THESIS

ANALYSIS OF PUBLIC UNIVERSITY FACILITIES COST

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ABSTRACT

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Comparing construction costs between public and private sector projects has been a topic of interest, specifically, which one is more cost efficient. Many researches have compared the two sectors, however, there is limited research with emphasis on university construction. This study focuses on the cost factors influencing project cost performed at public universities and comparing it with similar projects in the private sector. It also presents an analysis of the assorted reasons responsible for the difference or similarities in the two sectors. This study utilizes an exploratory, comparative case study methodology performed on a small sample number of public university projects and two sources of private sector cost data. A thorough analysis with a large dataset is required to conclude a generalizable outcome. The data of four categories of projects collected from five public universities is compared with the cost range obtained from two private entities based on cost per square foot. The results show that most of the public projects have comparable costs to that of their private sector counterparts. The cost data from the university projects is also compared with each other to explore if there are any possible relationships between the types of delivery methods and sustainability certifications based on two project performance indexes; cost and duration. Based on the limited scope of this research it can be surmised that Design-Build proves superior performance when compared to Design-Bid-Build and CM/GC. Based on the limited data, no significant conclusion could be made on the effect of LEED certifications levels on either cost or project duration. This research does provide a starting point for future research into the topic of public sector project costs when compared to private sector counterparts.

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1. INTRODUCTION

The purpose of this research is to compare cost of projects in public with private sector and to examine the various factors affecting the cost of construction at public universities in the US. This was done in two ways. First, the cost of public university projects were compared with those of similar types of projects in the private sector. Second, the cost of Colorado State University's (CSU) projects were compared with those of other public universities of similar size in the region. Third, these data sets identified the cost factors required to analyze reasons for the differences and similarities found in the cost comparison of public university projects.

Background

Construction as used in this thesis is considered the process of planning, designing, and building a facility that adds value to the project owner. Construction is frequently categorized in three broad types: buildings, infrastructure and industrial. Buildings are further divided into residential and non-residential. Non-residential buildings can be commercial or institutional. Dams, bridges, highways, water/wastewater, large public works and utilities are included in the infrastructure sector, also known as highway, heavy civil and heavy engineering. Chemical plants, refineries, power plants, mills and manufacturing plants come under the industrial category (Halpin, 2010).

The life cycle of a construction project includes the planning phase followed by design development, construction documents, bidding/procurement, construction phase and commissioning. The examples of construction phases are summarized below (csp-360.com, 2017):

- During the design development phase, planning and program documents are used to prepare schematic designs.
- The construction documents consist of detailed plans and specifications required to bid and build the facility.

- Bidding involves contractually assigning scopes of work to general and specialty contractor(s).
- Detailed submittals and shop drawings are prepared between the bidding and construction phase, but are generally considered to be part of the construction phase.
- The construction phase begins after detailed submittal reviews and the procurement of materials is completed. For some project delivery methods, the construction and submittal review overlaps for different scopes of work saving time and cost.

Difference Between Public and Private Construction

Public buildings are typically built to last for longer time periods than their counterparts in the private sector. Other differentiating influences may include political and social factors, and public funding through taxing. Due to these reasons, many complexities and conflicts can occur in all phases of public projects. Private projects are often less impacted by many of these factors and are governed to a greater extent by market returns with less influence from political conflicts and social issues.

The efficient use of resources within the construction industry is important (EconomyWatch, 2010) with the industry constituting six to nine percent of the gross domestic product of developed countries (Chitkara, 1998). According to the Associated General Contractors of America (AGC), construction has an enormous impact on the U.S. economy. It has over 650,000 employers and over 6 million employees creating facilities worth $1 trillion per year. The impact of construction on the U.S. economy is significant. One billion dollars of nonresidential construction spending increases GDP by $3.4 billion, adds $1.1 billion to personal earnings, and creates 28,500 jobs (Fuller, 2017).

Beyond standard construction spending, modern technologies are adding value to the built environment. The U.S. Green Building Council (USGBC) stated that the “green” building sector contributes 2.3 million jobs to the construction industry growing to about 3.3 million by 2018. The study also found that green construction accounts for labor income of $134.3 billion annually, which is predicted to increase to $190.3 billion by 2018. The direct contribution of the green construction industry to the GDP is expected to be $303.5 billion between 2015 and 2018. In addition to the GDP contribution and labor income, green construction is expected to contribute $8.4 billion to state tax revenue by 2018 (Shutters, 2015).

The contribution of universities to economic prosperity is significant. According to the National Bureau of Economic Research (NBER, 2017) the future global GDP per capita will be 4% higher if the number of universities doubles. This finding draws on the data from UNESCO on contributions of 15,000 universities in about 1,500 locations in 78 countries (Valero & Reenen, 2016).

Public universities are funded in multiple ways: state appropriations, tuition and fees, donor contributions, federal aid, grants, and research/technology transfer. The construction of facilities on a public university site is carried out by the funds available within the university (program money) or borrowed money from the state, typically in the form of bonds, or by grants and private donations. Debt financed public projects are more common for revenue producing facilities such as dorms and parking structures, which generate income sufficient to pay off the bonds. The university also gets grants from organizations or donor contributions that can be used to fund construction. It is important to understand the source of funds for construction of university facilities as the funds are either tax money, student fees or donor contributions. Investment of these kinds of funds often comes under scrutiny as it is public money and the public agency using it becomes answerable for the efficient use of funds (TheColoradoStateUniversityFoundation, 2017).

Problem Statement

A successful project is one which is completed within the scheduled time and assigned budget, in compliance with contract documentation and satisfies stakeholders requirements (Long, Ogunlana, Quang, & Lam, 2004). Although schedule, contract documents and stakeholders are important, the focus of this research will be limited to the project cost. Project cost is important to investigate because in the beginning of the project, it determines the budget of the project and towards the end of the project, it is an indicator of the performance of the project. A collection of factors influencing the project cost includes project characteristics, project team capabilities, technology utilized, design requirements of the client, contractor's experience and skills, and client's desired level of quality of construction (Park, Kang, Lee, & Seo, 2014). There are many uncertainties associated with the project cost items, especially with complex projects, that include technology, labor productivity, economic conditions, market conditions, prices, inflation and other risks. The reasons for these uncertainties are the uniqueness of projects; variability of time, cost and quality; and ambiguity with respect to information available (Khodakarami & Abdi, 2014). Elhag, Boussabaine, and Ballal (2005) also identified the presence of uncertainties and uncertain factors affecting construction cost. Hence, it is essential to determine the factors governing the cost to get an accurate reliable estimate of the cost of project. Project cost is assessed by various factors occurring before, during and after the construction. These factors include size of project; project location and its impact on cost of transportation and labor availability, cost of material, shipping, taxes and labor wages. In addition, site conditions like geology, soil conditions, ground water level, archeological artifacts, environmental factors, endangered species and existing conditions also affect project cost. Moreover, the project cost may be impacted by inflation over the project construction period, schedule requirements, team efficiency, communication within the project team, insurance requirements, technical review of the performance of project and contingencies (TheConstructor, 2015).

Park (2009) emphasized the need for accountability of money in public projects and on the expectation from the public that agencies spend money wisely. It is expected that public projects should be cost-efficient, safe, within schedule and budget, and meet the institutional standards of quality in accordance with the established budget.

Construction Requirements at Public Universities

There are certain similarities and dissimilarities in the public and private sector. However, the focus of this research is on public universities, hence, listed below are the requirements for construction at public universities.

- A public construction project and a private construction project can be different when it comes to regulations and laws. Different laws effect public construction as it may be subjected to procurement laws and other requirements under local government, state and national government regulations. Some taxes such as sales tax on materials are frequently exempted for many construction costs on public projects. This may lead to greater complexities during procurement and slightly lower material cost structures for public construction.
- Moreover, requirements for university construction face additional constraints like meeting university academic schedules such as beginning and end of semester to ensure the safety and convenience of students.
- University construction projects may also require specific architectural and aesthetic refinements to be consistent with other buildings on campus, which can impact the cost of the project.
- For many of the mission centered construction projects at a university, the project life may be significantly different from that of similar privately-owned construction projects. This needs to be addressed by investing additional budget to meet the intended useful life requirements of the project.

Purpose of Research

Several research studies have examined cost differences of public and private sector construction projects but limited research has focused on comparisons of project costs at public universities with similar private construction projects. The purpose of the research is to learn more about the largely unsubstantiated claim that public sector projects costs are higher than similar private sector project costs. To help inform this research the additional factors of project similarity, economic life, delivery system, sustainability, and scope and duration of the project construction were also reviewed as cost drivers for public university projects.

2. LITERATURE REVIEW

The success of a construction project is partially determined by whether the project is completed within the project budget, making cost estimation and control one of the most important aspects of a construction project (Rahman, Memon, Karim, & Tarmizi, 2013). Frimpong, Oluwoye, and Crawford (2003) add to the definition of project success by stating that success is meeting intended goals and objectives as defined in the project plan. The perception of success of a project varies with different parties involved in the project. The main three parties involved are owner, designer and contractor. Success for owner is completion of project within time and budget satisfying the intended purpose. Designer's perspective for success is delivery of project within design fee and profit margin. The designer also wants the project to be on time and within budget assigned for its own reputation. The project should also be completed with minimum problems and no liabilities. Contractors measure success of project in terms of schedule, profit, budget of project, safety and client satisfaction with no claims (Sanvido, Grobler, Parfitt, Guvenis, & Coyle, 1992). Cost of the project is an important factor from all three perspectives mentioned. Gu, Geng, Xu, and Zhu (2011) state that project cost depends on many technical, organizational and behavioral factors. These factors are determined with practical experience and intuition.

Even though project cost is a concern for the construction industry and perhaps the most important for the success of a project, research shows that projects are often not delivered within budget (Memon, Rahman, Abdullah, & Azis, 2010). The dynamic characteristic of the construction industry is due to the varying technology, budget and development process (Chan, Scott, & Chan, 2004).

Past research has shown that qualitative factors such as project complexity, project team interactions, contract requirements and market requirements are perceived as affecting estimates of construction cost more than the quantitative factors like gross external floor area, median floor height and construction duration which are fixed by the contractors and designers during initial phases of construction (Toh, Ting, Ali, Aliagha, & Munir, 2012). In total 79 cost factors identified were distributed into seven categories that are project complexity, technological requirements, project information, project team requirements, contract requirements, project duration and market requirements. Out of these 79 cost factors, only 35 were acknowledged as cost factors having effect on building industry by building contractors of Klang Valley, Malaysia through survey. Lowe, Emsley, and Harding (2006) suggested five variables as main cost drivers: gross internal floor area, function, duration, mechanical installations, and piling. The authors also noted type of procurement as a cost factor in a building.

Construction project cost is affected by project specific factors such as technology, design requirements, capability and management of contractor and level of construction sophistication, and characteristics of the project team (Chan & Park, 2005). Since the construction project is a multi-disciplinary undertaking involving many parties such as owner, design professionals, contractors and suppliers, combined efforts of all parties regarding decision making in field of design, implementation and technology affects the cost. Chan and Park (2005) also identified that high technological level, special skills of contractor, and public administration of the contract have major impacts on construction cost. In addition, technical expertise of contractor, owner's level of sophistication and contractor financial management capability also effect cost. To reach this conclusion, the authors collected data from Singapore building projects that were finished after 1992 and cost more than US$5 million.

Elhag et al. (2005) identified qualitative factors such as client's construction schedule, planning skills of contractor, procurement methods and market conditions as crucial factors for governing construction cost. With the help of literature reviews and interviews with quantity surveyors of north England, the authors identified 67 factors affecting pre-tender cost of construction and divided these factors into six different categories: 1) client characteristics, 2) consultant and design parameters, 3) contractor attributes, 4) project characteristics, 5) contract procedures and procurement methods, 6) external factors and market conditions. The methodology adopted was questionnaire survey of randomly selected 218 surveyors, of which 31%

responded. It was found that the factor affecting construction cost the most is the consultant and design parameter and the factor affecting the least is the contractor attributes showing that architects and designers have more influence over construction cost than the contractor.

Park et al. (2014) proposed an estimation model, which incorporated building information modeling and geographic information systems, for national road building cost and acknowledged construction costs, land acquisition costs and operations and maintenance (O&M) cost as the factors for project cost. The construction costs included cost of constructing bridges along with associated structures and related expenses. Land acquisition cost depended upon the average land values and acquired area. O&M costs are comprised of road repair, resurfacing and facility repair along with any bridge and/or tunnel repair and rehabilitation. It also included general repair, emergency and operations cost.

Highway projects from the year 1984 to 1997 from the State of Louisiana were used to prepare a construction cost model, which replicated the cost of past projects, to predict the cost of projects constructed between years 1998-2015. Details like contract cost, construction type, functional attributes, date of letting, and duration, location and changes in the contract were collected from 2827 highway and bridge projects. Wilmot and Cheng (2003) found that the model gave double the cost for the new projects. Cost of material, labor and equipment were the most prominent factors affecting the construction cost. Authors found that cost of petroleum products and construction machinery are the major factors leading to an increase of construction cost during the project. Other factors affecting the cost were specifications and standards of each contract, bid volume and changes to it, and changes in plan and construction practice.

Park (2009) identified 188 individual factors and categorized them into eight divisions to identify critical success factors: project scope (14), time (23), cost (38), quality (18), contract/administration (20), human resource (21), risk (20), health, and safety (20). Ten factors were common. Cost has the most number of factors assigned to it and is found to be the most critical factor for the success of project. This comes as no surprise, as there is less value created if the project is not competed in the assigned budget or is not profitable.

Cost predictions impact budget decisions which in turn impact the end result of projects in terms of scope, quality and functionality. Attoh-Okine (2002) identified the certain and uncertain factors effecting the cost of project as inflation, season and amount of construction activity. The cost components in highway projects as mentioned by the author are design cost, construction cost, maintenance cost, user cost, environmental cost and salvage value cost. Also, factors taken into consideration while predicting the construction cost are number of laborers used, material used, utilities required, floor space of construction, sales, overhead, schedule and other costs occurring over a period (Smith & Mason, 1997).

i. Design Cost

There are three stages of transportation design namely: phase 1 (preliminary design), phase 2 (preparation of construction documents) and phase 3 (construction inspection and contract administration). A study was conducted on highway projects of Illinois Department of Transportation (IDOT) to model design costs of consultant designed projects which involved estimating total labor hours and related design costs in phase 2 (Nassar, Hegab, & Jack, 2005). This data was from 59 projects from different districts of IDOT covering the entire design process and it was found that design costs could be predicted accurately to a certain extent only by using the mathematical model developed in this research and can be used while negotiating design costs.

Griffis and Choi (2013) performed a research study on the public projects in the state of New York. The focus of the research was to compare the cost of design if it is performed in-house or contracted out to private engineering consulting companies. The authors chose transportation projects and NYSDOT (New York State Department of Transportation) as it performs 50% to 80% of design in-house. The cost of design engineer varies in public and private industry. It was found that the public industry design engineer costs approximately 15% more than the private engineer to the taxpayer that affects the cost of the project but was not the sole reason for outsourcing of design of public projects. This means that total cost of NYSDOT career employee would be $6.5 million. The decision to design in-house versus outsourcing is based on cost effectiveness, best output in the least price, and consists of two basic factors related to procurement of design or inspection First is cost of design or inspection services and the second is life cycle cost of project. Cost of design and inspection consists of salary and benefits, and consultant overhead. Calculating the direct salary and benefits is the easy part but working out overhead of consultants is complicated. This is due to the cost of consultants included in their proposals. Moreover, the in-house costs do not have overhead costs for in-house professionals. Design cost is a small portion of the life cycle cost, usually 1%. A project can cost much more if not completed on schedule and the cost may also increase due to inflation with time. Hence, for engineering/design projects the DOT might have to consider whether to perform work in-house or outsource it. Direct cost analysis might show that in-house is beneficial but due to above mentioned reasons life cycle cost may increase and the benefit may turn to loss with time. In such cases, outsourcing seems to be a better option. The delay of the project, if performed in-house, could occur due to heavy project backlog. Sometimes selection of the private designer based on suitable qualifications may take up to 3-6 months delaying the project. The cost can also be affected by the design faults due to in-house inexperience with certain kinds of projects. This may also lead to outsourcing of design work to private firms.

Knight and Robinson Fayek (2002) developed a model, aimed to work during proposal or early phases of project, to predict design cost that was applicable to structural, mechanical and electrical design work. The design firms taken into account were consultants or client's consultant. The contract type was guaranteed maximum price with either project manager estimating the fee or fee as certain percent of total price. The size of the project varied with fee ranging from $100,000-$500,000. The authors wanted to create project awareness with this model and not to provide an estimation model. After consulting the design firms, project characteristic is identified as the major factor affecting project cost. These characteristics included time used for making decisions, knowledge base of client, project scope, scope definition, project manager's experience, client's consultant's experience, skill of design team, project team's experience, complexity of project, timeframe allotted and location. The authors focused on the importance of design by mentioning that the designers need to complete the design within the given time frame with no errors and should be in limit of the cost assigned both for design and for construction. This makes project design extremely critical and designers responsible for the successful project. Many things may cause fault in design, for instance, internal mismanagement, miscommunication and ill-defined scope of work leading to rework.

Riley, Varadan, James, and Thomas (2005) developed a model to quantify the cost of design of coordination for case study projects because coordination is a challenging and complex multidisciplinary task. The research focusses on the MEP coordination costs and benefits, and level of effort invested for effective coordination. Coordination not only involves coordination between different trades but also between structural and architectural systems. Variables affecting this cost identified are MEP density and plenum height. The authors focus on the importance of the MEP coordination by stating that effective coordination can avoid field conflicts in the project. The cost of such conflicts is difficult to predict as it varies with timing and type of interference, redesign requirement, and amount of trades impacted.

ii. Economic Life

Total cost incurred throughout the life of a project is the project cost (Ellis, 2007). It is composed of acquisition, facility management and disposal cost. The accurate estimation of initial cost, which comprises costs at all stages from design to construction to operating and maintenance cost including the profit made by the project, determines the project success (Kim et al., 2010). Since initial investment and maintenance cost are taken into account for life cycle cost analysis, the comparison of initial cost of construction is impacted by the quality, economic life, and operating efficiency of the initial design. When comparing cost of projects with similar functionality, the impact of economic life must be considered. The initial cost includes design, construction and supervision cost.

The literature has used different terms to define life cycle cost: cost in use, life cycle cost (LCC), whole life cost (WLC), and whole life appraisal (WLA). WLA not only includes the expenditure on the structure but also the revenues and performance associated with it over the period. Schade (2007) emphasized the importance of early investment to the construction client, a point also highlighted by Flanagan and Jewell (2008). These authors say that higher production cost can reduce the life cycle cost of the building. Therefore, comparison of initial project costs should take into account life cycle costs, at a minimum expressed by economic life of systems within in the building.

A life cycle cost assessment is essential for the project management in order to take necessary steps to control them (Woodward, 1997). The author states that many public and private organizations do not consider life cycle cost in the total capital. Life cycle cost begins with acquisition and ends at disposal of the physical asset. The author identifies the factors of life cycle cost as initial capital, O&M (operating and maintenance) cost and disposal cost. This is also supported by El-Haram, Marenjak, and Horner (2002) who identified these costs as WLC i.e. project cost inclusive of all direct and indirect costs. The initial costs were purchase, acquisition, finance, installation, commissioning and training costs. Operating cost consists of direct (labor, materials, expenses) and indirect (labor, material, establishment) costs. Maintenance cost (direct labor, material, fuel, equipment and services) was affected by planned, unplanned and intermittent maintenance. Disposal costs included demolition, scrapping and selling costs of the asset after it has finished its working life. The authors divided the above-mentioned costs into three categories: capital costs, facility management costs and disposal costs. The capital costs include costs of design, construction and commissioning of the facility. Facility management included the operating and maintenance costs. Disposal is the same as mentioned above.

Chang and Shinozuka (1996) emphasized the importance of life cycle cost and its inclusion in the project cost in order to make sure that the economic life of the infrastructure is considered in evaluating initial cost. The authors support this by mentioning the United States Intermodal Surface Transportation Efficiency Act (ISTEA), 1991 law that states that it is compulsory to have life cycle costs along with initial costs in the design and engineering of bridges, tunnels and pavements (Markow, 1995). The life cycle cost means the cost incurred on a project from the start of construction to the end of the facility life, including user costs, which is the societal cost during serviceability like maintenance work.

Hu, Wang, Liu, and Gao (2011) illustrated the importance of life cycle cost of bridges. There could be alternative designs to a single project but all alternatives need to be explored to identify the best option considering economic feasibility and life-cycle cost minimization. The construction of bridges included planning, project feasibility study, design and construction cost. The authors defined the life cycle economy cost of bridge as the total value of resource consumption during the useful life of the bridge. This cost comprised of direct costs such as planning, study, design, experiment, construction, maintenance, repair, management, insurance and disposal. In addition to the direct costs, it also included user, societal and environmental costs. The above costs were divided into construction, operation and disposal costs. Construction costs were from the planning to the completion of the construction. The operation costs were inclusive of costs beginning with services to the exit of the project. Disposal phase costs were inclusive of workers, equipment, materials, waste removal and recycling.

Investment for long economic life of the structure is important but there has to be a balance in this investment because beyond certain limit, further investment is wasteful and does not contribute to value in terms of the ratio of benefit to investment (Rosenfeld, 2009). This research involved eight ISO9000-certified construction companies that have vast data related to types of defects, their frequency, severity, causes and repair costs for future analysis in order not to repeat the same error. Due to the sensitive nature of data, only eight companies participated in the study, but these eight companies constructed about 13%

of all the housing units in the whole country. Hence, the number of companies participating is small but is considerable with respect to the industry. The results of this research supported the worth of investing in quality and the ratio of direct benefit to investment is around 2:1. The range of investment comes out to be 2% to 4% of company's revenue. The various direct costs related to quality analyzed in this paper are prevention costs (cost to prevent irregularities defects, mistakes during process), appraisal cost (cost invested to ensure quality), internal failure cost (cost to prevent irregularities defects, mistakes before handover) and external failure cost (cost to prevent irregularities defects, mistakes after handover). There are various hidden, intangible and indirect costs also involved. Investing less than 2% leads to failure costs and investing more than 4% resulted in diminished payback. Therefore, it appears that quality and economic life differentials have an important impact on initial costs, but this impact declines rapidly after 4% cost increase over baseline quality. This finding is important because it provides support for a narrow range of quality impacts on initial costs.

iii. Region

The factors affecting construction cost are country or region specific and should be taken into consideration (Toh et al., 2012). Responses of architects, engineers and surveyors of Nigeria showed that cost of materials, fraudulent practices and kickbacks and fluctuation of material prices are the three major causes of high construction cost (Elinwa & Buba, 1993) (Elhag et al., 2005) (Toh et al., 2012). High construction costs in Nigeria were due to inefficient human and material losses, shortage of materials, financing options and work payment, and poor contract management, but the most significant factor was price fluctuation. These problems are mostly associated with the underdeveloped countries and do not necessarily influence the construction cost in developed economies (Okpala & Aniekwu, 1988) (Elinwa & Buba, 1993) (Elhag et al., 2005). Due to the prevalent corruption in the Brazilian construction industry, the price generally exceeds the SINAPI's median, a database for quantities and quartiles for unit prices, by about 10% for the overall project cost. The corruption is at every step, from irregular quantities, overprices, quality, economic and financial balance to tax and profit (Signor, Love, & Olatunji, 2016). Wilmot and Cheng (2003) highlighted that districts are not consistent in their prices when compared with each other but certain patterns can be observed like asphalt pavement construction. This is based on research conducted by the authors on 2,827 highway and bridge projects constructed between 1984 and 1997 in Louisiana. The model developed for cost estimation purpose of highway construction included labor, materials, equipment, type of contract, and environment. It is expensive in remote areas with respect to asphalt construction sites. In addition, districts with less wetlands and clay have more of embankment materials. The important finding from this research is the impact of regional market factors on even basic commodity material prices.

In contradiction to the developing economies, developed economies like UK have cost factors such as project complexity, technological requirements, project information, project team management, contract requirements, project duration, and market requirement (Akintoye, 2000) (Toh et al., 2012). The study by Akintoye (2000) involved 84 very small, small, medium, and large firms in the UK. Above mentioned factors were found to be the governing ones from the 24 factors given consideration. Ashuri, Shahandashti, and Lu (2012) mentioned that leading factors for construction cost in UK are interest rates, investment intentions, architects' new commissions, production drawings, enquiries, orders, expected volume of work and building cost. Energy prices, which are usually ignored, are also among the factors affecting construction cost. In addition to energy, studying stock market indices, which are widely available, can be explored for correlations with construction cost.

Based on literature review, Kim, Han, and Kim (2008) adopted 64 factors affecting cost and divided them into five categories. This study was done to assess cost overrun factors in international projects. The five categories are situation of the country where the project is and owner of the project; type of bidding; project attributes and contractual conditions; organization and participants' characteristics; and skillset of contractor.

iv. Sustainability

Developers of UK are concerned about the application of green agenda. They believed that it would increase the cost, risks and even difficulties in getting financial support. Due to insufficient data of sustainable projects, it was difficult for the developers to make informed decisions about sustainability. Zhou and Lowe (2003) reviewed the literature to assess the benefits of sustainable construction against the challenges and limitations associated with it. Contrary to the general perception, it was found that business benefits were made by the pioneer projects in UK. The authors suggest that the stakeholders can be encouraged to use sustainable methods if economic performance of sustainable construction is established. The clients and professional consultants need to be educated about the long-term benefits of sustainable construction and creating a green built environment. Sustainable construction reduces the operating and maintenance cost thus increasing the performance and durability of the structure. It also creates an ideal living and working environment that improves the productivity and reduces the running cost in the long term. Some of the economic benefits mentioned in the paper are "total cost savings, tax savings, added value, more efficient resource use, productivity improvement, increased organizational effectiveness, positive image and support for local economy".

With the increase in environmental awareness, an innovative construction approach is being adopted in Malaysia named Industrial Building System (IBS), which has the advantage of decreasing construction duration, lowering project cost, improving quality, enhancing occupational health and safety, reducing construction waste and harmful emissions, and decreasing consumption of water and energy (Bari, Yusuff, Ismail, Jaapar, & Ahmad, 2012) (Kamar, Alshawi, & Hamid, 2009). Bari et al. (2012) studied the Malaysian industrial building projects to identify the factors influencing construction cost and ranked them per the preference of Malaysian IBS (Industrial Building System) stakeholders. These factors were associated with the project characteristics, contract procedures and procurement methods, government requirements, contractors' and consultants' attributes and design parameters, economics and external market conditions.

Green building refers to planning, design, construction and operation of a building considering energy use, water use, indoor environment quality, material section and effect of building on site (Kriss, 2014). A study (Rehm & Ade, 2013) conducted on 17 green buildings of New Zealand to assess the impact of such construction on the cost of project found that the cost of green buildings is higher than the modelled costs obtained from Langdon Blue Book and Rawlinsons New Zealand Construction Handbook but statistically insignificant. Moreover, conventional energy efficiency technologies can reduce the energy use by 20% to 30% in a commercial building. The life cycle cost is negative as the HVAC used is smaller and cheaper because of improved efficiency. Furthermore, the decrease in carbon footprint by approximately 16% can increase the life cost effectiveness (Kneifel, 2010) (Rehm & Ade, 2013). Life cycle cost can be decreased by increasing the energy efficiency by investing in decreasing carbon emissions (Kneifel, 2010).

v. Public vs Private Construction

Since public infrastructure contributes to the development of the economy, its availability and quality is extremely important (Sobotka & Czarnigowska, 2007). However, there is a need for private sector involvement in development of built environment infrastructure as there are limitations to public funds. Although public infrastructure is not required to be "profitable" financially, they should serve their purpose with the efficient use of limited public funds. Apart from the initial planning and construction, maintenance and operation costs are an important financial consideration. Since these financial requirements are to be determined at initial phases of a project, the projects managers should focus on determining the cost required to achieve the purpose of the facility and not just the initial cost of project.

Public construction projects are different as they have additional rules and regulations including that of military construction (MILCON) which represents 40% of United States' $30 billion federal construction investment. Blomberg, Cotellesso, Sitzabee, and Thal (2014) identified overarching techniques like failing to balance risk, additional public sector requirements, use of innovation, choice of construction specifications, and parametrization of implementation process to influence cost premium a lot along with 28 other factors. The study revealed that MILCON cost is more than that of private construction due to the above mentioned five factors.

Two factors, which are mainly governing the public project cost, are construction cost and engineering services cost, consisting of both design and site supervision (Hyari, Al-Daraiseh, & El-Mashaleh, 2016). The authors focus on the services cost in the paper by interviewing seven large consulting firms in Amman, Jordan and identify four factors affecting the cost namely; project type, category of engineering services, project location, construction costs and project scope. Project type was subdivided into buildings, transportation, water and sewage treatment and land developments projects. Design services, construction monitoring and supervision were subdivisions of engineering services. Project scope includes whether the construction is new or is the maintenance of an existing project.

The benefits of infrastructure privatization are primarily due to private sector's innovation and cost efficiencies. It mostly occurs in the selection/design and operation/maintenance stage and not necessarily in the construction stage. Maximum benefit can be achieved from ownership transfer and not just from operation and maintenance contract (Liddle, 1997). The author discusses the boost in privatization of infrastructure as it lowers the public budget deficits and helps overcome the infrastructure crisis prevalent in the country. The privatization of projects can occur in three ways: contracting out operation and maintenance to private company, selling constructed facility to private firm, and contracting construction, ownership and operation to a private company. Various factors improve the cost and performance in private construction compared to public projects. The aim to make profit encourages cost cutting, customer value increase, performance incentives and use of efficient resources. Public employees tend to have lower performance as their salary is linked to organizational position and not to project performance. Moreover, private companies can perform with more flexibility and freedom than public sector firms can as the public sector is influenced by bureaucracy and public interference. Private companies have skilled staff and research professionals who could be utilized when needed on other projects as they have many projects running parallel without the need of hiring contractors unlike in public sector. Private sector can also create more projects and increase investment but public sector organizations are limited in their ability to increase capital investment.

vi. Delivery System/Type of Contract

Due to an uncertain economy and a limited number of construction projects, the public sector, including public universities, is adopting alternative methods of project delivery. Shrestha and Fernane (2016) investigated 77 construction projects at United States' public universities to analyze cost, schedule and change orders for Design Build (DB) and Design Bid Build (DBB) projects. The study revealed that DB surpassed DBB in schedule saving and reducing change orders. An extensive study performed on 418 Design Build projects from database of DBIA (Design-Build Institute of America) supported the superior performance of Design-Build project delivery system in terms of cost and time performance. The focus of the study was time cost overrun (TOR), early start rate (ESR), early completion rate (ECR), and cost overrun rate (COR). It was found that more than 75% DB projects were completed within schedule but over 50% faced cost overrun creating uncertainty with cost efficiency of the project delivery system (Chen, Jin, Xia, Wu, & Skitmore, 2016).

Design build projects have many advantages over design bid build, including cost savings (Long, Banowsky, & Herrera, 2007). However, some difficulties are associated with this delivery method when it comes to public projects. This is due to the limitations on procurement, budgeting and tracking of projects. Long et al. (2007) explored the advantages of implementing design build method on wetlands mitigation project for Port of Houston Authority having total cost of less than $2 million, tight schedule and influenced by the weather conditions. Advantages noted in this research for using design build method are: tight schedule requirement was met, design changes were made within two weeks (something that takes months usually), field condition changes were met appropriately within schedule and adjustment of redesign costs was made within the project authorization keeping administrative burden to a minimum.

A study conducted on buildings by military construction (MILCON) to analyze the performance of design build and design bid build project delivery method proved the superiority of design build in terms of time and cost (Hale, Shrestha, Gibson, & Migliaccio, 2009). This study is meaningful as all the projects belonged to U.S. Navy Bachelor Enlisted Quarters. The parameters compared were project duration, project duration per bed, project time growth, cost growth, and cost per bed. This study involved 39 DBB projects and 38 DB projects of Naval Facilities Engineering Command (NAVFAC) between fiscal year 1995 and 2004 constructed by MILCON. The schedule of the projects varied from 404 days to 1078 days for DB and 675 days to 3160 days for DBB. The project cost for DBB was roughly $4.7 million to $27 million and for DB $3.7 million to $37.5 million. Contrary to this study, however, another research study found unconvincing positive impacts of DB over cost and productivity although the delivery system still proved beneficial for saving time (Ibbs, Kwak, Ng, & Odabasi, 2003). This study showed the greater impact of contractor experience over project performance irrespective of project delivery method adopted. The 67 projects selected from US with installed cost of more than $5 million (mostly between $25 million and $75 million) were having different project delivery methods including DB and DBB and contract types.

Tran and Molenaar (2012) emphasized the importance of selecting project delivery methods in the decision-making process by selecting 39 project delivery risk factors based on cost and schedule risk analysis of highway projects more than $100 million. Experts having more than 25 years of relevant experience were questioned via survey aimed at collecting data of three project delivery methods: DBB, DB and construction manager/general contractor (CM/GC). The authors found that different project delivery systems are better suited to manage different types of project risks. For instance, constructability of design was found to be a significant risk in DBB but was not perceived as a risk in DB and CM/GC.

Success of a project is measured in terms of its technical performance, schedule and budget compliance (Kim, An, & Kang, 2004). The study analyzed groundwater projects of Ghana and found that poor contract management is the major cause of projects exceeding their budget. This is due to low bidding contract award process, which makes inefficient bidders win projects that they fail in performing.

vii. Season

Reliable construction cost prediction is important in the construction industry as it can affect the decisions of contractors, investors and financial institutions. Hence, construction companies should take fluctuations in prices into account in creating cost estimates. Initial cost estimates can be affected by government policies such as taxes and seasonal events (Jiang, Xu, & Liu, 2013). Price of a project may also way with the seasonal changes in labor demand and material availability. Hence, this seasonality effect should be taken into account for construction pricing (Skitmore, Runeson, & Chang, 2006) (Jiang et al., 2013). Skitmore et al. (2006) found from literature that transfer of resources can counter the impact of such change in demand. In addition, they found that many firms are diversified and can handle transfer of resources internally across markets. Even transferability of resources does not help while taking into account the geographical change in demand affecting the tender prices heavily. Seventy percent of experienced construction contractors, in the UK emphasized the importance of cost in the industry by acknowledging cost of labor, material, plant, subcontractor, location and transportation, type and size of job, contract period, tender period, competitors, client, and professional service availability affecting the tender prices. Fellows (1991) highlighted the magnitude of seasonal impact by generating time series models that showed buildings cost indices are affected by annual affects and non-seasonal factors have impact on tender prices.

viii. Type of Project

The cost drivers in Germany based on the research done on 70 residential properties are found to be compactness of building, number of elevators, project gross external floor area, tentative project duration, opening ratio in walls, and region (Stoy, Pollalis, & Schalcher, 2008). Hollar et al. (2013) reviewed 461 bridge projects of North Carolina DOT between 2001 to 2009 and stated that preliminary design costs for a project are generally a percentage of construction cost depending upon the project parameters. The authors found that percentage of preliminary engineering cost in bridge projects is 28% but the usual practice is much more than this percentage. A survey was conducted on building constructors of Klang Valley, Malaysia to determine the critical cost factors among 79 cost factors identified from literature review. Only 35 factors were found as highly relevant factors by the small, medium and large construction companies amongst which client's requirements was the most critical one identified (Toh et al., 2012).

Lu, Niu, Qiu, and Liu (2015) broke down the construction cost of transmission projects into four types of expenses: construction cost, equipment purchase cost, installation cost and other costs. The authors identified 20 factors influencing construction cost from literature, including location, pollution limit, altitude, topography, number of transformer sets in a period, substation capacity, total area of site, total area within the wall, total construction area, main control building area, length of cable, ground levelling, ground filling, foundation treatment, entrance to substation, cable channel volume, wells, ditch and pond volume, steel, steel frame, cement and other materials weight. Other costs identified were site acquisition cost and clean-up costs during initial stages of construction.

Cost of labor, materials, equipment, item quantity, contract duration and location, quarter of year when the contract was let, annual bid volume, bid variance volume and changes in plan, standards and specification were identified as the factors affecting highway construction cost by Wilmot and Mei (2005). Love (2002) investigated the influence of type of project and procurement method for rework cost of construction. He emphasized the magnitude of rework cost by studying 161 Australian projects and found that rework constituted 52% of the projects' cost growth. The findings showed that type of project and procurement method have similar impact on rework cost.

A study examining the project cost of rehabilitation and replacement of water pipeline projects for mortar lining, microtunneling and sliplining found that the length of the project, diameter and material of pipe, access to pipe, cleaning and excavation, removal and replacement of valves, fire hydrants and contingencies, bypass and connections, traffic control and removal of obstructions govern the project costs (Selvakumar, Clark, & Sivaganesan, 2002). The length of the pipe was considered as the governing factor for cost. Moreover, the study lacked in considering major factors like valves and hydrants as cost items (Shehab, Nasr, & Farooq, 2014). Another research conducted for cost modeling of water supply distribution system showed that engineering; general contractors' overhead and profit; land acquisition; legal, fiscal and administrative costs and interest during construction impacted the total project cost (Clark, Sivaganesan, Selvakumar, & Sethi, 2002). Shehab et al. (2014) states that the above research includes 14 cost items such as pipe materials, valve, trenching, embankment, backfilling, boring, shoring, connections, removal, traffic control, lining, and corrosion control but lacked factors like chambers for inspection, curbs, gutters sidewalks, and abandoned pipes.

The construction cost of piling is dependent on the location and time, which means that similar scope can have different costs in different locations and/or and at different times. This can be elaborated as subsurface conditions, site conditions, pile geometry and specifications, weather, transportation means, governmental and environment laws, equipment, economics, contractors' experience, and contract requirements. It can be observed that the mentioned factors are location and time related. It is also dependent on factors like inflation, market prices, availability of materials and pricing. This study involved surveys conducted on 96 contractors and consultants, specialists in bored piling (Zayed & Halpin, 2005).

Najafi and Kim (2004) presented a cost comparison of life cycle cost between open-cut and trenchless pipeline construction. They broke down different aspects of project cost i.e. engineering and capital cost, and social cost for both construction methods. The various project cost factors examined in this study are preconstruction cost (planning and engineering), construction cost (direct, indirect and social) and post construction cost (operations and maintenance). Preconstruction cost is further broken down into land, permits, easements, design, planning, legal and contract drawings cost.

Determination of project cost is important for planning, budgeting and monitoring (Kim, Yoon, An, Cho, & Kang, 2004). Cost is one of the main criteria while making decision for a project feasibility during the design phase. Cost control plays a major role in sustaining contractor operations in the construction market (Günaydın & Doğan, 2004). The total area of the building governs the cost of project, which ultimately leads to the amount of material used for components of the building.

Summary of the Factors Affecting Cost

The factors identified through literature analysis above that affect the facility cost directly or indirectly can be categorized into four major groups:

- Economic life
- Delivery systems
- Sustainability
- Scope and duration of project construction

The design quality of the project affects the economic life, sustainability requirements and scope/duration of the project. Hence, the design as well as the cost incurred on design is an essential part of total project cost. Similarly, the region where the facility is located plays key role in determining the cost of construction of the facility. Cost of labor, material, equipment and environmental requirements along with price fluctuations in the region influence the schedule and cost of the entire project. In addition, the interest rates, local laws, taxes and regulations affect the project cost. Laws, taxes and regulations are also the primary reasons for difference in public and private construction. Moreover, public projects have additional requirements and specifications for procurement and construction standards. Private sector is profit motivated, hence tends to be more short term focused than the public sector. Private sector provides more flexibility and freedom to its employees than the public sector that can help in better individual performance. Furthermore, the public employees' salary is not linked to performance but to the position in the organization. The delivery systems are found to have significant impact over schedule savings, change orders and thus the construction cost. The delivery systems are found to have some difficulties in public projects due to the limitations on procurement, budgeting and tracking of projects. The seasonal/annual changes influence the demand for construction and affects the cost of construction. Type of project/facility is found to be one of major factors having effect on cost like compactness of the building and requirements of the building.

3. METHODOLOGY

This chapter presents the methodology used for collecting and analyzing data. The factors affecting project cost were identified through the literature review and interviews with the Facilities Management Department of CSU. Project data was collected from other public university's' Facilities Management Department via electronic mails with follow up messages and telephone calls. In addition, private sector data was collected from published cost reports from Rider Levett Bucknall (RLB) as well as proprietary cost information shared with the research team by a large, national contractor.

The research utilizes an exploratory comparative case study methodology (Creswell, 2007) using archival information, electronic mails and websites for collection of project data. CSU's archival data is referenced for completed project cost and is confirmed in meetings or via electronic mails with the relevant project participants. A brief summary of data sources and processes include:

- Most of the projects at CSU that are part of this study were complete at the time of study. Therefore, past records (or archives) were referenced for projects' data. In addition, knowledgeable officials from CSU Facilities Management Department were interviewed or contacted via electronic mail for confirmation of this data.
- The facility management websites of the comparison universities were referenced for initial data collection. This data was then sent out to the facilities department of the respective universities for confirmation and addition of missing data, if any.
- RLB cost data for private industry is obtained via electronic mail with reference to the web link containing the cost report data. The RLB data used in this study is the quarterly construction cost report for the third quarter 2016 (RiderLevettBucknall, 2016).
- Private sector cost data was provided by a large, national general contractor to validate the private sector cost data from the RLB quarterly report.

- Lastly, R.S. Means location adjustment factors were referenced to adjust cost at other locations to Denver value (RSMeans, 2016).

The basis of selection of comparative case studies started with a review of all facilities constructed at CSU in the past 5 years. CSU has a significant capital improvement budget including completion of $500M of construction on 12 projects in last two years. The case studies selected included parking structures, laboratory-intensive buildings, general classrooms and housing (dorms) projects. The projects, mentioned later in this section, were categorized based on these four types of facilities as they represented the core of standard building projects a typical university would undertake. Several projects, such as stadium, health services and recreation facilities, were considered atypical, "one-off" projects that would not represent typical construction across universities and therefore would not be appropriate candidates for comparison case studies. Donor funded projects are excluded from this study as the constructed facility is based on the requirements of donor and often found to be more expensive than like kind counterpart facilities.

Cost Impact Factors

The factors considered when comparing project cost in this study are:

a) Project scope (gross square footage and functional metrics)

b) Economic life

c) Sustainability (LEED rating)

d) Type of delivery system

e) Similarity of projects

Comparative variables were initial contract amount, design cost and duration. Table 1 below represents the data array sent to all case study participants.

Table 1: Sample of table forwarded to the universities for data collection:

Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers? (Y/N)	Gross square feet	LEED rating	Project scope metric
Name of facility										

Stipends for Proposer (Y/N)

Stipends are the amount paid by the university to the bid proposers on design-build projects in order to compensate them for the investment they made in preparing the proposal. Since the stipend is not an investment in the project construction, it is not used in the cost comparison in the results section. This information was collected at the request of the Facilities Management Department of CSU to determine prevailing practice among public universities and is not a determining factor in the study.

Project Scope Metric

Project scope is the most crucial factor affecting project cost. Therefore, any cost comparison between public and private sectors must attempt to normalize scope. The method for normalizing scope effects was to compare projects of similar type. Another proxy for scope is project size in gross square footage of floor area. A third project scope metric is functionality such as number of parking stalls for garages, number of seats for classroom buildings, number of beds for housing projects, etc. To control for scope effects, projects are categorized by type (parking structures, classroom buildings, lab buildings, and dorms), and then a cost per gross square foot and a cost per functional unit are calculated for comparison purposes.

Colorado State University Data

CSU is a land-grant institution located in Fort Collins, Colorado with about 32,000 students (Forbes, 2017) and campus size of 586 acres (U.S.News&WorldReport, 2017a). The region experiences semi-arid climate with low rainfall and four distinct seasons. The summers are mild to hot and dry, and winters moderately cold. The university is currently in a period of extensive new construction, remodeling and reconstruction. This research involves analysis of construction cost comparisons of CSU projects with similar projects at other universities of similar size and mission, as well as comparison to cost of comparable private sector projects. The cost value used for analysis is the initial contract value of construction and design and not the total final construction cost. In public sector construction, final costs often include some expenses that were unrelated to the project and involved payment for development across the university, such as sidewalk replacements or utility upgrades not directly related to project scope. If an owner's contingency is unspent after most risks have passed, many public owner's will use the contingency to buy additional scope, which is not an accurate reflection of project cost. Therefore, the final cost reported on projects is slightly higher than actual project cost due to such payments for additional work outside the project scope. Hence, project costs are considered as the initial contract value for Design-Build (DB) projects, whereas design fees plus initial construction contract cost is considered for CM/GC and Design-Bid-Build (DBB) projects.

Sampling of Comparable University Projects

The universities considered for the cost comparison and construction cost analysis are all public universities. Because procurement and contracting regulations do not apply to private universities, cost comparisons may not be valid between public and private universities. Moreover, the funding sources at public and private universities are different, with tuition and fees at private universities almost double that of public universities. Private universities are not bound by state design and construction standards and are not eligible for state program money to support building campaigns. This gap in standards and funding may influence the investment for construction. Hence, private universities are not considered in this research.

The public universities included in this research have similar size, mission and organizational structure as CSU. All universities in the sample are in the western or southwestern U.S. Listed below are the universities and their respective data relevant to this study. Data on the capital for projects included for comparison from each university are included in Chapter 4.

i. University of Houston

University of Houston is located in Houston, Texas with an enrollment of over 43,500 students (UniversityofHouston, 2017) and area of 594 acres (U.S.News&WorldReport, 2017c). Houston has mild winters with rare snowfall and long, hot summers with ample rainfall; average rainfall is 49.8 inches. Houston has a larger population and geographical size both larger than Fort Collins and dissimilar climate. CSU and University of Houston are both large public universities that have undergone a substantial capital building program in the last five years.

ii. Kansas State University

Located in Manhattan, Kansas, Kansas State University has approximately 24,000 students (KansasStateUniversity, 2017). It is America's first fully operational land-grant university. The main campus covers an area of 668 acres. Manhattan has hot, humid summers and cold, dry winters. It has 35.7 inches of precipitation annually on an average. The city of Manhattan has lower population than Fort Collins but both cities have dry cold winters and both Kansas State University and CSU are large land grant universities.

iii. University of Colorado, Boulder

Situated at the base of the Rocky Mountains in Colorado, the University of Colorado Boulder (CU) has approximately 31,000 students (UniversityofColoradoBoulderIR, 2016) and a campus area of 600 acres (U.S.News&WorldReport, 2017b). Boulder has warm, dry summers and cold, long winters. Both Colorado

State University and University of Colorado Boulder have similar size, location, climate, topography, and share similar construction market forces.

iv. University of Utah

The University of Utah is situated in Salt Lake City, Utah with an enrollment of approximately 32,000 (OfficeofBudget&InstitutionalAnalysis, 2017) and an area of 1,535 acres (U.S.News&WorldReport, 2017d). Salt Lake City has hot summers and cold, snowy winters. Even though Salt Lake City is much larger than Fort Collins, they have certain similarity in topography and climate. The size of the universities is similar.

The universities included in this study are summarized in Table 2 along with their characteristics that were examined when making their selection.

Table 2: Summary of details of all the Universities

University (Name)	Region	University (Summary)			Climate Zone	Remarks
		Mission	No. of students (approx.)	Area (sq. miles)		
CSU	Fort Collins, Colorado	Public, Land-Grant	32,000	0.92	Cold	Assmption based on proximity to Boulder
Univsersity of Houston	Houston, Texas	Public	43,500	0.93	Hot-Humid	
Kansas State	Manhattan, Kansas	Public, Land-Grant	24,000	1.04	Mixed-Humid	Assumption based on surrounding regions
CU	Boulder, Colorado	Public	31,000	0.94	Cold	
University of Utah	Salt Lake City, Utah	Public	32,000	2.40	Cold	

Private or Commercial Sector Data

This study involves a comparison of project costs at public universities with the private sector project costs for similar project types. Private sector data is obtained from three sources. The first source is RLB published quarterly cost reports for 12 cities in the U.S. (RiderLevettBucknall, 2016). This report furnishes necessary information to national and international companies in making key business decisions (RiderLevettBucknall, 2017) and is widely recognized as a reliable source of data for project cost in private industry. Wong and Ng (2010) used RLB's tender price index (TPI) data in their study involving forecasting TPI in Hong Kong with vector error correction model. While identifying key risks and risk mitigation factors Chan, Chan, Lam, and Chan (2010) gave example of fluctuations in steel reinforcement price from RLB quarterly Hong Kong construction cost report of 2008 to emphasize economic risks. A report evaluating the economical, technological and environmental factors involved in U.S. navy engineering construction used RLB index for comparing Office of the Secretary of Defense (OSD) rates (Kelsey, 2016). These studies show that the RLB cost reports are used in prior research for comparative cost studies. The region used from the RLB cost report is Denver market and cost data from all other regions where the universities are located is adjusted to Denver market using R.S. Means adjustment factors. Adjustments for market conditions is common practice in cost comparison studies as the adjustment factors used are from a common reliable source.

A second source of private sector data is from a proprietary data set provided to the research team by a large, national general contractor. The data is provided for each project type and each market in the study.

A third source of private cost data is from a 2016 consultant's report on facilities cost prepared for CSU's Facilities Management Department. The consultant's report included cost for the Denver market with the exception of one laboratory project from Utah State University, which was adjusted to Denver area by using R.S. Means City Adjustment factor.

Comparative cost data from the three private sector sources is available in tabular format in Chapter 4. This research focuses on analyzing the cost factors having impact on the overall project cost and comparing the cost factors within the public sector by analyzing data obtained for the above-mentioned projects and sources.

Limitations of Research

CSU data and data from other universities is compared with the RLB data that gives a generalized rate of private construction costs. Thorough research needs to be performed with a larger dataset of each category of facilities mentioned earlier in Chapter 3 to support or refute this exploratory research on limited data. Moreover, some amenities could be specific to hospitals and may not be applicable to a reseach laboratory. There could be special construction requirements for hospitals due to difference in service provided when compared to labs. In addition, it is assumed that dorms function more like 3-star hotels. Facilities like hostels or lodges in the private sector like dorms need to be considered for accuracy of results. Another constraint of this study is the limited number of projects. The reason is very few projects were constructed at similar public universities in recent years. Only a few projects qualify for the study after fulfilling the criteria for selection of projects. Hence, a rigorous quantitative study could not be performed.

The consultant cost data obtained from the Facilities Management Department of CSU was not verified by the research team of this study. Hence, it is only used as an additional verification source and not used for cost comparison of public vs private sector in Chapter 5, which is the emphasis of this study.

The economic life cost factor analysis is not presented in Chapter 5 due to insufficient data. The research team tried to collect economic life data from the universities participating in this study but could not get enough responses in this category to provide meaningful results. Hence, although the economic life data is mentioned in the university project data tabulated in Chapter 4 and literature review, it is presented for the informational purpose, but no comparison is presented further in the research.

Assumptions for Comparison of Project Type

The data obtained from universities is compared to that of private sector and there are some assumptions made for the same. Table 3 shows the comparison of each category of university with that of similar category in the private sector and shows any assumptions made due to lack of data.

Table 3: Assumptions made for comparison of the project type

Public university project type	**Private sector project type**	**Assumptions**
Parking	Parking	The parking is of two types, above grade and below grade. Both are compared separately with their own type.
Classroom	University data for RLB Classroom data for Contractor	The RLB cost data does not have classroom data in specific, hence the university data is assumed suitable for this comparison. Contractor's cost data provides classroom cost range but does not specify if the classroom is of university or includes data from K-12 level institutions as well. This could make a difference as most of the classrooms at a university including those part of this study offers many facilities along with the classrooms such as lounges, café, study rooms, etc.

Laboratory	Hospital for RLB Laboratory for Contractor	RLB does not have laboratory in their data and hospitals are the closest to the laboratory amongst all the other facilities in their cost report. The cost data of Contractor does have the labs but again it is not clear if the labs are from university or other private labs owned by private individuals or organizations. In addition, the size and facilities included in the labs part of this is not clear. Labs could be of different sizes serving different purposes. All this is not clear from the private data. Assumption is made that the data consists of labs from the universities also and hence this data is relevant to this study.
Dormitory	University and 3-star hotel data for RLB Dormitory data for Contractor	The RLB data provides university data which includes cost for all the facilities across the university including the dormitories. The university dorms have many amenities other than housing like kitchen, indoor games, television, reading rooms, furnishing etc. Due to this, they are closer to 3-star hotels that provide similar amenities in their facilities. Contractor data does provide the cost range of the dormitories but it is unclear if the dorms considered have similar facilities as provided by the public university dorms part of this study. The data is assumed to be including projects of similar nature as well.

4. RESULTS

This chapter presents comparison of public and private cost data, impact analysis of each cost influencing factor summarized in Chapter 2 and analysis of the magnitude of this impact.

I. Colorado State University

The projects considered for this study are described below along with their details relevant to this study.

a) Biology Building

The CSU Biology building is 151,000 square feet providing space for research laboratory (labs) and teaching facilities. It also consists of biotechnology labs. It serves the purpose of providing students a workshop space for getting hands-on experience. This building includes student advising suites, lounges for student networking and quiet study rooms. There are lecture halls, recitation rooms and general access computer labs. The building not only serves the Biology Department but also provides support for the College of Natural Sciences, College of Veterinary Medicine and Biomedical Sciences Department. (CollegeofNaturalSciencesBiology, 2017).

Figure 1: Biology Building: Source, Author

b) Chemistry Building

The CSU Chemistry building is 60,000 square feet providing additional lab space for synthetic organic and inorganic material programs, and polymer chemistry. It also provides space for open labs, lab support rooms and offices for faculty and graduate researchers. Similar to the biology building and most other buildings across the campus, this building also provides space for student interaction with each other and with faculty. (CollegeofNaturalSciencesChemistry, 2017) (NaturalSciencesChemistry, 2017).

Figure 2: Chemistry Building: Source, Author

c) South College Parking Garage

CSU South College parking facility is constructed for 650 parking spots. With four level parking space, it serves the southeast campus, oval and the new Health and Medical Center. This parking facility is also close to the University Station of the MAX Rapid Transit System (Source, 2016).

Figure 3: South College Parking Garage: Source, Author

d) Lake Street Garage

This precast concrete 4-story parking garage has 895 spaces for parking and is LEED Gold certified (CarlWalker, 2017) The parking garage includes some innovative designs like signal lights working on sensors showing vacant parking spots for ease of spotting space of parking (ParkNews, 2016).

Figure 4: Lake Street Garage: Source, Author

e) Aggie Village

CSU Aggie Village is a residential facility with capacity for 973 students in studio, one, two, three, and four bedroom fully furnished apartments for the students of CSU. It is a LEED gold certified building and contains spaces for student services. The gross area of this building is 433,462 sq. ft.

Figure 5: New Aggie Village Student Housing Facility, Colorado State University: Source, (Ketchum, 2016)

f) Laurel Village

CSU Laurel Village houses 615 students in two residence halls with space for integrated learning. This facility has a common building called the Pavilion, which is LEED platinum certified, making heavy use of repurposed material from the demolition of Lory Apartments, which previously occupied the site

(ColoradoStateUniversityHousing&DiningServices, 2017). The gross square footage of this facility is 202,000.

g) Behavioral Sciences Building (BSB)

CSU's Behavioral Sciences Building is 92,912 square feet of remodeled space along with 24,000 square feet of addition and has high tech classrooms with 3D projection systems, shielded environments for EEG testing, under floor air distribution systems, and spaces for individual and group study. It also has study lounges and office spaces. BSB is LEED gold certified and the project delivery utilized was CM/GC.

Figure 6: Behavioral Sciences Building: Source, Author

Table 4: Project data of Colorado State University

Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers? (Y/N)	Gross square feet	LEED rating	Project scope metric
BSB	CM/GC	$ 39,898,448.06	$ 3,299,704.47	50	-	54	-	116,212	Gold	650
Laurel Village	Design-Bid-Build	$ 7,802,874.00	Included in contract amount	30	-	26	-	202,000	Platinum	615
Aggie Village	Design-Bid-Build	$ 100,205,738.00	Included in contract amount	30	-	34	-	433,652	Gold	973
South College Avenue Garage	Design-Build	$ 15,274,701.00	-	100	-	20	-	220,000	-	650
Lake Street Parking Garage	Design-Bid-Build	$ 20,600,000.00	-	-	-	30	-	326,100	Gold	895
Biology	Design-Build	$ 59,024,123.00	-	50	-	35	-	151,000	Gold	-
Chemistry	Design-Bid-Build	$ 33,650,617.00	$ 4,457,058.00	50	-	31	-	60,000	Silver	-

II. University of Houston

The Stadium Parking Garage, considered part of this study, is mentioned below along with its details relevant to this study. The parking structure has 2300 stalls with 10,000 square feet of mixed use space. It has a retail space along with the parking facility.

Figure 7: Stadium Parking Garage, University of Houston: Source, (WHRArchitects, 2012)

Table 5: Stadium parking garage data, University of Houston

Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers? (Y/N)	Gross square feet	LEED rating	Project scope metric
Design Build	26000000	N/A	-	100000	18	-	750000	None	2300 stalls

III. Kansas State University

This university has two projects as part of this study.

- Engineering Phase IV Addition
- College of Business Administration

a) The Engineering Addition has research and office space as well as consolidated laboratories that were scattered at many locations earlier. The construction of the project started in April 2014 and completed in November 2015 (KansasStateUniversity, 2016b) (KansasStateUniversity, 2016c).

Figure 8: Kansas State Engineering Hall, Top View-West Side & Bottom View-Reception area: Source, (KansasStateUniversity, 2016d)

b) The College of Business Administration facility, started in September 2014 and completed in August 2014, has a lecture hall, classrooms, study spaces, computer labs, networking space and coffee shop.

The facility also has space for advisors, reception area, conference rooms and offices for faculty and staff (KansasStateUniversity, 2016a).

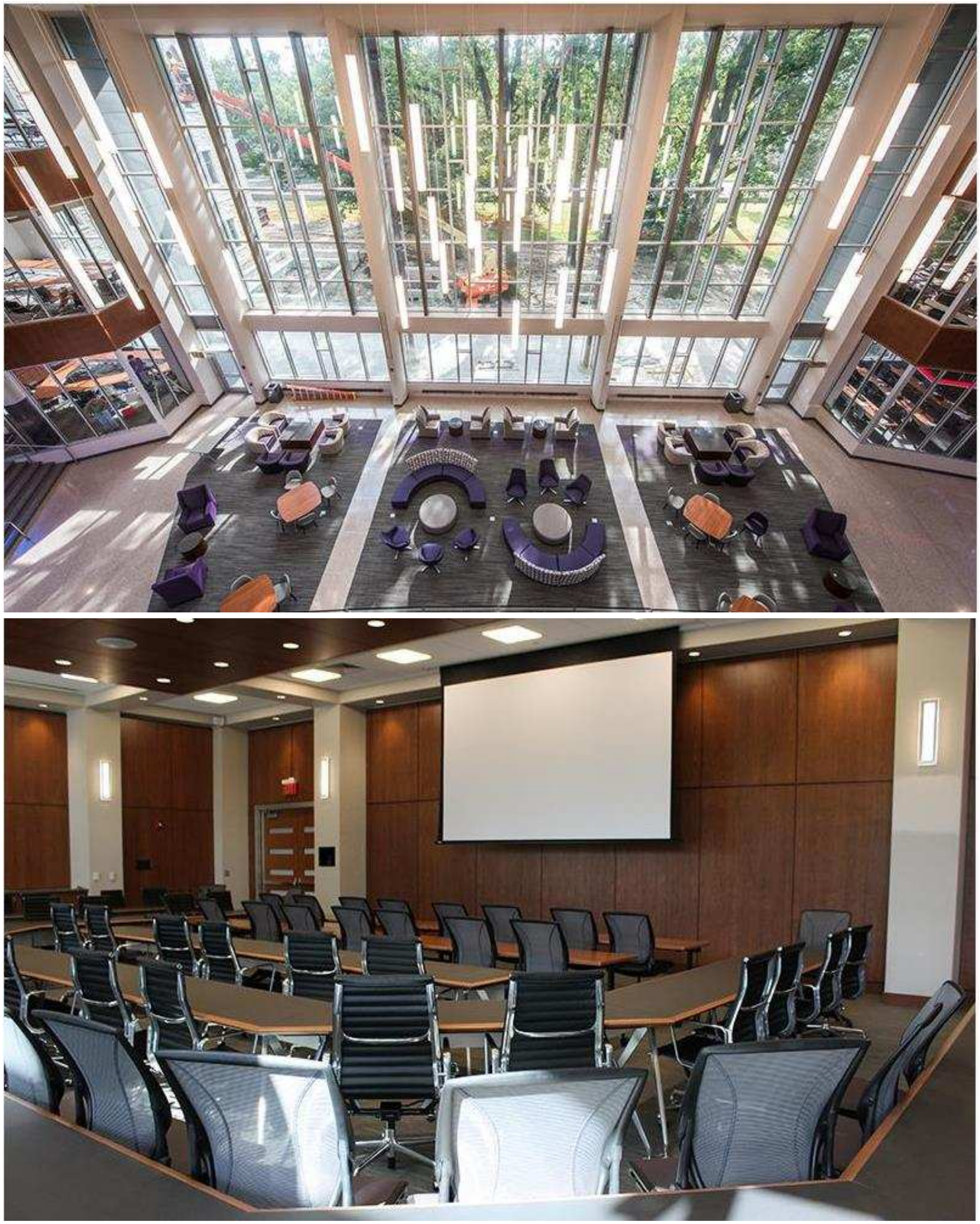

Figure 9: College of Business Administration, Kansas State University: *Source,* (CollegeofBusinessAdministration, 2017)

Table 6: Project data of Kansas State University

Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers? (Y/N)	Gross square feet	LEED rating	Project scope metric
Engineering Phase IV Addition	DBB	35,976,754	2,631,959	-	1,179,450	22	NA	107,000	None	Seats
College of Business Administration	DBB	$34,050,000	2,568,327	-	3,365,000	24	-	160,000	None	Seats

IV. University of Colorado, Boulder

Five projects are selected from the University of Colorado at Boulder as part of this research and are described below.

a) JILA Addition

JILA Addition is a joint institute of University of Colorado, Boulder and National Institute of Standards and Technology. Construction started in May 2010 and was completed in April 2012 (UniversityofColoradoBoulder, 2017a) to add a new six-story wing with advanced laboratories for laser experiments. Special provisions made to make the facility vibration resistant for accurate laser experiments are 2-foot-thick concrete basement foundation and spring-loaded flooring for pumps and mechanical equipment (CUBoulderToday, 2012). It is a LEED Gold certified building (USGBC, 2017a). JILA was established in 1962 and the acronym was Joint Institute of Laboratory Astrophysics but is no longer used because the institute has expanded in many areas of physics (UniversityofColoradoBoulder, 2017b).

b) Folsom Parking Garage

This is a two-story subsurface parking facility, underneath the new indoor practice facility. The project started in May 2014 and ended in January 2016 (UniversityofColoradoBoulder, 2017a) and is solar powered with motion sensor LED lights, exhaust fans for ventilation and elevator (CUBoulderToday, 2015).

Figure 10: Folsom Parking Garage during construction, University of Colorado Boulder: Source, (CUBoulderToday, 2015)

c) Baker Hall Renovation

Baker Hall was designed in 1937 and served as a residence for World War II US servicemen studying foreign languages (UniversityofColoradoBoulder, 2017d). The hall was renovated between May 2013 and August 2014 adding amenities like study spaces, classrooms, offices, common areas and reception (UniversityofColoradoBoulder, 2017a).

Figure 11: Renovated Baker Hall, University of Colorado Boulder: Source, (CUINDEPENDENT.COM, 2017)

d) Kittredge West Residence Hall Renovation

The project included renovation of a 274 bed facility providing additional amenities like reception, common areas, classrooms and offices. The construction started in May 2012 and ended in July 2013. In addition, it has automatic lighting and energy efficient windows (UniversityofColoradoBoulder, 2017c) and is LEED Gold certified by USGBC (USGBC, 2017b).

Figure 12: Kittredge West Hall, University of Colorado Boulder: Source*, (Housing&DiningServices, 2017a)*

e) Williams Village North

The construction of this LEED Platinum six story building started in January 2010 and ended in August 2011. It has energy and water efficient fixtures, on-site solar panels, advanced heat recovery systems and low volatile organic compound materials (UniversityofColoradoBoulder, 2017c).

Figure 13: William Village North, University of Colorado Boulder: Source, (Housing&DiningServices, 2017b)

Table 7: Project data of University of Colorado Boulder

Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers? (Y/N)	Gross square feet	LEED rating	Project scope metric
JILA Addition	CM/GC	$26.83M	$3.28M	NA	$520K	45	N	56,065	GOLD	-
Folsom Parking Garage	Design Build	$23.57M	NA	NA	NA	23	N	209,000	NA	534 stalls
Baker Hall Renovation	Design Build GMP*	$4,937,680	NA	NA	$847,837	14	N	114,489	Platinum	455 beds
Kittredge West Residence Hall Renovation	Design Build	$15,519,379	NA	NA	$579,597	14	N	74,297	Gold	274 beds
Williams Village North	Design Build	$32,500,000	NA	NA	$1,067,277	18	Yes $100k ea	131,246	Platinum	500 beds
	final	$39,293,253				construction phase only				

* Initial DB GMP contract only includes design, preconstruction, fee and general conditions. Construction cost is added to the contract after GMP is negotiated.

V. University of Utah

The projects from the University of Utah included in this study are:

a) Thatcher Building for Biology and Biochemistry

The building provides space for bio-analytical, bio-physical and bio-organic chemistry labs. It also has chemistry research labs, teaching labs, study spaces, lounges and reception hall. The project started on 03/31/2010 and ended in early 2013 (TheUniversityofUtah, 2015d).

Figure 14: Thatcher Building for Biology and Biochemistry, University of Utah: Source, (OklandConstruction, 2017)

b) Central Parking Garage

Central Parking Garage is a covered parking structure with approximately 800 stalls. The project started in June 2014 and ended in August 2015 (TheUniversityofUtah, 2015a).

c) Northwest Parking Garage

Northwest Parking Garage has approximately 300 parking stalls on four levels. The project started in September 2014 and ended the following year in August (TheUniversityofUtah, 2015c).

d) Donna Garff Marriott Honors Housing

This facility, started on 07/30/2009 and completed on 06/28/2012, is designed to encourage interaction and activities for better living and learning experience. It is a housing facility with space for resident advisors and live-in staff/faculty including parking and café (TheUniversityofUtah, 2015b).

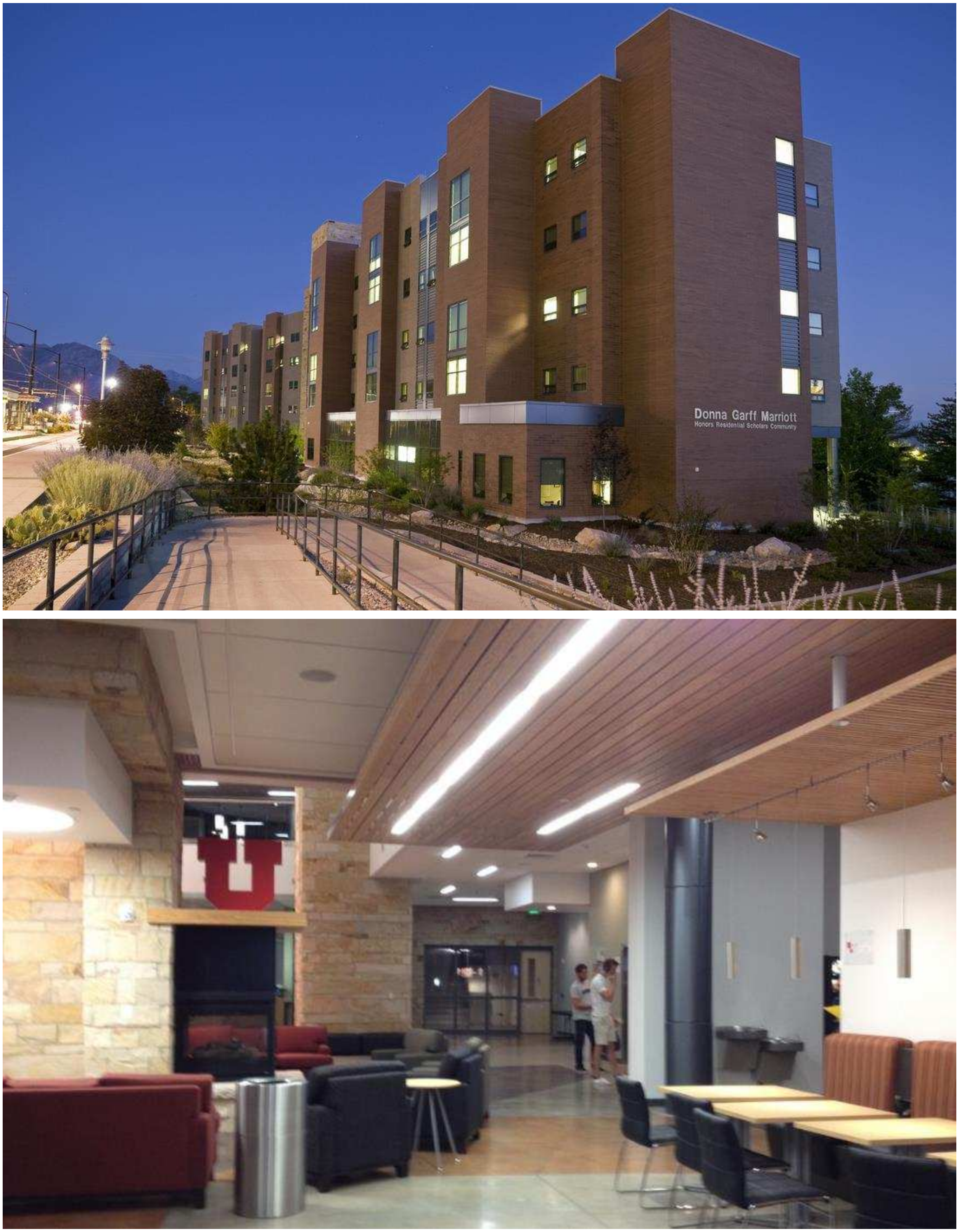

Figure 15: Donna Garff Marriott Honors Housing, University of Utah: *Source*, (UtahMasonryCouncil, 2017)

Table 8: Project data of University of Utah

Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Stipends for proposers ? (Y/N)	Gross square feet	LEED rating	Project scope metric
Thatcher Building for Biology and Biochemistry	CMGC	$16.8M	$1.45M	50	$250K	28	N	50,000	Silver	12 labs, 140 student seats
Central Parking Garage	Design/Bid/ Build	$12.3M	$1.1M	50	0	15	N	264,960	No	819 stalls
Northwest Parking Garage	Design/Bid/ Build	$6.8M	$538K	50	0	11	N	103,405	No	315 stalls
Donna Garff Marriott Honors Housing	Design/Build	$27.5M	NA	50	$1.1M	24	Y	163, 726	Gold	309 beds

VI. Private Cost Data

The comparable data from the cost reports of RLB, as described in Chapter 3, are shown below. The cost ranges for the Denver market are used as comparable to university facilities. The categories included in the RLB cost report were not exact matches, so are hotels are compared to university residence dorms, hospitals are compared to lab intensive classrooms, and education is compared to general purpose classrooms. RLB cost data includes private garage category. Hospitals were chosen as a comparable to lab-intensive classroom buildings because of similar mechanical, electrical, and plumbing/piping demands. Although not an ideal comparable, hospitals represent the closest functional fit to lab-intensive classrooms in the RLB database. The university residence/dorms are multi-residential facilities with additional amenities included with them. The dorms analyzed in this study, have community features such as kitchens, meeting rooms, recreational activity areas (ping pong, video games, TV etc.) and study rooms. The rooms are fully furnished with beds, mattresses, study desk & chair, wardrobe closet, drawer and curtains along with kitchen appliances and in-house washer dryer units. All these inclusive amenities represent a larger scope than usual multi-residential facilities constructed by private industry. Hence, the dorms are compared with both 3-star hotels and university projects, as they are similar to both categories in terms of design and construction, provided amenities and life cycle cost.

Table 9: Rider Levett Bucknall cost data (RiderLevettBucknall, 2016)

Location	**Denver**	
Average cost/SF	**Low**	**High**
Parking Garage - Above Grade	$ 50.00	$ 70.00
Parking Garage - Below Grade	$ 90.00	$ 120.00
Hotel (3-star)	$ 150.00	$ 185.00
Hospital	$ 370.00	$ 455.00
Education (University)	$ 285.00	$ 400.00

The cost ranges provided by the private sector do not include design costs or owner contingency funds. In order to make the data comparable to the data collected from universities, costs provided by RLB, Contractor (C1) and Consultant (C2) were increased by 12% to include design fees of 10% and a small bid contingency of 2%. Moreover, the schedule from the universities does not include the design duration for Design-Bid-Build projects. After consulting with the experts in the industry regarding the timing difference between Design-Build and Design-Bid-Build a period of nine months is added to parking projects' construction duration and 12 months added to other projects' construction duration due to complex structures to normalize data. This is shown in the comparison tables later in this section.

Table 10: Rider Levett Bucknall cost data with 12% increase

Location	**Denver**	
Average cost/SF	**Low**	**High**
Parking Garage - Above Grade	$ 56.00	$ 78.40
Parking Garage - Below Grade	$ 100.80	$ 134.40
Hotel (3-star)	$ 168.00	$ 207.20
Hospital	$ 414.40	$ 509.60
Education (University)	$ 319.20	$ 448.00

Table 11: Original Contractor (C1) cost data

Factor	**1**		**0.99**		**1.04**		**0.92**	
Location	**Denver**		**Salt Lake City**		**Kansas City**		**Houston**	
Average cost/SF	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Parking Garage - Above Grade	$ 70.00	$ 90.00	$ 69.30	$ 89.10	$ 72.80	$ 93.60	$ 64.40	$ 82.80
Parking Garage - Below Grade	$ 80.00	$ 100.00	$ 79.20	$ 99.00	$ 83.20	$ 104.00	$ 73.60	$ 92.00
Classroom Buildings	$200.00	$ 350.00	$ 198.00	$ 346.50	$ 208.00	$ 364.00	$ 184.00	$ 322.00
Lab Buildings	$250.00	$ 425.00	$ 247.50	$ 420.75	$ 260.00	$ 442.00	$ 230.00	$ 391.00
Dormitories	$170.00	$ 290.00	$ 168.30	$ 287.10	$ 176.80	$ 301.60	$ 156.40	$ 266.80

For the comparison with RLB and contractor, university cost ranges from other markets were adjusted for the Denver market in this study based on R.S. Means city adjustment factors in 2016 (RSMeans, 2016). Hence, only the Denver region cost values of contractor were unadjusted for this study. The R.S. Means city cost indexes are used to calculate the adjustment factors for other cities with respect to Denver region and are shown in Table 12.

Table 12: R.S. Means adjustment factors

City	City cost index	Adjustment factor
Denver	92.3	-
Kansas City	102.2	1.11
Houston	87.1	0.94
Salt Lake City	89.4	0.97

Table 13: Contractor (C1) cost data after 12% increase for design and contingency

Location	**Denver**	
Average cost/SF	**Low**	**High**
Parking Garage - Above Grade	$ 78.40	$ 100.80
Parking Garage - Below Grade	$ 89.60	$ 112.00
Classroom Buildings	$224.00	$ 392.00
Lab Buildings	$280.00	$ 476.00
Dormitories	$190.40	$ 324.80

Another set of data obtained from the Facilities Management Department of CSU provides consultant cost values for projects both in the public and private sector. Although this data is received from the Facilities Management Department, a reliable source, it was not verified by the researchers of this study. Hence, this cost data range is only used as an additional verification source of the cost of the projects but is not used in the comparison and conclusion.

Table 14: Consultant (C2) cost data with 12% increase for design and contingency

Location	**Denver**	
Average cost/SF	**Low**	**High**
Parking Garage - Above Grade	-	-
Parking Garage - Below Grade	-	-
Classroom Buildings	$ 374.00	$ 492.00
Lab Buildings	$ 238.00	$ 792.00
Dormitories	$ 398.00	$ 545.00

The comparative table for each category of project for the universities selected is shown later in this chapter along with the cost range obtained from Table 9 and Table 13 for the private sector. The cost is calculated per scope metric; per bed, per stall and per square feet relevant to the type of facility along with cost per square foot (sq. ft.). The cost is calculated per stall, per bed and per seat for parking, dorms and classrooms respectively. While both cost per square foot and cost per metric is calculated for parking, dorms and classrooms, cost per square foot is only calculated for labs as the project metric is unavailable.

<u>Tables of Public University Projects in Their Respective Project Category</u>

The projects from the universities participating in part of this study are categorized based on the type of project and presented in a tabular format in the sections below.

i. Parking

Comparative table of public and private facility for cost per square feet is shown below. It can be observed from the table below that underground parking facility is most expensive. Three projects are DBB and other three are DB. Only one facility has LEED certification.

Table 15: Parking project data

University	Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Denver Adjusted Cost	Duration in months	Gross square feet	LEED rating	Project scope metric (stalls)	Cost/sqft	Cost/stall
University of Colorado Boulder	Folsom Parking Garage	Design-Build	$23,570,000.00	N/A	-	-	$23,570,000.00	23	209,000	-	534	$ 112.78	$44,138.58
University of Utah	Central Parking Garage	Design-Bid-Build	$12,300,000.00	$1,100,000.00	50	-	$12,978,981.58	24	264,960	-	819	$ 48.98	$15,847.35
University of Utah	Northwest Parking Garage	Design-Bid-Build	$ 6,800,000.00	$ 538,000.00	50	-	$ 7,107,445.29	20	103,405	-	315	$ 68.73	$22,563.32
University of Houston	Stadium Parking Garage	Design-Build	$26,000,000.00	N/A	-	$100,000.00	$24,629,577.46	18	750,000	-	2300	$ 32.84	$10,708.51
Colorado State University	South College avenue garage	Design-Build	$15,274,701.00	N/A	100	-	$15,274,701.00	20	220,000	-	650	$ 69.43	$23,499.54
Colorado State University	Lake street garage	Design-Bid-Build	$20,600,000.00	Included in contract amount	-	-	$20,600,000.00	30	326,100	Gold	895	$ 63.17	$23,016.76

ii. Classrooms

Comparative table of public and private facility for cost per square foot for each market is shown in the tables below. It can be noted from Table 17 that only CM/GC projects have LEED certifications. The other two projects are DBB projects having no LEED certifications.

The BSB project was built in two phases: BSB and BSB addition. The details of both the phases are provided in Table 16. The two projects are considered as one as the same BSB building is extended with an additional building that was delivered using the same project delivery method and equal LEED certification.

Table 16: BSB and BSB addition project details

Project	**Project delivery system used**	**Initial contract amount**	**Design costs (if not DB)**	**Economic life used in LCC**	**FFE budget**	**Duration in months**	**Gross square feet**	**LEED rating**	**Project scope metric**
BSB	CM/GC	$32,290,081.22	$2,707,278.92	50	-	31	92,212	Gold	413
BSB addition	CM/GC	$ 7,608,366.84	$ 592,425.55	50	-	23	24,000	Gold	237

Table 17: Classroom project data

University	Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Denver Adjusted Cost	Duration in months	Gross square feet	LEED rating	Project scope metric (seat)	Cost/sqft	Cost/seat
Kansas State University	Engineering Phase IV Addition	Design-Bid-Build	$35,976,754.00	$2,631,959.00	-	$1,179,450.00	$44,055,799.12	34	107,000	-	1290	$ 411.74	$ 34,151.78
Kansas State University	College of Business Administration	Design-Bid-Build	$34,050,000.00	$2,568,327.00	-	$3,365,000.00	$44,271,896.20	36	160,000	-	180	$ 276.70	$245,954.98
University of Utah	Thatcher Building for Biology and Biochemistry	CM/GC	$16,800,000.00	$1,450,000.00	50	$250,000.00	$17,457,746.48	28	50,000	Silver	140	$ 349.15	$124,698.19
Colorado State University	Behavioral Sciences Building	CM/GC	$39,898,448.06	$3,299,704.47	50	-	$41,840,897.47	54	116,912	Gold	650	$ 357.88	$ 64,370.61

iii. Laboratory

Comparative table of public and private facility for cost per square foot is shown below. Table 18 below shows three laboratory projects having three types of delivery methods. One of the projects is LEED Silver while other two are LEED Gold.

Table 18: Laboratory project data

University	Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Duration in months	Gross square feet	LEED rating	Cost/sqft
University of Colorado Boulder	JILA Addition	CM/GC	$26,830,000.00	$3,280,000.00	-	$520,000.00	45	56,065	Gold	$546.33
Colorado State University	Biology	Design-Build	$59,024,123.00	N/A	50	-	35	151,000	Gold	$390.89
Colorado State University	Chemistry	Design-Bid-Build	$33,650,617.00	$4,457,058.00	50	-	31	60,000	Silver	$635.13

iv. Dormitory

Comparative table of public and private facility for cost per square foot is shown below. The dormitory data provided in Table 19 has six projects. Two DBB projects are from CSU while the other four projects are DB projects. All the projects have LEED certifications of either Gold or Platinum.

Table 19: Dormitory project data

University	Project	Project delivery system used	Initial contract amount	Design costs (if not DB)	Economic life used in LCC	FFE budget	Denver Adjusted Cost	Duration in months	Gross square feet	LEED rating	Project scope metric (beds)	Cost/sqft	Cost/bed
University of Colorado Boulder	Baker Hall Renovation	Design-Build	$33,994,762.00	N/A	-	$847,837.00	$34,842,599.00	14	114,489	Platinum	455	$304.33	$76,577.14
University of Colorado Boulder	Kittredge West Residence Hall Renovation	Design-Build	$19,085,656.00	N/A	-	$579,597.00	$19,665,253.00	14	74,297	Gold	274	$264.68	$71,771.00
University of Colorado Boulder	Williams Village North	Design-Build	$39,293,253.00	N/A	-	$1,067,277.00	$40,360,530.00	18	131,246	Platinum	500	$307.52	$80,721.06
University of Utah	Donna Garff Marriott Honors Housing	Design-Build	$27,500,000.00	N/A	50	$1,100,000.00	$27,701,408.45	24	163,726	Gold	309	$169.19	$89,648.57
Colorado State University	Laurel Village	Design-Bid-Build	$40,200,000.00	Included in contract amount	30	-	$40,200,000.00	26	202000	Platinum	615	$199.01	$65,365.85
Colorado State University	Aggie Village	Design-Bid-Build	$100,200,000.00	Included in contract amount	30	-	$100,200,000.00	34	433652	Gold	973	$231.06	$102,980.47

Cost Comparison of Public with Private Sector

Comparison of projects from the university and private sectors is presented in Table 20. This comparison is further verified with consultant data in Table 21. The detailed analysis of Table 20 is presented in Chapter 5. As the consultant data is only used for verification of cost values, it can be seen from Table 21 that the cost of projects at the universities are either within the consultant range or less than its minimum verifying the universities have met with the cost standards of private industry. It can be observed that the C2 values are higher than the C1 values. In addition, the C2 cost range is broader than the C1 cost range. Moreover, parking data is not available for the C2.

Table 20: Public-private cost comparison

Project	Average cost/sqft of projects	RLB Cost Range				Comparison (with RLB) Remarks	C1 Cost Range		Comparison (with C1) Remarks
		Min.	Max.	Min	Max.		Min.	Max.	
Parking (below grade)	$ 112.78	$100.80	$134.40			Lies within range	$ 89.60	$112.00	Exceeds max. limit
Parking (above grade)	$ 55.00	$ 56.00	$ 78.40			Less than min.	$ 78.40	$100.80	Less than min. limit
Classroom	$ 348.87	$319.20	$448.00			Lies within range	$224.00	$392.00	Lies within range
Labs	$ 524.12	$414.40	$509.60			Exceeds max. limit	$280.00	$476.00	Exceeds max. limit
Dorms	$ 245.97	$ 168 (3-star hotel)	$ 207.2 (3-star hotel)	$ 319.2 (University)	$ 448 (University)	Lies within max. of 3-star hotel and min. of university	$190.40	$324.80	Lies within range

Table 21: Verification with consultant cost values

Project	Average cost/sqft of projects	C2 Cost Range		Comparison (with C2) Remarks
		Min.	Max.	
Parking (below grade)	$ 112.78	-	-	N/A
Parking (above grade)	$ 55.00	-	-	N/A
Classroom	$ 348.87	$374.00	$492.00	Less than min.
Labs	$ 524.12	$238.00	$792.00	Lies within range
Dorms	$ 245.97	$398.00	$545.00	Less than min.

C1: Contractor

C2: Consultant

<u>Comparison Between Project Delivery Indexes and Sustainability Indexes</u>

The public university projects are further compared with each other to establish any potential relative significance between various groups in each type of cost factor identified in Chapter 3 i.e. project scope, type of project delivery and sustainability. The type of project is used for control scope. As shown in the comparison tables economic life comparison and analysis was not performed due to unavailability of data. Hence, this study focused on comparison of different project delivery systems and investment in different levels of sustainability. For this, comparison indexes were calculated for each type of project and eventually an average of these indexes was expressed based on cost/sq. ft., cost/metric and project schedule. These indexes were then compared in Chapter 5 providing a detail comparison of project delivery methods and LEED certifications. The indexes are tabulated in the Table 22 and Table 23 series.

Table 22: Project delivery indexes

Table 22a: Project delivery cost/sqft index

Project Delivery	Parking (above ground)	Classrooms	Labs	Dorms	Parking (above ground)	Classrooms	Labs	Dorms
	Average (all projects) Cost/sqft				Index Cost/sqft			
	$ 56.63	$ 348.87	$ 524.12	$ 245.97				
	Average Cost/sqft							
DB	$ 51.13		$ 390.89	$ 261.43	0.90		0.75	1.06
DBB	$ 60.30	$ 344.22	$ 635.13	$ 215.04	1.06	0.99	1.21	0.87
CM/GC		$ 353.52	$ 546.33			1.01	1.04	

Table 22b: Project delivery cost/metric index

Project Delivery	Parking (above ground)	Classrooms	Dorms	Parking (above ground)	Classrooms	Dorms
	Average (all projects) Cost/metric			Index Cost/metric		
	$ 19,127.10	$ 117,293.89	$ 79,679.44			
	Average Cost/metric					
DB	$ 17,104.03		$ 81,177.35	0.89		1.02
DBB	$ 20,475.81	$ 140,053.38		1.07	1.19	1.06
CM/GC		$ 94,534.40			0.81	

Table 22c: Project delivery duration index

Project Delivery	Parking (above ground)	Classrooms	Labs	Dorms	Parking (above ground)	Classrooms	Labs	Dorms
	Average (all projects) Duration				Index Duration			
	22.40	38	37.00	21.67				
	Average Duration							
DB	19.00		35	17.50	0.85		0.95	0.81
DBB	24.67	35	31	30.00	1.10	0.92	0.84	1.38
CM/GC		41	45			1.08	1.22	

Table 22d: Summary of the project delivery indexes

Project Delivery	Index Cost/sqft	Index Cost/metric	Index Duration
DB	0.90	0.96	0.87
DBB	1.03	1.11	1.06
CM/GC	1.03	0.81	1.15

Table 23: Sustainability indexes

Table 23a: Sustainability cost/sqft index

LEED	Parking (above ground)	Classrooms	Labs	Dorms	Parking (above ground)	Classrooms	Labs	Dorms
	Average (all projects) Cost/sqft				Index Cost/sqft			
	$ 66.55	$ 348.87	$ 524.12	$ 245.97				
	Average Cost/sqft							
None	$ 55.00	$ 344.22			0.83	0.99		
Silver		$ 349.15	$ 635.13			1.00	1.21	
Gold	$ 63.17	$ 357.88	$ 468.61	$ 221.65	0.95	1.03	0.89	0.90
Platinum				$ 270.29				1.10

Table 23b: Sustainability cost/metric index

LEED	Parking (above ground)	Classrooms	Dorms	Parking (above ground)	Classrooms	Dorms
	Average (all projects) Cost/metric			Index Cost/metric		
	$ 23,351.46	$117,293.89	$81,177.35			
	Average Cost/metric					
None	$ 18,154.68	$140,053.38		0.78	1.19	
Silver		$124,698.19			1.06	
Gold	$ 23,016.76	$ 64,370.61	$88,133.35	0.99	0.55	1.09
Platinum			$74,221.35			0.91

Table 23c: Sustainability duration index

LEED	Parking (above ground)	Classrooms	Labs	Dorms	Parking (above ground)	Classrooms	Labs	Dorms
	Average (all projects) Duration				Index Duration			
	21.00	38	37.00	21.67				
	Average Duration							
None	20.50	35			0.98	0.92		
Silver		28	31			0.74	0.84	
Gold	30.00	54	40	24	1.43	1.42	1.08	1.11
Platinum				19.33				0.89

Table 23d: Summary of the sustainability indexes

LEED	Index Cost/sqft	Index Cost/metric	Index Duration
None	0.91	0.99	0.95
Silver	1.11	1.06	0.79
Gold	0.94	0.87	1.26
Platinum	1.10	0.91	0.89

5. CONCLUSION AND DISCUSSION

This study involved cost comparison of public university projects with private sector projects of similar nature. In addition, the cost affecting factors, identified in Chapter 3, were compared to establish their impact and significance of impact with respect to each other. The discussion of these comparisons is addressed in three sections; public-private comparison, comparison of public university projects based on cost/sqft and cost/metric, and comparison of public university project data based on indexes. The project data along with cost data from the universities and calculated indexes are presented in Chapter 4. The cost data from the private sector is also shown in the Chapter 4. The average cost data for CSU projects and other public university projects along with the cost ranges for RLB and contractor (C1) are summarized in the Table 24. As a reminder the cost of the Folsom parking facility was not used in determining the average cost of parking projects due to its attribute of being an underground facility.

Table 24: Summary of cost values for CSU, other university and private sector

Project Type	CSU Average $/SF	Other University Average $/SF	RLB Range	C1 Range
Parking	$ 66.3	$ 50.2	$ 56.0 - $ 78.4	$ 78.4 - $ 100.8
Classroom	$ 357.9	$ 345.9	$ 319.2 - $ 448.0 (University)	$ 224.0 - $ 392.0
Laboratory	$ 513.0	$ 546.3	$ 414.4 - $ 509.6 (Hospital)	$ 280.0 - $ 476.0
			$ 319.2 – $ 448.0 (University)	
Dormitory	$ 215.0	$ 261.4	$ 168.0 - $ 207.0 (3-star Hotel)	$ 190.4 - $ 324.8
			$ 319.2 – $ 448.0 (University)	

Public-Private Comparison

The cost of public and private projects was compared using three metrics: cost per square foot, RLB and the C1 cost range.

i. Parking Data Comparison

It can be derived from Table 15 and Table 24 that none of the projects exceeded the maximum cost range from RLB. Both the, Central parking garage and Stadium parking garage have lower cost/sqft than the minimum limit of RLB.

Table 15: Parking project data (summarized)

University	Project	Cost/sqft
University of Colorado Boulder	Folsom Parking Garage	$ 112.78
University of Utah	Central Parking Garage	$ 48.98
University of Utah	Northwest Parking Garage	$ 68.73
University of Houston	Stadium Parking Garage	$ 32.84
Colorado State University	South College avenue garage	$ 69.43
Colorado State University	Lake street garage	$ 63.17

When the public university parking projects' cost, projects from CSU and other universities, are compared with the cost range available from the Contractor, C1 range, it was found that all the above surface parking projects have lower cost/sqft than the minimum limit of C1 cost data. The Folsom parking garage is an underground parking facility and this may be the reason for the higher cost/sqft of this project. The difference between the maximum of C1 and Folsom parking is 0.78 dollars/sqft. It was observed from the comparison of public university and private sector parking projects that the parking projects are well within the cost range with the exception of the Folsom parking garage. When compared to the C1 cost range data the Folsom parking garage had a slightly higher cost. There could be many reasons for this that needs to be further studied but the scope of this study suggests only one reason that is special design and construction requirements related to an underground parking facility.

ii. Classroom Data Comparison

The classroom project data from public universities was compared with university construction cost data of RLB (Table 17). The summarized Table 17 below and Table 24 indicates that the cost/sq. ft. of all the projects lies within the RLB and C1 cost range with two exceptions. The College of Business Administration at Kansas State University and Engineering Phase IV Addition.

Table 17 summarized: Classroom project data (summarized)

University	**Project**	**Project scope metric (seat)**	**Cost/sqft**
Kansas State University	Engineering Phase IV Addition	1290	$411.74
Kansas State University	College of Business Administration	180	$276.70
University of Utah	Thatcher Building for Biology and Biochemistry	140	$349.15
Colorado State University	Behavioral Sciences Building	650	$357.88

The College of Business Administration building had a lower value than the minimum limit of the RLB cost range. The Engineering Phase IV Addition cost/sqft exceeded the maximum limit of the C1 cost data. It may be observed from the data in Table 17 that the cost/metric is lowest for the Engineering Addition building due to high number of seats. This could have led to excessive cost/sqft as the building is making use of most of the square footage.

iii. Laboratory Data Comparison

The laboratory spaces in public universities are compared to the hospital data in RLB and lab data in the C1 cost range. The JILA Addition at the University of Colorado Boulder and Chemistry building at CSU both exceeded the RLB and C1 cost range (Table 18 summarized and Table 24) while CSU Biology building is within the cost range of both RLB and C1 cost data.

Table 18 summarized: Laboratory project data (summarized)

University	Project	Cost/sqft
University of Colorado Boulder	JILA Addition	$546.33
Colorado State University	Biology	$390.89
Colorado State University	Chemistry	$635.13

The JILA Addition exceeded RLB by approximately $37 per sq. ft. and C1 cost range by $70 per sq. ft. The CSU Chemistry exceeded RLB by approximately $125 per sq. ft. and C1 cost range by $160 per sq. ft. These excesses in construction costs may result from the assumptions made for the comparison in Table 3. Both these facilities have specific requirements that may not be present in the hospitals and hence requiring extra budget. Similar assumptions were made while comparing public university labs cost with the cost data of C1. Again, only the Biology building lies within the cost range, both the other labs, JILA addition and Chemistry, are well above the upper limit of the cost range of this private sector company. Reasons for the higher cost from RLB can be cited as the lack of laboratory data from this company. Hence, a comparison with dissimilar facilities i.e. hospitals could be the reason for higher public projects cost but reasons for the comparison results with Contractor data needs to be explored. This cost data range was obtained from a Contractor and should be examined for details in order to explore the type of labs used for attainment of this data. Whether those labs are similar to the labs in consideration in this study, only then can a conclusion be made. As for this study, the data from the public university is higher than the private sector and the cost could have been minimized, assuming the above assumptions don't have any significant impact on the project cost.

iv. Dormitory Data Comparison

It is derived from the Table 19 and Table 24 (Table 19 summarized is shown below) that all the dorms lie in the cost range of C1 dormitory.

Table 19 summarized: Dormitory project data (summarized)

University	Project	Cost/sqft
University of Colorado Boulder	Baker Hall Renovation	$304.33
University of Colorado Boulder	Kittredge West Residence Hall Renovation	$264.68
University of Colorado Boulder	Williams Village North	$307.52
University of Utah	Donna Garff Marriott Honors Housing	$169.19
Colorado State University	Laurel Village	$199.01
Colorado State University	Aggie Village	$231.06

However, different inferences can be made from the RLB cost comparison. Baker hall, Kittredge hall, Williams Village and Aggie Village are more expensive than the maximum limit of the 3-star hotel cost range but are within the university facility cost range. Donna Garff and Laurel Village lie within the cost range of 3-star hotel but are too low than the university minimum cost range.

Comparison of Public University Projects Based on Cost/sqft and Cost/metric

The university project data is also compared with each other for project delivery and sustainability impacts. This is further elaborated in next section where comparison is carried out based on cost and schedule indexes. Reasons for any inference made in comparison are explored but it is based on the limited data and other aspects are needed to be considered to make any concrete statement.

i. Parking Data Analysis

The Folsom parking garage is an underground parking facility and is the most expensive of all the projects part of this study. The cost/sq. ft. and cost/stall are much higher than the rest of the projects. Moreover, it took more time for construction of this project compared to other projects in terms of the gross sq. ft. The number of stalls are also second least among the projects. Due to limited number of projects it cannot be concluded whether DB or DBB is better in cost performance, but some observations can be made. Three projects have cost/sqft within the order of $60-$70 per sqft. The projects are Northwest parking garage a DBB project South College Avenue parking garage, a DB project and Lake Street garage, a DBB project. The major difference is in the number of stalls available in these parking garages. Northwest parking has 315 spots, South College Avenue has 650 and Lake Street has 895 spots. Even though cost/sqft is almost of the same order but the stalls are the least in Northwest parking and maximum in the Lake Street garage. In addition, both are DBB but the cost performance per stall differs extremely making Northwest most expensive of the three projects and Lake street as the least expensive. Stadium parking garage, a DB project, is most cost efficient both in terms of both cost/sq. ft. and cost/stall.

Due to this difference in comparison results of projects with different delivery systems, a conclusion on which delivery system takes less time for construction cannot be achieved. The results contradict the literature review performed that shows cost and schedule gain in design-build delivery system. This could be due to the limited number of projects part of this study and large sample size is required to study further in this area. It is possible that construction of parking garages is not affected by the type of delivery methods. Only one of the parking projects have considered LEED certification. Lake Street garage has LEED Gold certification and it can be observed that it took maximum schedule for construction amongst all the projects, but the area and stalls are comparatively more than the other projects except Stadium parking, and although sustainability consideration has not affected its economic investment as compared to other projects. Any further conclusion cannot be made in sustainability area as the other five projects do not have any certification and more data is required for any statement to be made.

ii. Classroom Data Analysis

The duration of both the CMGC projects is more compared to the DBB projects when considered with respect to the gross square footage. As the CM/GC projects have LEED certification and DBB projects do not, it cannot be concluded that the CM/GC projects take longer schedule. The reason for more duration could be fulfillment of sustainability requirements. Hence, no conclusion can be made about the efficiency of the delivery system from these two projects.

The comparison of DBB and CM/GC projects cannot be made from sustainability view point as DBB projects do not have certification. The two CM/GC projects in Table 17 are LEED certified projects and this maybe the reason for excessive cost and duration. It can be observed from the two CM/GC delivered projects that higher LEED certification does not necessarily increase cost of the project. BSB has LEED Gold certification and Thatcher Building is LEED Silver but BSB is more economical in terms of cost/seat. However, BSB appears to have longer schedule than the Thatcher building with respect to square footage and seats.

iii. Laboratory Data Analysis

Cost per sq. ft. for Chemistry is more than the Biology and JILA facility making design-bid-build the most expensive delivery system. The Biology facility is found to be the least expensive, hence it can be concluded that design-build is best option in terms of project budget. JILA Addition, a CM/GC project, took most time for construction while Chemistry building took least duration of construction that is four months better than the DB Biology project. However, Biology building is approximately 2.5 times Chemistry building in area making four months duration margin extremely insignificant. In addition, Biology building has LEED Gold certification while Chemistry building is LEED Silver making it even better in terms of cost and duration invested in higher LEED certification. Although, it is difficult to comment whether CM/GC or DBB is better with the limited number (only three) projects but DB's performance seems to be far superior to its other two counterparts. This comparison is based on the data available but since the usage of the three buildings is very different, hence the above analysis needs further examination based on the facilities provided by the three buildings.

iv. Dormitory Data Analysis

The cost per bed varies for all the projects but lies mostly between $70,000 and $90,000 per bed. Laurel Village is cheaper in terms of cost per bed and Aggie Village is the most expensive one having cost per bed exceeding $100,000 per bed. Baker hall, Kittredge West and Williams North have cost proportional cost with respect to number of beds and area, but the pattern is not followed in the other three projects. Moreover, the cost/bed is similar only for Baker Hall and Kittredge West Residence Hall maybe because both are renovation projects. The rest of the four projects have higher cost/bed than the two renovation projects mentioned above except Laurel Village that despite being LEED Platinum certified is the cheapest of all the projects. Aggie Village of CSU has the maximum cost/bed.

Four projects are DB and two projects, both from CSU, are DBB and none of them is CM/GC. Only one DB project is cheaper in cost/sq. ft. than the DBB projects, the other three have more cost/sq. ft. In addition, the cost/bed of one of the DBB project is more than the DB projects and the other is less. Hence, a conclusion cannot be made on project delivery.

Although all the projects are LEED certified, no conclusion could be made in this area. Some of the LEED Platinum certified are cheaper in terms of cost/sq. ft. and cost/bed than the LEED Gold certified, and some are expensive. Donna Garff Marriot Honors of University of Utah, the cheapest of all the projects is a LEED Gold certified project and Baker Hall renovation of CU that is a LEED Platinum certified project is the highest in terms of cost/ sq. ft.

<u>Comparison of Public University Data Based on Indexes</u>

Cost and duration index of all the projects based on project delivery and sustainability is calculated for comparison of performance of delivery systems and sustainability impacts on cost and schedule.

The index is calculated by dividing the project average of cost per sqft or duration by the average of all the projects for each project delivery system and for each LEED certification level. An index score of 1.0 indicates that the project cost is equal to the total average and an index of greater than 1.0 indicates costs above total average. An index lower than the total average i.e. less than 1.0 is mark of efficiency and is desirable. An example of index calculation is shown below.

All the parking projects are surface with exception of Folsom Parking that is below surface. The subsurface parking project, Folsom parking garage, is not considered in the index calculation as it skews the results, which is not desirable as this project has specific requirements in terms of design and construction that are not related to surface parking garage. Although below surface parking is not considered in the index calculation, the example of index calculation is of below surface parking. This is to make the depicted calculation simple as there is only one project is this category. The rest of the calculations follow the same method. The project details are:

Project Delivery type: DB

Duration (in months): 23

LEED Rating: None

Cost/sqft: $ 112.78

Cost/metric (stall): $ 44138.58

Project Delivery Indexes

Since there is only one project delivery in this example calculation and it is DB, all the calculations are shown for DB only and the denominator for average of DB and total average will be 1.

Cost/sqft Index:

Average (all projects) cost/sqft = $\frac{112.78}{1}$ = 112.78

Average cost/sqft of DB projects = $\frac{112.78}{1}$ = 112.78

Cost/sqft Index = Average of DB/Total average = $\frac{112.78}{112.78}$ = 1.0

Cost/metric Index:

Average (all projects) cost/stall = $\frac{44138.58}{1}$ = 44138.58

Average cost/stall of DB projects = $\frac{44138.58}{1}$ = 44138.58

Cost/stall Index = Average of DB/Total average = $\frac{44138.58}{44138.58}$ = 1.0

Duration Index:

Average (all projects) duration = $\frac{23}{1} = 23$

Average duration of DB projects = $\frac{23}{1} = 23$

Duration Index = Average of DB/Total average = $\frac{23}{23} = 1.0$

Sustainability Indexes

Since there is only one project delivery in this example calculation and it has no LEED certification i.e. None, all the calculations are shown for "None" only and the denominator for average of "None" and total average will be 1.

Cost/sqft Index:

Average (all projects) cost/sqft = $\frac{112.78}{1} = 112.78$

Average cost/sqft of None projects = $\frac{112.78}{1} = 112.78$

Cost/sqft Index = Average of None/Total average= $\frac{112.78}{112.78} = 1.0$

Cost/metric Index:

Average (all projects) cost/stall = $\frac{44138.58}{1} = 44138.58$

Average cost/stall of DB projects = $\frac{44138.58}{1} = 44138.58$

Cost/stall Index = Average of DB/Total average = $\frac{44138.58}{44138.58} = 1.0$

Duration Index:

Average (all projects) duration = $\frac{23}{1}$ = 23

Average duration of DB projects = $\frac{23}{1}$ = 23

Duration Index = Average of DB/Total average = $\frac{23}{23}$ = 1.0

Project Delivery

The cost/sqft index for project delivery shows that DB projects cost/sqft index (0.90) is least among the three delivery methods (DB, DBB and CM/GC). DBB cost index and CM/GC cost both have equal index of 1.03 slightly more than the total average. DB is the most cost-effective delivery method for every square foot area of the project.

The cost per metric index for DB is 0.96, lower than the average indexes of all projects. The average cost for DBB projects is considerably higher than the average cost per metric for all the projects with cost per metric index of 1.11. CM/GC projects have cost per metric index of 0.81, the lowest of the three projects deliveries. These values imply that DBB projects cost highest for every unit (metric) while CM/GC cost the minimum, making it the most efficient delivery method in terms of cost per metric.

The duration index is least for DB with index of 0.87 and CM/GC has maximum schedule with 1.15 duration index. DBB, with duration index of 1.06, is higher than DB duration index and total average. This shows that DB has least schedule while CM/GC has the maximum schedule.

It can be inferred from the above comparison that DB is the most effective form of project delivery having all three indexes below the average of the all projects. Although it is higher than CM/GC in cost/metric index, but the other two indexes are better making it more efficient than CM/GC. DBB and CM/GC are less efficient compared to both DB, but it is hard to comment which one is better of the two as both have two indexes more than total average and one below. However, CM/GC seems better in terms of cost performance as the cost indexes are better than DBB.

Sustainability

While some of the projects included in this study have various LEED certifications including silver, gold and platinum, some projects do not have any sustainability certification. The projects are categorized based on the LEED certification, namely none, silver, gold and platinum, in Table 23. Cost/sqft index for projects with no LEED certification is found to be least among the four LEED categories mentioned and is lower than the average index of all the projects. This implies that the LEED certification increases the cost of the project although not considerably as the rest of the projects with certifications are also of the order of total average index. LEED Platinum projects, with a cost/sqft index of 1.10, more than total average index and LEED Silver projects are found to be most expensive with index of 1.11. Gold certification has a cost/sqft index of 0.94, lower than the total average of all projects and slightly more than the projects with no LEED certifications. This implies that projects with no LEED certification cost less compared to LEED certified projects, but no conclusion can be made whether lower certifications cost less than the higher ones. It seems from the index values that the cost does not depend on level of LEED certifications as LEED Silver and Platinum have same index and LEED Gold has index 0.02 higher than the Silver and Platinum, which is an insignificant value.

Cost per metric index comparison shows that the cost per metric index of LEED Platinum projects is lower than average cost per metric of all the projects i.e. 0.91. In addition, the projects with no certification have index of 0.99, which is slightly lower than the total average but more than the LEED Platinum. LEED Silver has the maximum value of 1.06 and the only category with index more than the total average of 1.0. Gold has the least index of 0.87 contrary to what was observed in the cost/sqft index. Hence, it can be concluded that the cost per metric is uninfluenced by the sustainability certification. LEED certification does not appear to impact cost per metric indexes as LEED Platinum and Gold have lower values with projects with no certifications and LEED Silver has more index value. It can also be observed that the level of certification does not have a regular pattern affecting the cost, similar to cost/sqft index.

The duration index is found to be least for LEED Silver projects with 0.79 and Platinum follows with duration index of 0.89 and "None" with 0.95. All three categories have schedule index lower than the total average duration. LEED Gold certified projects have almost much higher duration index than the average of all the projects with duration index of 1.26. Therefore, it does not appear that LEED certification has any impact on project duration as LEED Platinum and Silver perform better than "None" while Gold proves to be the worst out of the four.

It can be concluded from the above three comparisons that the projects not certified by LEED proves to be most efficient as all the indexes are below total average, but LEED Platinum has performed better on two indexes and the third index is slightly more than the total average. It can be concluded that both LEED Platinum is better in overall performance than LEED Silver and LEED Gold. LEED Gold have, in general, better index values than LEED Silver, although less efficient than "None" and LEED Platinum. However, the duration index of LEED Gold is much higher than the total average making it extremely inefficient than LEED Silver in duration index category. It should be noted that there are only two LEED Silver certified projects, one in classrooms category and other in laboratory, limiting the scope of any conclusion. It can also be observed that LEED Gold classroom projects have almost same average cost/sqft as LEED Silver projects while none of the classroom projects have LEED Platinum certification.

Future Research

As an exploratory case study several metrics that were originally thought to be straight forward measures of cost and schedule were in fact more complex than thought. This study was limited by the small sample size of projects in the public sector, geographic and climatic regions, and the similarity of private project requirements to those of similar public projects. The main contribution of this research is the initial exploration of the relationships of categories that may impact cost and duration/schedule on public projects. For this reason, comparing public sector cost to similar projects in the private sector appears to be more complex than originally thought.

Future research should include project examples from around the country, both public and private, so comparisons can be made without the use of indexes and cost data from one contractor and one consultant. The lessons learned about data relationships can be expanded and improved with a larger data set to be more representative of public sector project costs with the hope of making some generalizations from which to build on for other researchers who want to look at micro cost drivers.

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