designer, contractor and external factors. The percentages associated with the analysis of these factors lead to cost overrun (Figure 2). The results shows that most of the causes of design changes are related to designer and contractor as 45.85% and 27,1% respectively. However the impact of these design changes are considerably lesser in comparison to clients and external factors which in our analysis contributes 10.45% and 16.7% respectively.

The major players involved in design changes are clients, consultants and contractors apart from the unforeseen or external factors. The opinions of these researchers in determining the topmost player responsible for design changes also varies among the researchers. In a genuine sense, the impact of design changes could be more in case of owner induced design changes associated with the scope of work. The key player who can contribute substantially in eliminating the design changes is the consultant. If consultants can develop a complete design management approach by involving the owner and contractor at the design stages in a collaborative manner as in design-build or lean construction approach, many later on design changes can be avoided. Many of the causes can be get rid of by implementing the effective communication between the parties thereby improving the delivery and authenticity of the information. Active involvement of the contractor during the design phase can make the communication process very fruitful and results in minor design changes in the future. Establishing the collaborative culture and cohesive project environment will improve the project performance and results into better coordination and systematic thinking [6, 37].

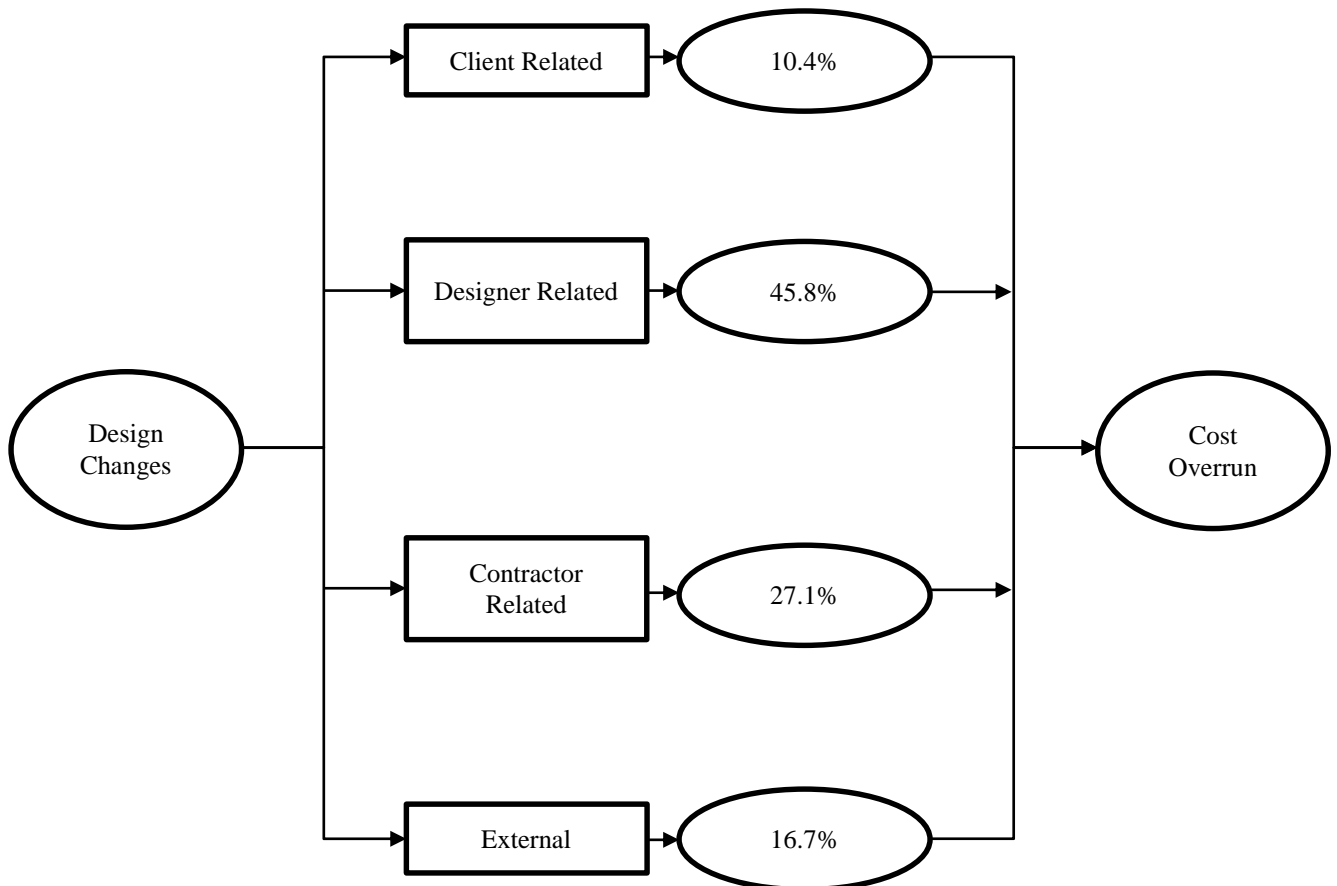


Figure 2. Summary of Results

5. Conclusion

Extensive published literature has acknowledged the unfavorable effect of design changes on project performances but has dealt with the impact and causes of design changes either separately or project specific. As a result, the relationship between impact and causes of design changes could not be established for general construction.

In continuation to fill this gap in research, the effect of design changes on the cost of the project is discussed sequentially by first quantifying the cost overrun caused by design changes and then identifying the causes of design changes to develop the mitigating strategies for overcoming the design changes. As seen from the trend of cost overrun, it can be concluded that due to design changes, the impact on cost varies differently within a range of 5% to 40% on average. However, lack of communication among the stakeholders is considered to be the most critical cause of design changes as reflected by some researchers. It is advocated that effective communication would improve collaboration and would assist in developing the cohesive project environment in management decision-making. The review carried out in this study values the former studies on changes in design within construction literature. The design company can make use of this opportunity to analyze the reasons with the help of production change and redesign costs to target design problems and identify specific methods to improve design performance.

6. Conflicts of Interest

The authors declare no conflict of interest.

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