META-ANALYSIS OF DESIGN-BID-BUILD (DBB), COMPETITIVE SEALED PROPOSAL (CSP), DESIGN-BUILD (DB), AND CONSTRUCTION MANAGER AT RISK (CMR) REGARDING SELECTED PERFORMANCE METRICS

A Thesis

by

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ABSTRACT

The need for a one size fits all type of project delivery system still persists within the architecture, engineering, and construction (AEC) industry. However, owners still feel the need for a more refined system that could help meets their various demands within time and budget. These demands in part are due to the performance benefits the various project delivery system offers to project stakeholders. Ranging from higher project complexity to the level of communication and integration, these project delivery systems have been used to produce world class buildings and state-of-the-art projects. Unlike competitive sealed proposal (CSP), over the decades, traditional low bid design-bid-build (DBB), construction manager at risk (CMR), and design-build (DB) has gained significant credits and awareness in the industry due to their vast popularity and usage in different varieties of project type in the U.S and around the world.

Several studies however have been conducted to quantify these performance benefits and wastes levels, in terms of the commonly used metrics namely; time, unit cost, cost growth, delivery speed, schedule growth, production rate, safety, project change, and project quality. This paper meta-analytically organizes and summarizes decades the construction literature that quantifies the differences in performance benefits and waste levels between DBB, CSP, DB, and CMR project delivery methods in terms of project cost growth, schedule growth, project change, and quality to unfold the trends, patterns and/or identifies possible differences in the results. Findings reveal that despite several

research efforts, few studies present statistically significant comparative results between the studied project delivery systems for all the identified key waste and performance metrics. Other project delivery characteristics such as owner involvement, project team preference, project team chemistry and experience, project team participant`s involvement and entry time, and overall team characteristics was found across studies to have tremendous impact on the levels of waste, performance, and benefits associated with the delivery systems and project outcomes irrespective of the project delivery system adopted.

Overall, this paper intends to contribute to the existing body of knowledge by summarizing decades of project delivery systems performance research, while identifying and comparing the range of project performance values that can be achieved by using DBB, CSP, DB, or CMR. The paper also intends to allow for an improved understanding and proper implementation of the studied project delivery systems performance.

DEDICATION

To my family, friends, professors, and the entirety of my office (Texas A&M office of the division of finance and administration) who have supported me throughout this research and my stay at Texas A&M University.

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1. INTRODUCTION

1.1 Background

In the United States, there are numerous amount of project delivery systems used for project procurement and execution. From the conventional procurement method (DBB) to the most recent method (IPD), these procurement methods are being utilized in the construction industry throughout the United States and all around the world. According to numerous sources and literature, the most commonly used delivery system in the United States architecture-engineering-construction (AEC) industry are conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), construction manager at risk (CMR), and integrated project delivery (IPD) or lean integrated project delivery (LEAN-IPD). Several industrial factors have ultimately led to the emergence and development of alternative project delivery systems. Factors such as delay, lack of communication, project complexity, collaboration, risk allocation, incentives, lack of trust, varying stakeholders` involvement, cost, time, safety, quality etc. among construction stakeholders are common examples of the problems that often led to the invention of a new project delivery system. However, the performance benefits or the amount of waste generated by each individual procurement method has not been validated by research. On one hand, other than individual case studies, there has not been a comprehensive study that shows the benefit of each procurement method regarding performance value through a scientific statistical analysis, most especially in the case of comparing the less collaborative project delivery methods – Design-Bid-Build (DBB) and Competitive Sealed Proposal (CSP) and the more collaborative delivery methods – Design-Build (DB) and Construction Manager at Risk (CMR). On the other hand, there still exists the need to evaluate DBB, CSP, DB, and CMR delivery systems in order to understand each system`s performance benefits based on the numerous key metrics that have been readily identified within the AEC industry in order to derive and quantify the amount of benefits or wastes generated by using these project delivery systems.

Kashiwagi (2008) studied the various procurement methods and project delivery methods used in the architecture-engineering-construction (AEC) industry, and challenged the theory of having multiple or vast variety of procurement methods to solving the industrial issues on the ability to meet project schedule and budget. However, changing the delivery method (product and process design) in the AEC industry will significantly improve the industry's ability to meet the aforementioned factors as well as schedule and budget. The study on one hand concluded that it is not until an owner utilizes either the conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), or construction manager at risk (CMR) project delivery system will result in optimal project outcome, but rather how the owner procures the project participants (e.g. architect or constructor); that is the use of "best value" in the procurement process. On the other hand, the author states that this approach can be used in any of the delivery systems, hence this would allow for an overall improvement in projects` constructability within budget and meeting the anticipated schedule.

Using the above description as a baseline for this study, the authors of this research paper explored the procurement and delivery performance using various metrics such as project cost growth, time and schedule growth, project change, construction speed, and quality to identify, quantify, and compare the performance and waste levels of projects procured with the conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), or construction manager at risk (CMR) project delivery system.

1.2 Problem Statement

Even though various research studies have been done on the different project delivery systems in the construction industry, it is still unclear to date which of the delivery method is the best amongst them. This is because projects vary in kind, cost, size, and location (The Texas Legislative Council 2012), and also in terms of completeness of plans and specifications (Ibbs 2003). The usual norm of the architecture-engineering-construction (AEC) industry whenever a new project delivery system is invented is to characteristically benchmark the new delivery system performance (benefits and disbenefits) against other available delivery systems that are currently in use, which then provides a performance measurement scale. Some decades ago, such comparisons were performed when CMR emerged as well as the emergence of DB (El Asmar et al. 2013).

Although, they might have been often regarded to as cousins due to their procurement requirements similarities within the construction industry, there has not been a survey of literature that vehemently shows any study that has statistically compared and quantified the level of waste, performance or benefits of the two least collaborative project delivery systems (DBB and CSP), likewise is the case of the more collaborative project delivery systems (DB and CMR). Aside from anecdotal examples and few other case studies, very minimal amount of literature review exists to support the superiority of DBB, CSP, DB, or CMR in terms of quantifying the amount of waste generated, their performance level, and benefits. Instead, much of the literature regards DBB or CSP when compared with alternative project delivery methods (DB or CMR) as being prone to increasing construction cost, schedule growth, higher rate of change orders, unsatisfactory quality, lower worker productivity, less sustainability. Hence, this is not always the case for every project. Other studies also show that the above factor (waste metrics) could be achieved by the utilization of adequate process and product design, implementing lean principles, best practices or best-value methods in the procurement and delivery process (Kashiwagi 2008; Cho and Ballard 2011; Korkmaz et al. 2013) throughout the various stages and activities involved in the delivery systems. Just as in the case of Design Build (DB) and Construction Manager at Risk (CMR), previous reviews also indicates that facilities procured with either Conventional Design-Bid-Build (DBB) or Competitive Sealed Proposal (CSP) can also produce less waste, yield greater performance benefits, sustainably built, energy efficient, yield cost savings, and greater end user quality (Moeck and Yoon 2004). Although, for the most part, the lack of incentives and other human factors has been identified to be some of the potential problems or setbacks that allows project delivery methods to perform poorly (Teo and Loosemore 2003). The hypothesis that the less collaborative (DBB and CSP) does not yield optimal performance benefit or minimal overall waste like the case of the more collaborative (DB and CMR) (in terms of cost and time savings, schedule, delivery speed, construction speed and quality etc.) has not yet been supported statistically. For this meta-analytic study, the above hypothesis is considered as the starting point for this research study. Nonetheless, the purpose of this study is to create an in-depth literature comparisons and quantify the waste levels, performance and benefits in projects that are procured using the DBB, CSP, DB, and CMR delivery systems. This comparison will be used to understand the benefits of the various project delivery methods (DBB, CSP, DB, and CMR) available for use in the AEC industry and if it's worth the use and investment.

1.3 Research Questions

This research study is intended to investigate and answer the following questions:

- Is any project delivery methods typically geared to eliminating waste or sustainably the best?
- What makes a specific delivery method better than the other one?
- How are the least collaborative (DBB and CSP) delivery methods superior in performance to the more collaborative (DB and CMR) delivery methods and vice versa?

- What are the various benefits associated with these delivery methods?
- What are the various components associated with these benefits?
- How can the various project participants benefit or implement the various delivery methods better?
- Is it the delivery methods that have a problem or the ways they are implemented in the industry today?

1.4 Research Goals and Objectives

1.4.1 Research Goals

Unlike the least collaborative delivery methods (Design-Bid-Build (DBB), Competitive Sealed Proposal (CSP)), previous studies on the various types of project delivery methods utilized in the United States shows that the more collaborative delivery (Construction Manager at Risk (CMAR), Design-Build (DB), and Integrated Project Delivery (IPD)) methods tends to yield better project outcome in terms of cost, waste, safety, quality, schedule, delivery speed, and construction speed due to their higher level of interaction amongst the construction stakeholders (Korkmaz et al. 2013). Likewise, other studies also shows that the less collaborative delivery methods can also achieve the same outcomes like the alternative delivery methods when implemented properly. This research study is aimed to meta-analytically assess the various metrics; namely project cost growth, schedule growth, construction speed, change order, and project change associated to measure and quantify the level of performance and waste generated in the procurement and execution of the four project delivery methods.

1.4.2 Research Objectives

This study is intended to systematically and critically analyze various literatures on project delivery systems in order to identify the different benefits associated with the use such project delivery system (DBB, CSP, CMR, and DB) by comparison using a meta-analysis approach (see methodology section below). This study aimed to also create a knowledge base procurement reference for construction stakeholders (i.e. to contribute to the body of knowledge that already exists). Ultimately, the study aimed to create awareness for the construction industry and stakeholders on manner to identify the levels of performance and eliminate waste in terms of cost, time, cash flow, safety, quality, schedule, delivery speed, and construction speed, which allows for an improved knowledge and understanding of the four delivery systems. Overall, this study is intended to enable and help owners and other construction stakeholders choose the appropriate delivery method or procurement process between DBB, CSP, CMR, and DB to utilize for their next or future project(s).

1.5 Definitions – Project Delivery Method and Procurement Process

There are several definitions attributed to the various project delivery systems used in the United States AEC industry today. Irrespective of their variation in definitions, these project delivery systems explain the appropriate timing of each project stakeholder`s involvement officially in the delivering process, while it also emphasis on the relationships among the project participants contract and communication (American Institute of Architects and Associated General Contractors of America (AIA-AGC) 2004). The effects of the numerous project delivery systems used in the US on performance factors such as construction cost growth, construction speed, time, project change, and project quality outcomes for different project types has been researched heavily (see literature review section). As mentioned earlier in the *Introduction* section of this paper, there are numerous delivery systems used in assigning contractual responsibilities to project participants for the design and construction of projects in the United States. For comprehensiveness, the four identified delivery systems (DBB, CSP, CMR, and DB) out of the numerous existing project delivery methods in the U.S. are further described and defined. These definitions are used for better understanding of each of the project delivery systems. Likewise, for better illustration, Figure 1, 3, 5, and 7 presents visual representation of the four delivery methods: DBB, CSP, DB, and CMR, while Figure 2, 4, 6 and 8 shows the linear timeline from the project inception to completion of the four delivery systems. The solid black arrow lines in the figure represent contractual relationships whereas the thick gray lines represent communication or coordination relationships between the construction stakeholders.

Design/bid/build is one of the most widely used project delivery system traditionally in the United States AEC industry, in such a way that the owner or its agent holds separate contracts with a designer/architect/engineer and a contractor. Generally, the owner typically contracts with a designer or design firm to provide a complete set of design documents. Subsequently, the owner or its agent then solicits for fixed price bids from constructors to perform the design work. The very constructor with the lowest bid offer is usually selected and enters into an agreement with the owner to construct the project(s) according to the attached contractual plans and specifications.

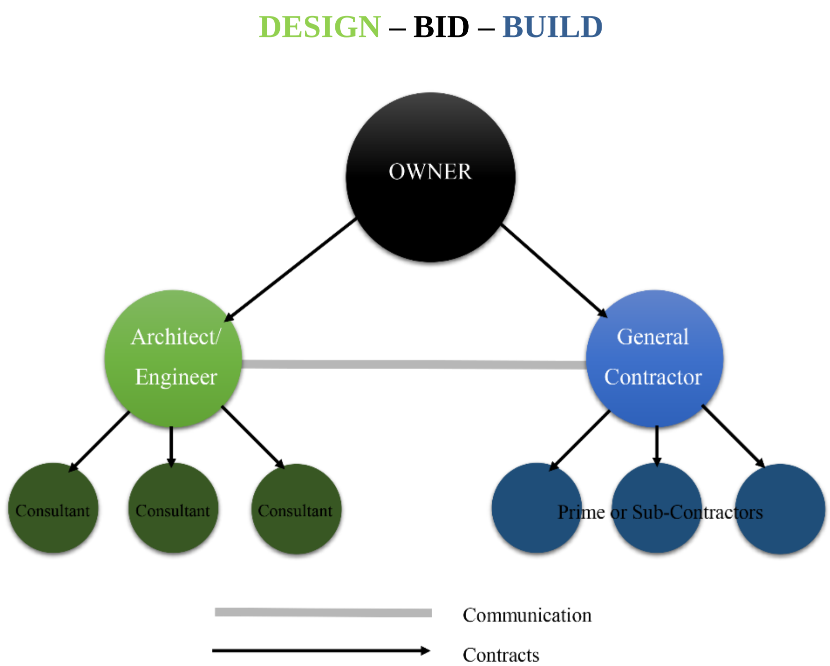

Figure 1. DBB contract and communication link

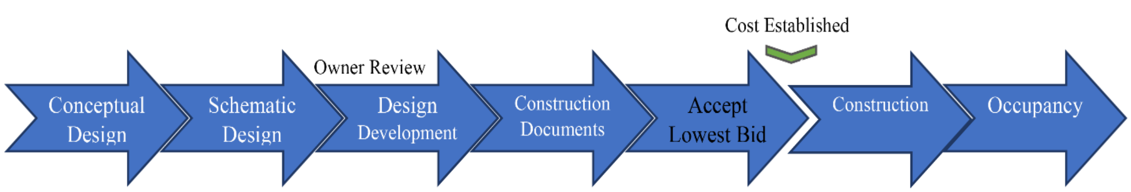

Figure 2. DBB project typical timeline

Competitive sealed proposal deals solely with the selection of the constructor once the design has been completed. Very much like the DBB procurement method, CSP allows the owner or its agent to choose the contractor based on consideration other than the strict “lowest-bidder”. This contractor selection is often regarded as the “best value” contracting method mostly in the public sector, where the builder is contracted based on either a lump sum amount or a cost-of-the-work up to a guaranteed maximum price (GMP) amount (Flake, 2012). With CSP the owner may only negotiate the cost of design after the selection of the design firm. Upon completion of the design and construction documents, the owner publically advertises the project to contractors in “call for interest,” determining which companies desire to bid and perform the work. Interested firms receive a request for proposal (RFP), which includes construction documents, project scope, project budget, selection criteria, project schedule, and other necessary information. Afterwards, the owner can rank, score, or pick a contractor based on contractor`s reputation, price, safety record, long-term cost, experience, prior performance, owner-contractor relationship, schedule, proposed methods of construction, constructor`s product and process design, historically underutilized businesses (HUB) projections, or other relevant factors as spelled out in the request for proposal. At this point, the owner negotiates in good faith the contract terms and conditions with the highest ranked contractor to achieve the “best value” for the execution of the project. Should the parties not come to an agreement, the owner may then negotiate with subsequently ranked firms until construction terms and conditions are agreed upon, at which point the owner executes the contract for construction and provides a notice to proceeded (NTP) according to the terms and conditions of the contract.

According to the Associated General Contractors of America (AGC), CSP delivery method is further define as a best value delivery system that is designed, “To assist public owners in ensuring that evaluation and award of construction contracts using performance factors in addition to cost are conducted in a fair and competitive manner” (Associated General Contractors of America, 2012, p.1).

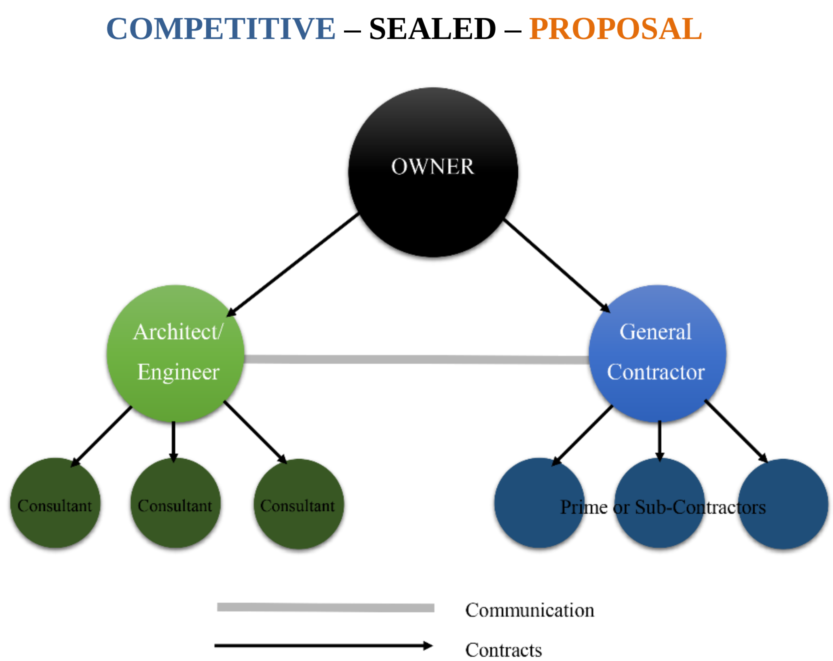

Figure 3. CSP contract and communication link

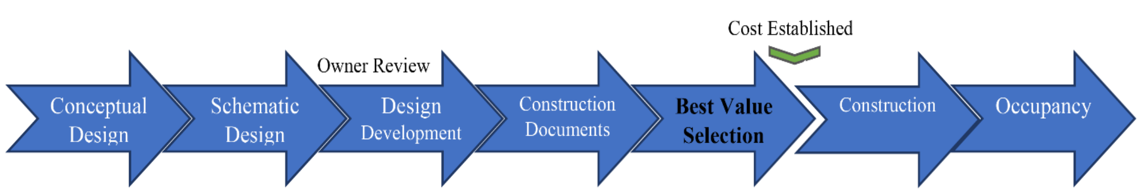

Figure 4. CSP project typical timeline

Design/build is also one of the most used project delivery methods in the United States AEC industry. It is a form of single entity enterprise where the owner procures both the architectural and construction services as a single entity to provide both design and construction services under a single contract, which is known as the design-builder. Contractually, design/build offers the owner a single point of responsibility for design and construction services. In some case, portions or all of the design and construction may be performed by a single design/ build entity or selected specialty work, or all may be subcontracted to other companies, but the designer/builder remains the only link to the owner. This delivery method in part is seen by some participants in the AEC industry as a solution for addressing some of the potential problems and limitations possessed by DBB, CSP, or CMR delivery method. This delivery system typically utilizes a request for proposal/request for qualification procedure instead of the typical invitation for bids accustomed with DBB delivery system. This DB delivery method solely gives the design-builder entity the details and controls of the design with less control and involvement of the owner or other project participants. This process often result in the design build project delivery systems` ability to compress the overall delivery process with the use "fast-track" construction; an ability to overlap between the project design and construction phases. In the end, the DB entity is liable for most the risk associated with the delivery process. These risks include the firm fixed cost which will include that of the subcontractors and specialties (if any), as well as design and construction costs, which is often due at proposal response (Graham 2001; Ibbs et al. 2003; El Wardani et al. 2006).

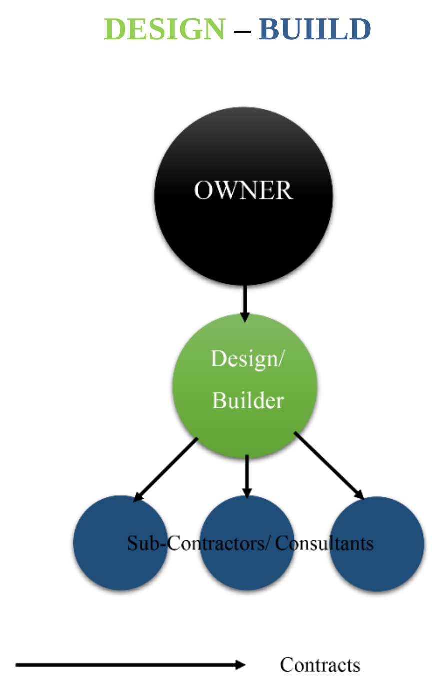

Figure 5. DB contract link

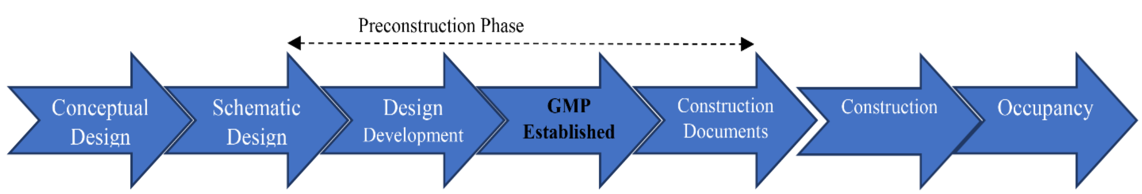

Figure 6. DB project typical timeline

Construction management at risk is a project delivery system where the owner has a separate contract with a designer and a constructor. On one hand, contractually, the owner procure a designer or a design firm to produce the design for a facility on a contract. On the other hand, the owner selects a constructor to perform construction work construction and management services in accordance with the plans and specifications, for a guaranteed maximum construction price (GMP) which is typically established when the design is around 50% to 90% developed. This delivery method is similar to that of DBB and CSP in such a way that the contractor acts as the general contractor during construction, but the constructor usually has significant input for both the owner and the designer during the pre-construction process or design phase unlike DBB and CSP. Another contrasting advantage of the CMR is that the owner typically deals with a hybrid construction or general contractor unlike the traditional general contractor with DBB.

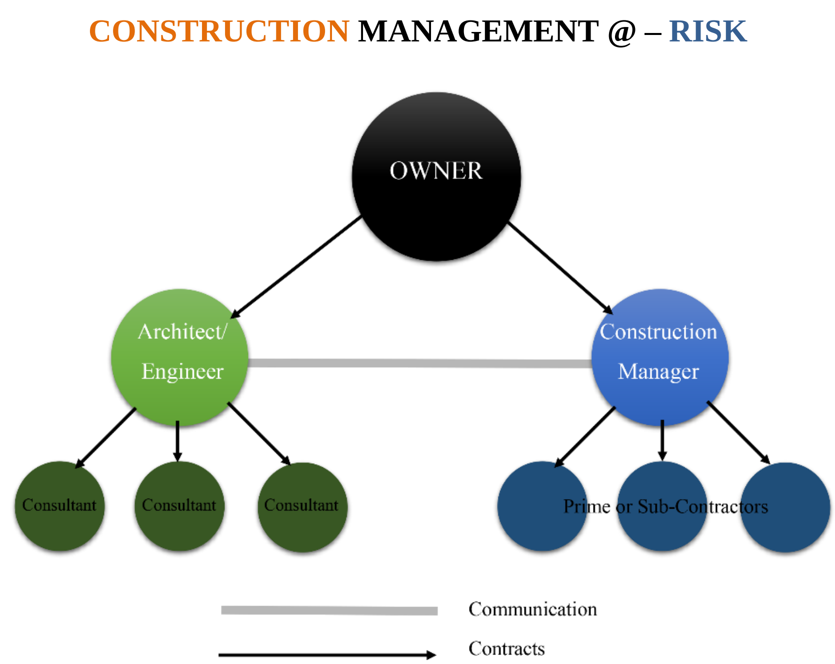

Figure 7. CMR contract and communication link

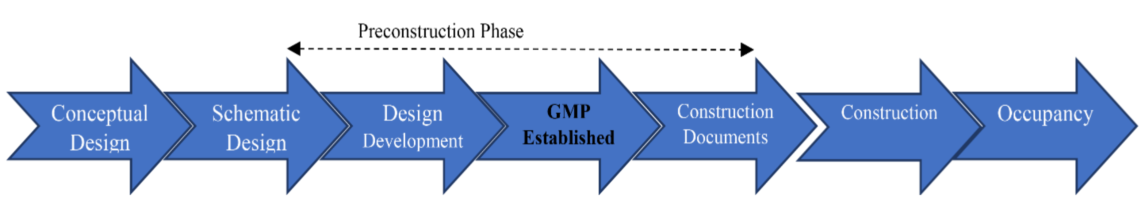

Figure 8. CMR project typical timeline

1.5.1 Differences among DBB, CSP, DB, and CMR delivery systems

The differences among the four delivery systems (DBB, CSP, DB, and CMR) are multifold. A side-by-side comparison of these four methods (see Table 1) allows for the identification of each method’s strengths and weaknesses, as well as the display of their various performance and the owner`s expected benefits or pitfalls. These differences in the delivery methods can also be clearly seen by comparing Figures 1 to 8 above.

The DBB delivery method is linear in nature, with the owner’s selection of a contractor taking place following the full design of a project. Under the DBB delivery method, the owner selects a design firm to create contract documents consisting of project drawings (the actual design) and job specifications. Although, depending on the size of the project and its complexity, the drawings typically consist of seven main design disciplines: Civil, Architectural, Structural, Mechanical, Electrical, Plumbing, and Telecommunications as designated by the Construction Specification Institute (CSI). Upon design completion, the project drawings become the contract documents, which are then, advertise for contractors to bid. After these bids are accepted, opened, and reviewed by the owner, the general contractor with the lowest bid is offered the job, contingent on their ability to provide accurate insurance and bond coverage. If the general contractor is able to meet the necessary insurance and bond requirements and accepts the job, a contract is signed to perform the work on the project. Since the design is considered as the contract document, and was completed and issued by the owner without the early consent, presence, or involvement of the general contractor during the conceptual and design phase, any changes that need to be done after the work begins are the owner's responsibility. These changes are often referred to as '*change orders*.' Likewise, without the contractor`s participation in design, the contractor is not held liable for any items missing in the construction documents, resulting in a reduced contingency fund. However, items that are not shown in the construction documents increases the cost incurred by the owner, hence, providing a potential avenue for profit from the contractor`s perspective. Any further work scope added to the post design phase and after the contract has been awarded due to errors and omissions is charged to the owner in the form of change orders, which increases the contractors contract value; thus, covering additional costs incurred. For the most part, contractors view this change orders as an opportunity to increase their cost bottom line by charging change-ordered work to the owner at an increased rate. Typically, a lump-sum contract is often associated with the DBB delivery method where project savings are shifted to the contractor's bottom line. This factor thus result in the contractor changing interests to finding other means to reduce job costs, which can be achieved by decreasing the quantity and quality of materials installed, as well as the product and process design methods by which they are installed.

1.5.2 Strengths and weaknesses of the delivery systems

Table 1: Basic characteristics of the four project delivery systems

CHARACTERISTICS	DBB	CSP	DB	CMR
Owner holds separate contracts with A/E and Contractor	✓	✓	✗	✓
Contractor selected based on qualifications	✗	✓	✓	✓
Defined project scope prior to construction	✓	✓	✗	✗
Single point of accountability	✓	✓	✓	✓
Cohesive team driven philosophy	✗	✗	✓	✓
Aggressive bidding	✓	✗	✗	✗
Ability to fast-track project	✗	✗	✓	✓
Contractor included in design	✗	✗	✓	✓
Change flexibility	✗	✗	✓	✓
Owner privy to all Contractor data via open book policy	✗	✗	✗	✓
Simplicity of project delivery	✓	✓	✗	✗
Conducive to large or sophisticated projects	✗	✗	✓	✓
Conducive to small or simplistic projects	✓	✓	✗	✗
Owner retains project savings	✗	✗	✓	✓
Increased quality of construction	✗	✓	✓	✓
All work is competitively bid	✓	✓	✗	✗
Guaranteed maximum price (GMP)	✗	✓	✓	✓
Lowest construction cost	✓	✓	✗	✗
Contractor absorbs up-side risk	✗	✗	✗	✓

(Source: adopted from Neidert et al. 2012)

In contrast to DBB, the CSP delivery method allows the owner or its agent to choose the contractor based on consideration other than the strict “lowest-bidder”. Unlike DBB, this contractor selection is often referred to as “best value” contracting mostly in the public sector, where the builder is contracted based on either a lump sum amount or a cost-of-the-work up to a guaranteed maximum price (GMP) amount (Flake, 2012). With CSP the owner may only negotiate the cost of design after the selection of the design firm. Upon completion of the design and construction documents, the owner publically advertises the project to contractors in “call for interest,” determining which companies desire to bid and perform the work. Interested firms receive a request for proposal (RFP), which includes construction documents, project scope, project budget, selection criteria, project schedule, and other necessary information. Afterwards, the owner can rank, score, or pick a contractor based on contractor`s reputation, price, safety record, long-term cost, experience, prior performance, owner-contractor relationship, schedule, proposed methods of construction, constructor`s product and process design, historically underutilized businesses (HUB) projections, or other relevant factors as spelled out in the request for proposal. At this point, the owner negotiates in good faith the contract terms and conditions with the highest ranked contractor to achieve the “best value” for the execution of the project.

Like DBB and CSP, Design-Build (DB) procurement process is also linear in nature but shorter due to the delivery`s ability to fast track and limited amount of contract involved in the process. As mentioned above in the definition, the owner typically has a single contract with a designer and constructor as an entity which is referred to as the design-builder. By contract, the design-builder provides both the architectural and construction services as a single entity for project execution. The designer in a DB delivery system is part of the entire design and construction team from project conception to completion, instead of the typical separate entity/contract with the owner as in the case of DBB and CSP. Likewise, the construction manager`s role become much involved as it serves as the owner`s agent or representative within the DB entity and other project participants involved. Unlike DBB or CSP delivery systems, the owner in a DB contract has numerous ways or options of selecting the final design-builder. This may be done by a "best value" (unit cost fee or total project cost, or low bid) procurement as in the case of CSP delivery system, or direct negotiation, or mainly by the firm's qualification. Upon selection, the design or pre-construction phase begins and in accordance with the contract agreement, a Guaranteed Maximum Price (GMP) is established around 50% to 90% of the design completion with all the fixed cost established in the GMP. The procurement process for the DB entity selection is typically a two-step process whereby the owner first sends out a request for proposal (RFP), which includes construction documents, project scope, project budget, selection criteria, project schedule, and other necessary information for teams to submit their qualifications. Afterwards, the owner will shortlist the firm that responded to the RFQ base on factors spelled out in the qualification, and then send out a request for proposal (RFP) to the shortlisted firms requesting information such as cost information, schedule, design approach and innovation, and details that defines the entire project scope and quality of the project to be delivered. On one hand, the owner may also select the final DB firm based on factors such as firm`s reputation, safety record, experience, prior performance, relationship, schedule, proposed methods of construction, constructor`s product and process design, historically underutilized businesses (HUB) projections, or other relevant factors as spelled out in the RFP. On the other hand, the selection could be made on a combination of pricing, qualification, and design/construction approach.

Finally, CMR delivery method is very similar to that of DB but with little variation in the amount of contracts, team selections, and the number of key players involved in the procurement process. Unlike DB delivery system, the owner typically have a separate contract with the architect/engineer or design firm and construction firm to provide architectural and construction services. Like DB and CSP, the owner also selects the contractor using the "best value" procurement approach, which may also be done in a two-step process – RFQ, followed by RFP. The owner however has the option of selecting both the designer and the constructor at different time or simultaneously, but the contractor`s selection is typically made before the completion of the construction documents. With this type of contractor`s selection or delivery system, the contractor has the opportunity to work directly with the designer to provide important inputs such as constructability issue, schedule, clash detection, materials, cost overrun, and other important construction features during the pre-construction phase; i.e. before the design is complete and before construction could begin. Like DB system, CMR also gives the owner or the project participants the opportunity to fast track. Since the construction manager serves as the owner`s agent or representative in this delivery system, the constructor can easily subcontract all or portion of completed works with an approve design at any time to other specialty consultants involved in the project by the owner.

1.5.3 Appropriate Project Delivery Method Selection

The selection of an appropriate project delivery system for a specific project can be regarded as a complex and strenuous decision-making process due to the high level of risks and uncertainties associated with the overall process. From the owner`s point of view, there are many factors that exist in the construction industry today which warrants the selections of the best and appropriate project delivery method. However, there has been no single research or previous practice that has yet determined the appropriateness of a single project delivery method that best suit the needs of every construction project "a one size fits all" delivery method. These factors may range from size of the project to its complexity. Some of the factors includes; scope of work definition, location, cash flow, availability, constructability, approvals, contract, organization, method, delivery speed, cost, sustainable/green initiatives, delays, quality, project characteristics and risk and relationships factors as well as other pertinent issues that are not listed here. Besides the enlisted factors, owners may still wrongfully select a procurement method based on familiarity, lack of knowledge, or perceived ease of use. Ultimately, in order for owners to choose the delivery method that produces the "best value," it is paramount for the owner to take some of the aforementioned factors into consideration from the conception of the project to completion as a tool towards project delivery method selection. For instance, over the past fifteen years, Texas has seen a dramatic change in the ISD preferred type of project delivery systems chosen for new school construction. DBB is now rarely used and CSP and CMR are the preferred methods for ISDs (Reinisch et al. 2012).

According to Gordon (1994), owner's ideal construction contracting method should at least have an ideal mixture of the following four parts:

1. Scope definition: This is identified as the portion of the project's tasks in terms of design, construction, and its economics which is assigned to the constructor.
2. Owner`s organization: The business entity or construction stakeholders with which the owner holds a construction contract. E.g. architect/engineer, construction manager, facility manager, developer, lawyer etc.
3. Contract: This is the type of binding agreement between the owner and the construction stakeholders for work performed and how payments will be made. This could be in form of a lump-sum, GMP, target value or cost-plus payment.
4. Method/Award: This is referred to as the method used by the owner to choose and contract the constructor and/or the price. This could be done by competitive bidding, best value, experience, finance, or negotiation.

2. LITERATURE REVIEW: COMPARING DELIVERY METHODS

From the conventional procurement method (DBB) to the most recent method (IPD), there are numerous project delivery methods that are being utilized in the construction industry throughout the United States and all around the world. According to numerous sources and literatures, the most commonly used delivery system in the United States AEC industry are the conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), construction manager at risk (CMR), and integrated project delivery (IPD) or lean integrated project delivery (LEAN-IPD). However, most of these studies differ based on the subject area identified, metrics used and their characteristics, such as the size, type and location of projects studied and the benefit metrics that are employed. The literatures below focus on the current and gap in knowledge by emphasizing on the aforementioned project delivery characteristics and differences. These literatures provide a strong background as well as help understand the basis of this meta-analytic study and how decades of literatures have been analyzed to compare the various project delivery methods.

Neidert et al. (2012) study empirically compared the performance of CMAR and CSP in the construction of higher education facilities using data collected from Texas A&M University. The study consists of 33 projects constructed by The Texas A&M University System, 19 of the facilities were procured using CMAR while the other 14 were procured using CSP. According to the study, the overall results show a reduction in change order quantity and schedule growth when using CMAR over CSP. However, further results also show that CSP is more appropriate and likely to result in decreased project and construction costs when compared to CMAR.

Ibbs et al. (2003) study compared DBB, DB and alternative project delivery methods using data from 67 global projects from the Construction Industry Institute's (CII) database projects by comparing performance metrics such as cost growth, schedule growth, and productivity. Cost growth and productivity for DB was not found to perform better than DBB. However, schedule growth results present better performance of DB when compared to DBB. Conversely, the study also found timesaving as definitive advantage for project procured with DB project delivery method. Based on the study`s results, project management expertise and experience of the contractor was identified to have a greater impact on project performance outcomes than focusing on project delivery system’s strategy only.

A similar study was conducted by Hale et al. (2009) where the researchers compared DBB and DB delivery method performance using schedule saving and cost growth as the determining metrics. The research sample consisted of 77 building facilities, 39 of the facilities were procured using DBB, while the other 38 were procured using DB. This facilities were constructed and used by the Naval Facilities Engineering Command. After adjusting for location, time as well as other existing outliers, the authors concluded that DB exhibited a 2% reduction in cost growth per bed, with a schedule growth in days which doubles that of DBB. In addition, (Love 2002) researched the influence that linear and dynamic project delivery methods have on rework costs using 161 construction projects throughout Australia. Through a questionnaire survey, the researcher concluded there was no significant difference in rework costs based on differing project delivery methods.

The Texas Legislative Council (2012) qualitatively and quantitatively compared CSP and other alternative project delivery methods such as DB and CMR. A total of 59 projects were surveyed and the metrics used for the study were intended to define superiority among the three delivery methods based on the following factors:

(i) *The primary purpose of the project* – For project types that were procured exclusively through a single alternative project delivery method, the DB method was the method most commonly used and accounted for the procurement of all of the highway projects, transit projects, wastewater projects, and a river channel ecosystem restoration and recreation project; All but one of the electric utility projects and all of the street and landfill projects were procured using the CSP method. The CMR method was the exclusive method of procurement for all of the water plant projects; Building projects were procured using an almost even mix of the three alternative project delivery methods while water distribution and water supply projects were procured using an even mix of the CSP and CMR methods).

(ii) *Year the project was contracted* – Comparing across years from 2007 to 2012, the CSP method was the most commonly used of the alternative project delivery methods during the first three years of the six-year period in the survey (from 2007 to 2009), accounting for 20 of the 31 projects procured during that three-year period and for which respondents provided substantial information. However, the DB method accounted for as many project procurements (11) as did the CSP method in each of the latter three years of the period (from 2010 to 2012); In 2007, all of the civil works projects cited in the responses were procured using only the CSP method and the CMR method. Thereafter, the projects contracted from 2008 to 2012 were procured using a mix of all three alternative project delivery methods, including the DB method.

(iii) *Rationale for using the project method* – Survey results indicate that entities most often chose the DB method of project procurement when the rationale was to save time, but that they tended to choose the CSP method when the rationale was to select the best qualified contractor for the job. The cost factor and the interest in saving money do not seem to confer an advantage to any single method over another to the extent that entities would choose one procurement method predominantly over another. Based on all of the responses received and frequency with which each rationale is cited, the respondents appear to have a nearly equal interest in saving time, saving money, and selecting qualified contractors as a factor in their rationale for selecting an alternative project delivery method.

(iv) *Number of bids received for the project* – this data was not analyzed due to factors beyond the entity's control.

(v) *Actual cost of the project if completed or estimated cost if not completed* – On the other hand, the more costly reported projects, for which the actual cost of the project was more than $25 million, were procured most often using the DB method (12 out of 23, or 63.2 percent, of all projects in this cost range were so procured).

(vi) *Advantages in using the chosen method* – Cost savings and innovation were the two most common advantages that respondents observed in using an alternative project delivery method over the conventional method; Projects procured using the DB method were most often cited by respondents who observed advantages in the use of an alternative project delivery method, with 25 observations altogether for DB projects. The most common advantage observed in the use of the DB method was innovation (observed in eight of the DB projects where an advantage was observed).

(vii) *Disadvantages observed in using the chosen method* – More than 75 percent of responses did not cite any observed disadvantages in the use of an alternative project delivery method, suggesting that most entities generally found the use of such methods to be positive; Half of the observations of a disadvantage in the use of the DB method cited a difficulty in its use, with the remainder of the observations being evenly divided between ineffectiveness in the use of and unfamiliarity with the method. Survey responses indicate a similar breakdown of the disadvantages observed in the use of the CSP method.

Pocock (1996) conducted a study on the delivery performance of the conventional DBB, CMR, DB and other alternative project delivery systems using a total of 209 construction projects by the military. The performance metrics used for the delivery methods comparison were schedule growth, cost growth and design deficiencies. Partnered projects (DB, CMR) were most successful in terms of schedule growth; while DB performed favorably well with cost growth and design deficiencies. According to the study results, projects procured with conventional DBB projects did performed worse overall in areas such as schedule growth, design deficiencies, and modifications. The study highlights the degree of team integration as a determining factors impacting the outcome of project delivery methods and project performance.

Rojas and Kell (2008) empirically conducted a comparative analysis of the cost growth performance of Pacific Northwest Public Schools procured using CMAR and DBB. The research study objective was to determine CMAR’s cost growth performance when compared to the conventional DBB. The author used three metrics in the research analysis: change order growth in terms of change order dollars as a percentage of original contract dollars, GMP as a guarantor of total construction cost, bid-buyout data as the difference between the pre-bid owner’s estimate, and the final construction contract cost. Categorically, a data set of sample size of 297 completed public school projects was used in the analysis with varying location throughout the states of Oregon and Washington. The following research results was computed from the study: CMAR maintained a 1.55% decrease in change order growth when compared to DBB, only 25% of CMAR projects finished at or below their GMP, and CMAR resulted in a 29% increase in cost growth when compared to DBB. The researchers concluded that a CMAR GMP is not an effective guarantee of the maximum price, and that when compared to DBB, CMAR is not an effective method of cost growth control. However, it is noted that the studies sample consisted of 273 DBB projects compared to only 24 CMAR projects, which suggests an inaccurate representation of the study sample as a whole, and plausible statistical insignificance.

Bennett et al. (1996) compared cost growth, schedule growth, and projects quality performance of the combination of 332 DBB and DB projects in the UK. The authors result conclusively showed that DB projects improved by 30% in delivery speed, 12% in construction speed, and a 13% less in unit cost when compared DBB projects. Similarly, in a study conducted by Sanvido and Konchar (1998) using another Construction Industry Institute's (CII) data also indicated that projects procured with DB delivery systems performed better than CMR projects, whereas both DB and CMR yield better performance than projects procured with the DBB delivery systems. Out the various metrics identified in the research design, delivery speed, construction speed, and unit cost shows statistically significant results.

Reinisch et al. (2011) compared the costs associated with the use of project delivery systems (PDSs) by Texas ISDs in the new construction of public elementary schools. A comparative means test was used to compare the cost per student amongst Texas ISDs that used CMR and CSP as their PDSs. With the “best value” procurement method associated with CSP unlike conventional DBB project delivery method that selects the contractor on a lowest bidder basis, the CSP procurement method proved to be beneficial to cutting costs. Ultimately, the study result showed that the CSP system resulted in an approximate savings of $4,000 less per student in ISDs spending to have new schools constructed when compared with CMR system. According to the study, a savings of about $96,000 would have been achieved in their total costs per student had the new 24 ISDs projects were procured using the CSP delivery system instead of the CMR delivery system that was used.

Kulkarni et al. (2011) study compared cost performance and reducible change orders of 17 CMR and 13 CSP projects by the same owner. The cost performance metrics used in the study are errors, omissions and design modifications which occur as a result of change orders. The study results shows that the overall cost performance is more reliable for CMR than for CSP projects. The cost of reducible change orders for all three categories (errors, omissions and design modifications) are lower for CMR than for CSP projects. However, in some instances cost performance for CSP contracts were both positive and negative, confirming that CSP contracts may result in loss as well as cost savings.

Riley et al. (2005) conducted a study on the factors warranting change order on the effects that linear and dynamic delivery systems have on the frequency and magnitude of change in mechanical construction. The study assembled change order data from 120 new mechanical construction projects that were procured using DBB and the DB delivery methods for a period of 6 years (1996 – 2002) in central Pennsylvania. Qualitatively, the study beseeched from the project manager on each project to identify the source of the 598 known changes. The change orders were grouped into two categories for easy identification: owner-initiated change and that of unforeseen conditional change (orders generated on the field). Overall, the study showed that the average size of all the DB change orders in terms of dollars amount was about 50% lower when compared to the conventional DBB, on the other hand, the average size of unforeseen change orders in dollars was about 86% lower on DB projects. Research results clearly identify dynamic delivery systems as a means of reducing the costs associated with changes in construction. Inconclusively, the study also showed that the difference in frequency of changes between the delivery methods was not statistically significant. Additionally, the researchers sample consisted of projects constructed by a sole contractor, suggesting that results cannot be applied to the population of contractors as a whole.

Quantitatively and qualitatively, Riley et al. (2005) conducted another study using three case studies to determine the advantages or disadvantages of using mechanical contractors on projects procured with design-build on green building projects. The research study indicated that the early involvement of mechanical contractors in the DB delivery method resulted in a significant cost savings and an effective final product when compared with the projects procured with the DBB system approach. The willingness of the DB mechanical contractor's to readily embrace new innovative solutions and technologies in their product and process design was also found significant in the study.

Korkmaz et al. (2013) conducted a study to analyze the effect of project delivery systems on attaining a highly sustainable and efficient performance building. The study identified twelve in-depth case studies by comparing DBB, CMR, and DB projects and their sustainable outcomes. The effects of each project delivery method characteristics upon projects` construction completion were examined to determine project performance. The results showed that final project outcomes, particularly those of the sustainability goals were highly impacted due to the level of integration in the delivery process. According to the study, achieving better facilitation and implementation of integration in DB and CMR projects were identified. Similarly, the potential for DBB to yield higher levels of integration and excellent project outcome was also identified in the study only if other key project participants (e.g. constructor) are informally involved early enough in the project delivery process phases. Other factors were found crucial in achieving excellent overall project success and team integration which includes project team obligation towards design and construction sustainability goals, project team compatibility, and design charrette.

In a recent studies by Cho and Ballard (2011) compared IPD with other non-IPD delivery methods. A total of 49 projects were included in the study to seek if the Last Planner System (LPS) has any influence on projects procured with the IPD and non-IPD like project delivery systems when compared by performing a t-test. This LP system is a production system that helps control the level of task workflow in projects, while improving the overall performance of the project. Ultimately, the study results showed that the implementation of the Last Planner System into the project delivery systems improves projects performance. The results were also unable to show any statistical significant variations in projects performance (cost and quality) between the different projects delivery systems compared.

More recently El Asmar et al. (2013) conducted a study on the performance Integrated Project Delivery (IPD) system and empirically compared it to other alternative delivery methods (DBB, DB, and CMR) by evaluating various performance metrics such as schedule growth, cost growth, quality, safety, project change, communication, labor, environmental, and business. The results on one hand indicate that IPD like projects achieved performance improvements with statistically significant results in fourteen metrics across six analyzed areas such as: project change, schedule growth, project quality, stakeholder's involvement and communication, project environment, as well as the financial performance. On the other hand, non-statistically significant result where found in performance areas such as: unit cost, cost growth, construction speed, and rework. This study results in part also conform to that of Love (2002) study on the influence that linear and dynamic project delivery systems have on rework costs, which concluded that there was no significant difference in rework costs based on the project delivery methods utilized.

To summarize the literature review, Horman and Kenley (2005) conducted a study to quantify the level of wasted time and activities in the architecture engineering construction (AEC) industry. The magnitude of wasted activity time within the construction industry was indicated in the study by the contrasting state of existing knowledge. Conclusively, irrespective of the procurement methods used in project acquisitions, the study indicated that 50% of the effective construction time is approximately dedicated to wasteful activities. These quantified wasteful activities though is said to vary substantially from projects to projects, mostly in terms of project scope, size, and complexity. All in all, according to the study, potential improvement in the level of wasted time and activities in construction industry can be considerable improved by implementing lean construction process into the design/construction process and product design through waste reducing initiatives.

2.1 Significance of Study

This research study seek to contribute to the body of knowledge that already exist through systematically reviewing and summarizing decades of literatures on project delivery methods that identify the range of project performance and benefits that can be achieved by using any of the four studied delivery systems (DBB, CSP, DB, and CMR).

The reported data was collected from various completed projects ranging from private to public sector and from residential to highway construction that utilize any of the four project delivery methods. This research findings should benefit owners and other construction stakeholders by providing improved understanding and knowledge of the four delivery systems for future implementation. This research findings should inform the architecture engineering construction (AEC) industry or project participants within the industry as to what project delivery systems are being utilized, the rationale to selecting a specific delivery method, and the range of benefits associated with any chosen project delivery systems.

3. METHODOLOGY

This paper meta-analytically review and analyze the body of literature that has quantitatively reported levels of performance, benefits and wastes generated by using conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), or construction manager at risk (CMR) as a project delivery systems. Numerous literatures and research studies pertaining to the level of project delivery performance, benefits, or wastes have been conducted over the years; and their results have offered a valuable indicator of project delivery inefficiency and wasteful practice in the architecture engineering construction (AEC) industry. Yet, these results have been long overdue, which requires the need to synthesis the results with a replicable and well-structured analysis. This process however requires the pooling and gathering of various research results that provides thorough analyzed systematic view of the project delivery performance benefits and waste levels character quantitatively. Such process can be achieved with the use of meta-analysis as a research methodology.

3.1 Meta-Analysis

Meta-analysis as a methodology provides an opportunity of gathering a clear and complete understanding of the quantifiable characteristics of project delivery system performance in design and construction. The method provides a means for evaluating and quantifying the level of delivery performance, benefit, and waste studies.

According to Rosenthal and DiMatteo (2001), “meta-analysis is a methodology for systematically and comprehensively examining a body of research, carefully formulating hypotheses, conducting an exhaustive search and establishing inclusion/exclusion criteria for articles, recording and statistically synthesizing and combining data and effect sizes from these studies, searching for moderator and mediator variables to explain effects of interest, and reporting results.” Glass (1976) defines it as “the analysis of analyses…the statistical analysis of a large collection of…results from individual studies for the purpose of integrating the findings. It provides a lucrative and critical assessment that contrasts with the casual, narrative discussions of research studies which (often) typify our attempts to make sense of the rapidly expanding research literature.” According to Hunt (1997), “meta-analysis offers a systematic means of integrating and accumulating the findings of individual studies to achieve an authoritative position regarding the issue under examination.” Meta-analysis can also be used to detect the relationships, patterns, or average effect sizes in individual case studies where results and findings prove to be conflicting or insignificant (Hunt 1997, p. 8).

Horman and Kenley (2005) used meta-analysis to quantify the levels of wasted time from conception to completion of projects in the construction industry. Likewise, El Goftar et al. (2014) meta-analytically compare existing literatures to seek project performance between projects that are procured by either using design-build or design-bid-build project delivery systems.

Practically, meta-analysis is used for collecting relevant statistical data from identical individual studies, which are then combined and analyzed statistically to provide an average (Lyons 1998). And to date, the methodology is now commonly used in various fields such as management, medicine, education, psychology, and sociology and in an emerging scope of publications (Lyons 1998; Hunt 1997; Rosenthal 1991).

3.2 Research Method

The goal of this study is to meta-analytically analyze existing literatures while evaluating and comparing the performance benefits and the levels of waste generated for projects that are procured using conventional design-bid-build (DBB), competitive sealed proposal (CSP), design-build (DB), or construction manager at risk (CMR) as a project delivery method. This meta-analytically research methodology used for this study requires three distinct stages. The three stages (search, coding, and statistical) respectively are used to combine the outcomes of previously analyzed literatures and research studies that identifies the levels of project delivery performance, benefits and wastes generated by using any of the four delivery systems.

3.2.1 Stage A – Search Procedures

This stage entails the assessment of existing body of literature available and the industrial practices which will serve as the study`s reference point. Manual and computer searches was conducted extensively on the subject matter with reference to construction and related literature. Two key important steps were involved in this stage: the first step was intended to acknowledge the current state of the AEC industry knowledge; this step results in the location of 28 relevant studies, while the second step was intended to categorize some of the important metrics needed to be analyzed in order to accomplish the research goal; this step results in the creation of table 2. According to the literatures, the project delivery systems performance metrics identified both qualitatively and quantitatively are the dependent variables that were measured upon project completion. The project delivery systems` key performance, benefits, or the levels of waste metrics analyzed in this meta-analytic study was based primarily on the performance metrics identified within earlier research works and/or case studies. Some of these performance metrics are highlighted in the *Literature Review* section which includes journal papers, technical reports, and conference proceedings. These reviews thus resulted in the dataset that are presented in this study (see data analysis section). Table 2 below presents the list of the various studies and dataset gathered for the purpose of this study. An inclusion rule was generated for each individual study in order to obtain better and non-biased results. Each study was included if: (1) it conveyed sufficient information to allow for statistical data accumulation (2) a statistical description of the data was provided in study. These studies were carefully searched and included following an appropriate keyword search (e.g. project delivery methods, competitive sealed proposal, design-bid-build, delivery performance, project delivery and construction wastes, quantifying construction waste, partnering in construction, project delivery method procurement, construction cost and time control, and construction schedule) into the internet search engine publishers such as: Elsevier, ASCE Library, Google Scholar, AIC, Scopus, Emerald Insight, Science Direct, Research Gate etc.

The first stage procedures resulted in the identification of 28 relevant studies. The comprehensive list of information regarding each study are summarized in Table 2. The table chronologically identifies each study author(s), the year of the publication, publication type, project type (i.e. the various kind of project(s) that was identified in the study), and the project/study location. Out of the 28 studies identified, one study could not be found (Rakesh et al. 2013) due to the restriction placed by the researcher. In addition, five out of the studies acquired during the search process failed to allow for adequate meta-analytic combination due to the studies insufficient information and hence were not included in the study for further analysis. The studies are: Hyun et al. 2008, Molenaar et al. 2009, Riley et al. 2005, and Water Design–Build Council 2009.

Unlike with most methodology, one of the most common problem with meta-analysis is the availability of unpublished studies and the relevancy of studies. This exclusion of non-published studies increases selection bias (walker et al. 2008). However, the remaining 23 studies were subjected to the next stage (coding procedures) and included in the study for further analysis.

Table 2: Basic information of identified studies

Reference	Study Author(s)	Publication Year	Publication Type	Project Type	Project Location
1	Bennett et al	1996	Journal	General/Public Sector	United Kingdom
2	Pocock	1996	Journal	Public Sector	USA
3	Konchar M. and Sanvido V.	1998	Journal	Industrial	USA
4	Ibbs et al.	2003	Journal	General (CII)	USA, Canada, Middle East, Latin America
5	Riley et al.	2005	Journal	Mechanical Project	USA
6	Riley et al.	2005	Journal	Green Building Project	USA
7	Groppel et al.	2005	Report	Education	Dallas
8	Col Debella, D. and Ries, R.	2006	Journal	Education	USA
9	FHWA	2006	Report	Highway	USA
10	Rojas and Kell	2008	Journal	Public Sector	USA
11	Hyun et al.	2008	Journal	Multifamily Housing	USA
12	Water Design–Build Council	2009	Journal	Water & Wastewater	USA
13	Molenaar et al.	2009	Journal	Public and Private Projects	USA and District of Columbia
14	Hale et al.	2009	Journal	Military Buildings	USA
15	Rajan et al.	2010	Journal	Multiple Projects (ENR)	USA
16	Korkmaz et al.	2010	Journal	General	USA
17	Beville et al.	2010	Journal	Education	Texas
18	Culp	2011	Journal	Water & Wastewater	USA
19	Touran et al.	2011	Journal	Transit Projects	USA
20	Shrestha et al.	2011	Journal	Highway	Texas
21	Kulkarni et al.	2012	Conference proceedings	Public Sector	USA
22	Texas Legislative Council	2012	Report	Public Sector	USA
23	Neidert et al.	2012	Journal	Education	Texas
24	Reinisch et al.	2012	Journal	Education	Texas
25	El Asmar et al.	2013	Journal	General	USA
26	Rakesh et al.	2013	Journal	Education	Texas
27	Minchin et al.	2013	Journal	Highway	Florida
28	Nikou Goftar et al.	2014	Conference proceedings	Public Sector	USA

3.2.2 Stage B – Extraction/Coding Procedures

Following search procedure, two steps are necessary for the extraction and coding of the identified studies. According to Alarcón 1993, Serpell 1995, performance and waste levels in the construction and manufacturing industry includes such activities as delays, delivery times, quality, costs, lack of safety, rework (project change), long distances, unnecessary transportation trips, inappropriate delivery selection or management of methods, product and process design, equipment and poor constructability. The process of eliminating wasteful activities from the industrial ways of doing things can help improve levels of profitability, enhance competitive advantage, as well as enhance the levels of performance (Horman and Kenley 2005). Using the above description of waste and level of performance, studies were coded under the performance and waste metrics outlined (see table 3 and 4) with further discussion in the following section. Due to varying terminologies and the way studies are reported across studies, some studies` findings reclassification was needed. For instance, in a study conducted by Kulkarni et al. (2011), cost performance in terms of project change for CSP was reported to be both positive and negative, confirming that CSP contracts may result in loss as well as cost savings. In order words, indicating that such performance under the project delivery method is a waste will be absurd. Project delivery performance levels could be categorized as wasteful, crucial, efficient or ineffective. All these factors are dependent on the owner's choice of project team selection or selecting the most appropriate delivery systems. Overall, with varying degrees of terminology and detail, the literatures identified in this studies have adopted the above classification system to an extent. The final stage of this research study contributes further to the aforementioned two stages and it entails further analyzing the identified studies in order to differentiate the listed performance metrics as shown in table 3.

3.2.3 Stage C – Statistical Procedures

Quantitative and qualitative descriptive statistics from the various identified studies were collected, combined, and included in the meta-analysis. The descriptive statistical analysis consists of testing whether DBB, CSP, DB, or CMR leads to better performance when compared against one and another. However, analysis such as univariate, multivariate, and Anova t-test were performed on each of the identified study dataset to compare the four project delivery methods as shown in table 5 to 9, and to test whether a particular delivery method (e.g. DBB) performs better than the other alternative project delivery systems (CSP, DB, and CMR) or vice versa, based on each of the identified performance and waste metrics listed for the purpose of this study. The descriptive statistics collected provides an estimate of the statistical nature of the variables of interest under each performance and waste metrics. For clarity and comprehensiveness, detailed description of each study and statistical significance value are further explored for each individual analyzed metric to determine each delivery system`s performance against another and to further identify and analyze the results whether a particular delivery system results in a higher level of performance, benefit or waste.

Table 3: Studies information categorized by listed metrics

		Metrics/Line Items									
Studies	Year	Cost Growth	Time/Schedule Growth	Construction Speed	Project Change (change orders)	Quality (sustainability, turnover)	Data Set	Studies Delivery Methods			
Bennett et al	1996	✓	✓	–	–	✓	332	DBB	DB		
Pocock	1996	✓	✓	–	✓	–	209	DBB	DB		
Konchar M. and Sanvido V.	1998	✓	✓	✓	–	✓	351	DBB	DB	CMR	
Ibbs et al.	2003	✓	✓	–	✓	–	67	DBB	DB	OTHERS	
Groppel et al.	2005	✓	✓	–	–	–	66	CSP	DBB		
Riley et al.	*2005*	✓	–	–	–	✓	*?*	*DBB*	*DB*		
Riley et al.	*2005*	–	–	–	✓	–	*120*	*DBB*	*DB*		
Col Debella, D. and Ries, R.	2006	✓	✓	✓	✓	–	88	DBB	DB	CMR	
FHWA	2006	✓	✓	–	–	✓	22	DBB	DB		
Hyun et al.	*2008*	✓	✓	✓	✓	–	*24*	*DBB*	*DB*		
Rojas and Kell	2008	✓	–	–	✓	–	297	DBB	CMR		
Hale et al.	2009	✓	✓	✓	–	–	77	DBB	DB		
Molenaar et al.	2009										
Water Design–Build Council	*2009*										
Beville et al.	2010	✓	✓	–	–	✓	238	DBB	CSP	CMR	DB
Rajan et al.	2010	✓	✓	–	✓	✓	400	DBB	CMR		
Culp	2011	✓	✓	–	–	✓	?	DBB	DB	DBO	DBFO
Reinisch et al.	2011	✓	–	–	–	–	55	CSP	CMR		
Shrestha et al.	2011	✓	✓	✓	–	–	22	DBB	DB		
Touran et al.	2011	✓	✓	–	–	–	9	DBB	CMR	DB	DBOM
Kulkarni et al.	2012	✓	–	–	✓	–	30	CSP	CMR		
Neidert et al.	2012	✓	✓	–	✓	–	33	CSP	CMR		
Texas Legislative Council	2012	✓	✓	–	–	✓	59	CSP	CMR	DB	
Korkmaz et al.	*2013*	–	–	–	–	✓	*12*	*DBB*	*DB*	*CMR*	
Rakesh et al.	*2013*	✓	✓	–	–	✓	*?*	*CSP*	*CMR*		
El Asmar et al.	2013	✓	✓	✓	✓	✓	35	IPD	OTHERS		
Minchin et al.	2013	✓	✓	–	–	–	60	DBB	DB		

Italics not included in studies for further analyses

Table 4: Sample level of waste and performance metrics (identified within studies)

Line Items	Design – Bid– Build (DBB)	Competitive Sealed Proposal (CSP)	References
Cost growth	Positive effects of cost and productivity changes were not convincing has DBB perform well when compared with DB.	Higher degree of innovation and overall cost savings were some advantages that are associated with the use of alternative project delivery method over the DBB method.	Ibbs W. C, Kwak H.Y, Ng T, Odabasi M. A (2003) and Texas Legislative Council (2012)
Time / Schedule growth	Conventional DBB projects showed worst performance in areas such as design deficiencies, modifications, and schedule growth.	Higher degree of flexibility when compared with alternative delivery methods.	Pocock (1996) and Texas Legislative Council (2012).
Construction speed	Productivity rate was not found convincing, which means DBB performs well on speed when compared with alternative delivery methods.		Ibbs W. C, Kwak H.Y, Ng T, Odabasi M. A (2003)
Project change (change orders)		In some instances cost performance (errors, omissions and design modifications) for CSP contracts were both positive and negative, confirming that CSP contracts may result in loss as well as savings.	Kulkarni A, Rybkowski Z. K, Smith J (2011)
Quality (sustainable, turnover, functionality)	There are potentials for DBB to yield higher levels of integration and excellent project outcome if it informally involves key project participants (e.g. constructor) early enough in the project delivery process.		Korkmaz, S., Swarup, L., and Riley, D. (2010, 2013)

The table above shows the list of the identified performance and waste metrics that are used for the purpose of this research study. These metrics were based on some of the aforementioned metrics included in earlier researches that has been highlighted in the previous section of this research study. In addition, the table briefly highlight some key findings of the line items studied in this paper by comparing the least collaborative project delivery systems (DBB and CSP) with the more collaborative project delivery systems (DB and CMR). Research studies and results are summarized under each delivery methods with each reference.

3.3 Data Analysis

The dataset identified for the purpose of this study are shown in Table 3, they were further broken down and discussed in the order of the identified key performance metric; namely cost growth, time-schedule growth, construction speed, project change, and quality, which will be used to determine the levels of performance and waste between the four project delivery system (table 5 to 9). There are abundance of studies, reports, articles and researches that has been conducted comparing all four project delivery system against one and another in areas such as cost, schedule, time, and quality. Some studies compared three or up to five different delivery systems under some of the aforementioned metric. However, limited literature exist in terms of benchmarking the less collaborative DBB and CSP against one another. Although, this could be as a result of their closeness in characteristics (see Table 1.) and procurement (see figure 2 and 4), or even the lack of knowledge and awareness of their differences, which is the main intent of this research study. Since it was very difficult to collect studies and data that solely compared DBB and CSP or all four delivery systems (i.e. DBB, CSP, DB, and CMR) together as an entity, enough studies were identified and collected to empirically and meta-analytically analyze each project delivery method performance. Thus, for the purpose of this study, all four project delivery system`s performance are benchmarked against one and another or collectively in some instances to help determine the levels of waste, benefits or performance of all four delivery system. Unlike Table 3, Table 5 – 9 below further identifies the statistical procedure and methods that were used for each studies. It also shows if the studies report any statistical significant p-value as well as other major findings that are within each studies. These are presented as either percentage increase or decrease or as a plus or minus. The study's findings and result are discussed in the *Result and Discussion* section that follows.

3.4 Delimitations and limitations

3.4.1 Delimitations

This research chooses to focus mainly on the metrics defined in the table above. Since the metric are some of the important underlying factors within the architecture engineering construction (AEC) industry, the author intended to create more awareness by mainly focusing on these areas. Most literature however, also focused on the metrics used in the paper. Likewise, there are total of five identified literatures in this study that are not included in the study analyses. One of them is due to an embargo placed on the study, while the other four are due to the way they are reported. The intent of this paper is to continue with an in-depth analysis of the current state of the construction industry in order to provide a better background knowledge and awareness of the identified project delivery methods for future purpose. Other metrics or underlying factor that are applicable for further research includes labor factor, constructability, production rate, safety, risk, communication, recycling rate, overhead and profit etc..

3.4.2 Limitations

Since it was very difficult to collect studies and data that solely compared DBB and CSP or all four delivery systems (i.e. DBB, CSP, DB, and CMR) together as an entity, the studies identified in the research are mainly either DBB or CSP performance being compared with other alternate delivery methods (i.e. CMR, DB). Likewise, the type of projects that were procured with the four project delivery systems ranges from residential type projects to highway construction. Acquiring literature or dataset on a specific project type was equally difficult. Unlike DBB and other alternative delivery systems, CSP delivery method is not a commonly used procurement system in the private sector and in most states in the United States. They are however frequently used in most ISDs, universities and government sectors. The above factors limit the availability of literatures, datasets and significant studies to compare the four project delivery systems using the identified performance metrics. Nevertheless, for the purpose of this study, the four delivery system`s performance are benchmarked against one and another to help determine the levels of waste, benefits or performance of DBB, CSP, DB, and CMR.

4. RESULT AND DISCUSSION

4.1 Research Findings

The systematic analysis of identified data set will be describe in the order of the listed performance and waste metric chronologically with each metric; namely cost growth, time-schedule growth, construction speed, project change and quality, which will be used to determine the levels of performance and waste between the two project delivery system. Following each table, each categorized metric and findings will be further discussed separately.

Table 5: Delivery Method Cost Performance

			Cost Growth (CG)		
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Bennett et al	1996	DBB, DB	U/M	R^2=0.51	13% higher CG than DB
Pocock	1996	90 DBB, 40 DB	T-test	p= 0.286	12.8% DBB CG vs 6.7% DB
Konchar M. and Sanvido V.	1998	116 DBB, 115 DB	U/M	R^2=0.24	5.2% less CG than DB
Ibbs et al.	2003	40 DBB, 27 DB	U/M	R^2=0.053	7.8% less CG than DB
Groppel et al.	2005	42 DB&CMR, 24 CSP	N/A	N/A	CSP=$13.3M vs $254.3M for DB&CMR
Col Debella, D. and Ries, R.	2006	25 DBB, 26 CMR, 34 DB	A/T-test	p= 0.557	No difference between the CG
FHWA	2006	11 DBB, 11 DB	N/A	N/A	3.8% less CG than DB
Rojas and Kell	2008	222 DBB, 6 CMR	A/T-test	p= 0.05	3.25% DBB CG vs 19.40% CMR
Hale et al.	2009	39 DBB, 38 DB	AV	p= 0.011	4% DBB CG vs 2% DB
Beville et al.	2010	DBB, CSP, CMR, DB	N/A	N/A	CSP and CMR less CG

Table 5 Continued

Cost Growth (CG)					
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Rajan et al.	2010	DBB, CSP, CMR, DB	N/A	N/A	2.5% CSP CG vs 7.69% DBB
Reinisch et al.	2011	14 CSP, 19 CMR	U/M	R^2=0.51	2.8% less CSP CG than CMR
Shrestha et al.	2011	16 DBB, 6 DB	A/T-test	p =0.751	6.3% DBB CG vs 7.8% DB
Touran et al.	2011	1 DBB, 2 CMR, 5 DB, 1 DBOM	N/A	N/A	0.5% DBB CG vs 16.7% CMR
Kulkarni et al.	2012	13 CSP, 17 CMR	N/A	N/A	26% cost saving for CSP vs 21% CMR
Neidert et al.	2012	14 CSP, 19 CMR	A/T-test	p=.068	3.7% cost saving for CSP vs 5.2% CMR
Texas Legislative Council	2012	31 CSP, 11 CMR, 17 DB	N/A	N/A	23.1% cost saving for CSP vs 38.5% CMR & DB
El Asmar et al.	2013	DBB, IPD	A/T-test	p= 0.471	DBB CG is not significant to IPD
Minchin et al.	2013	30 DBB, 30 DB	A/T-test	p= 0.105	20.42% DBB CG vs 45% DB

Key: CG: Cost Growth; U/M: Univariate/ Multivariate; AV: Anova; N/A: Not Applicable; A/T-test: Anova/T-test.

4.1.1 Cost Performance

Cost performance on each delivery system is accessed through project cost growth. The total cost of the project as reported after the project is finished against the budgeted cost. By definition, the level of the project delivery performance or waste is quantified in terms of percentage by comparing the difference between the actual and total construction award costs to the total contract construction award costs.

$$\text{Cost Growth \%} = \frac{\text{Actual Total Cost} - \text{Total Contract Award Cost.}}{\text{Total Contract Award Cost.}} \text{ X } 100$$

Bennett et al. (1996) reported a 13% increase in cost growth in DBB over DB in the general/public sector construction in a research that was conducted in the United Kingdom. A study by Pocock (1996) on 25 public sector projects showed 12.8% cost growth for DBB and 6.7% for DB, which shows a 5.7% less cost growth for DB. Likewise, in the study conducted by Konchar and Sanvido (1998) showed a similar result in favor of DB projects of about 5.2% less cost growth in DB usage as the project delivery system in comparison with DBB. In a study conducted by Ibbs et al. (2003) on 67 building projects using data from the construction industry institute (CII) showed a favorable 7.8% less cost growth for DBB. In order words a cost savings of 7.8% when compared with the DB projects. Groppel et al. (2005) reported a tremendous savings by the Dallas ISDs from switching from DB and CMR to CSP. A cost comparison of $13.3M cost saving for CSP and $254.3 for both DB and CMR within the ISDs first quarter the same bond programme in 2004-2005. Col Debella and Ries (2006) studied a total of 88 educational project across the United States, all of which used DBB, CMR, and DB delivery system. The study showed a p-value of 0.557 with a 95% confidence level. In order words, this means there are non-statistical significant result in the three delivery system in their cost growth, they all performed well and within budget. In a report published by FHWA in 2006, 11 pairs of highway projects was investigated in different states in U.S. using DB and DBB delivery method. Favorably, DBB reflected a 3% less cost growth as compared to DB. Rojas and Kell (2008) looked at a total of 222 DBB project compared to 6 CMR in Washington and Oregon and found a highly statistically significant of 3.25% cost growth with DBB projects, while CMR projects showed a 19.40% cost growth. In a study conducted by Hale et al. (2009) on 38 DBB and 38 DB naval building project showed only a 2% cost growth in DBB compared to DB. Beville et al. (2010) studied four delivery methods (DBB, CSP, CMR, and DB) on educational projects, the results showed a less cost growth in CSP and CMR projects compared to CSP and DB. A study analyzing ENR best projects in Texas by Rajan et al. (2010) compared the impact DBB, CSP, CMR, and DB delivery methods on the various projects analyzed in the study showed a 2.5% cost growth in CSP projects as compared to a 7.69% cost growth in DBB projects. Reinisch et al. (2011) compared cost on public elementary school projects procured with CSP and CMR delivery system in the state of Texas. The study showed a 2.8% cost savings in CSP projects when compared with that of CMR projects. In a highway project studied by Shrestha et al (2011) showed an average increase of 6.3% cost growth in DBB project as opposed to a 7.8% in DB. That is a 1.5% cost saving in projects procured using DBB. Touran et al. (2011) also studied highway project that also resulted in a 0.5% cost growth for DBB project as compared to a 16.7% cost growth in CMR projects. Kulkarni et al. (2012) compared cost growth in 17 IPD-like projects (CMR) and 13 non-IPD like projects (CSP). The study showed a 26% cost saving for CSP projects as opposed to a 21% CMR projects. Neidert et al. (2012) conducted a study on the use of CSP and CMR at the Texas A&M University System`s project. A total of 14 CSP and 19 CMR projects was analyzed and the result favorably showed a 3.7% cost saving for CSP projects as compared to 5.2% CMR projects. The Texas Legislative Council (2012) conducted a survey on the use of CSP, CMR, and DB on projects in the public sector. According to the report, CSP projects resulted in a 23.1% cost saving compared to a cumulative 38.5% for CMR and DB projects. Like Kulkarni et al. (2012), In a study conducted by El Asmar et al. (2013) on IPD and non-IPD project over different states in the United States, the study p-value (0.471) showed a non-statistically significant cost growth in DBB/CSP as compared to the IPD project. Finally, Minchin et al. (2013) conducted a study on 51 highway projects that was completed between 2002 and 2010 in the state of Florida. According to the study and supporting FHWA (2006) and Shrestha et al (2011) observation, DBB showed almost 20% cost growth as opposed to 45% in DB. In order words, an approximate 25% cost savings in projects procured with DBB project delivery method.

Overall, from table 5 above, like DB and CMR, very few studies did not showed DBB and CSP less favorably in terms of cost growth. Although, some studies did report statistical significance, few results reported were not statistically significant, and there were a few results that tend to be contradictory to typical findings on the topic. The studies in the above table for the most part shows that wherever DBB or CSP is benchmarked against DB and/or CMR or vice versa, they either or both resulted in a significant cost savings. Across the studies, it is identified that both DBB and CSP procurement type (lowest bidder and /or best value) has a significant influence on the overall project cost savings. This In order words can be described as a very low level of waste generated in terms of cost and a higher level of performance and benefit to the owner`s savings as compared to the other project delivery systems (DB and CMR). On the other hand, where DBB and CSP are compared, the results also shows better performance in CSP project.

Table 6: Delivery Method Time/Schedule Performance

			Time/Schedule Growth (TSG)		
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Pocock	1996	90 DBB, 40 DB	T-test	p= 0.286	27.76.8% DBB TSG vs 26.23% DB
Konchar M. and Sanvido V.	1998	116 DBB, 115 DB	U/M	R^2=0.24	11.4% higher TSG than DB
Ibbs et al.	2003	40 DBB, 27 DB	U/M	R^2=0.177	2.4% higher TSG than DB
Col Debella, D. and Ries, R.	2006	25 DBB, 26 CMR, 34 DB	N/A	N/A	Not significant
FHWA	2006	11 DBB, 11 DB	N/A	N/A	9% higher TSG than DB
Hale et al.	2009	39 DBB, 38 DB	AV	p= 0.037	DBB with higher TSG than DB
Rajan et al.	2010	DBB, CSP, CMR, DB	N/A	N/A	48.87% DBB TSG vs % 3.69% CSP
Shrestha et al.	2011	16 DBB, 6 DB	A/T-test	p= 0.167	5.1% DBB TSG vs 20.5% DB
Touran et al.	2011	1 DBB, 2 CMR, 5 DB, 1 DBOM	N/A	N/A	100% DBB TSG vs 8.3% CMR <
Neidert et al.	2012	14 CSP, 19 CMR	N/A	N/A	Fewer CSP TSG vs CMR
El Asmar et al.	2013	DBB, IPD	A/T-test	p= 0.131	DBB TSG is not significant to IPD
Minchin et al.	2013	30 DBB, 30 DB	A/T-test	p= 0.105	23% DBB TSG vs 20.2% DB

Key: TSG: Time/Schedule Growth; U/M: Univariate/ Multivariate; AV: Anova; N/A: Not Applicable; A/T-test: Anova/T-test.

4.1.2 Time/Schedule Performance

Like cost growth, the level of the delivery performance or waste is also quantified in terms of percentage by comparing the difference between the total built construction and total planned construction time to the total as planned construction time.

$$\text{Const. Schedule Growth \%} = \frac{\text{Total as Built Const. Time} - \text{Total as Planned Const. Time}}{\text{Total as Planned Const. Time}} \text{ X } 100$$

In a study conducted by Pocock (1996) on 25 public sector projects showed a non-statically significant 27.76.8% schedule growth in DBB projects as compared to 26.23% in DB projects. Like the unfavorable DBB cost growth, Konchar and Sanvido (1998) study again resulted in 11.4% higher schedule growth for DBB as compared to DB. In a study conducted by Ibbs et al. (2003) on 67 building projects using data from the construction industry institute (CII) showed a 2.4% higher schedule growth for DBB as compared to DB. Col Debella and Ries (2006) study showed a non-significant result in the schedule growth of the three delivery method. FHWA (2006) study on highway projects showed a 9% higher schedule growth for DBB as compared to DB. Conversely, Hale et al. (2009) study on the 76 naval building projects showed a higher schedule growth in DBB projects over DB projects. In a study conducted by Rajan et al. (2010) on ENR best projects showed a 48.87% schedule growth in DBB project as opposed to 3.69% growth in CSP projects. Supporting Ibbs et al. (2003) observation, Shrestha et al. (2011) showed only 5.1% schedule growth in DBB projects compared to 20.5% in DB projects. Touran et al. (2011) showed a 100% schedule growth in DBB projects as opposed to only 8.3% in CMR projects. Neidert et al. (2012) study showed a fewer schedule growth in CSP projects than CMR projects. In a study conducted by El Asmar et al. (2013) on IPD and non-IPD like project over different states in the United States, the resulted p-value (0.131) showed a non-statistically significant difference in schedule growth for non-IPD like project delivery systems (DBB and CSP) as compared to the IPD project schedule growth. Finally, the Florida highway projects studied by Minchin et al. (2013) showed that schedule were exceeded by 23% for DBB projects and by 20.2% in DB projects against their intended schedule.

Overall, the results from table 6 above reflects a highly non-statistical significant conclusion. On the other hand, one might also argue that since the result are not reported consistently (a typical barrier in meta-analysis), drawing a concrete or global conclusion will be obscured. In general, out of the four studied project delivery methods DBB and/or CSP performed poorly in terms of schedule growth when compared across the identified studies for the most part.

Table 7: Delivery Method Construction Speed Performance

Construction Speed (CS)					
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Konchar M. and Sanvido V.	1998	116 DB, 115 CMR	A/T-test	0.09	DB 5.8% faster than CMR
Col Debella, D. and Ries, R.	2006	25 DBB, 26 CMR, 34 DB	A/T-test	p=0.002	DBB 73% higher CS than DB
Hale et al.	2009	39 DBB, 38 DB	AV	p <0.001	DBB with longer CS days than DB
Shrestha et al.	2011	16 DBB, 6 DB	A/T-test	p <0.001	18.3 days DBB vs 6.8 DB days
El Asmar et al.	2013	DBB, IPD	A/T-test	p =0.168	DBB TSG is not significant to IPD

Key: CS: Construction Speed Growth; U/M: Univariate/ Multivariate; AV: Anova; N/A: Not Applicable; A/T-test: Anova/T-test.

4.1.3 Construction Speed Performance

By definition, the level of the level of the project delivery performance or waste is quantified in square feet per day. In order words, it is the ratio of the total area completed per day to the total as-built construction time from the day construction begins to substantial completion.

$$\text{Construction Speed (sf/day)} = \frac{\text{Area}}{\text{Total as Built Construction Time}} \text{ X } 100$$

In the study conducted by Konchar and Sanvido (1998) on 115 CMR and 116 DB project delivery method, the result showed that the projects procured with design build project delivery system were 5.8% faster in construction speed than CMR procured projects. Col Debella and Ries (2006) study showed a very highly statistical significant result (pv=0.002) that DBB projects were 73% slower in construction than DB. Conversely, Hale et al. (2009) study on the 76 naval building projects also showed a statistical significant result of DBB projects with longer construction days DB projects. On the other hand, Shrestha et al. (2011) observation on the highway projects showed a 6.8 days growth construction speed in DBB projects compared to 18.3 days in DB projects. Finally, growth in construction speed or days was found insignificant between DBB/CSP projects when compared with IPD projects in the study conducted by El Asmar et al. (2013).

Overall, according to the study's results from table 7 above, four out of the five identified studies were unfavorable in construction speeds for DBB project as compared to other delivery methods (CMR, DB, and IPD). Conversely, three out of the four studies (Col Debella and Ries 2006, Hale et al. 2009, and Shrestha et al. 2011) also reflects a highly statistical significant conclusion.

As mentioned earlier in this study, varieties of factors could be responsible for construction speed or construction delays. For instance, according to Konchar and Sanvido (1998), variables such a project size, project delivery system, contract unit cost, project team communication, percent design complete before the construction entity joined the project team, as well as project complexity (Ibbs, 2003) are identified to be the determinant factors for construction speed or construction delays. Quantifying waste and performance metric across the studies, it is identified that construction speed and project size shows a higher correlation for DBB. On the other hand, the lack of interaction within DBB stakeholders resulted in DBB slightly decreased construction speeds with increasing project size. In order words, this type of waste could be eliminated if there are better and improved form of interaction amongst stakeholders. Besides the varying level of interaction within the four delivery systems, DB and CMR delivery system has the ability to perform well in overall construction speed due to their ability to "fast track" – a way of overlapping design and construction phase before that actual construction begins.

Table 8: Delivery Method Project Change Performance

		Project Change (PC)			
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Pocock	1996	90 DBB, 40 DB	T-test	N/A	41.84% DBB vs 9.39% DB
Col Debella, D. and Ries, R.	2006	25 DBB, 26 CMR, 34 DB	A/T-test	p=0.06	No significant difference between DBB & CMR
Rojas and Kell	2008	222 DBB, 6 CMR	A/T-test	N/A	No statistically significant difference between CMR & DBB
Rajan et al.	2010	DBB, CSP, CMR, DB	N/A	N/A	Not significant- negative impact on project
Kulkarni et al.	2012	13 CSP, 17 CMR	N/A	N/A	No significant difference between CSP & CMR
Neidert et al.	2012	14 CSP, 19 CMR	A/T-test	p=.018	19.64% CSP PC vs 13.21 % CMR
El Asmar et al.	2013	DBB, IPD	A/T-test	p =0.224	Not significant- IPD vs Non IPD project

Key: PC: Project Change; U/M: Univariate/ Multivariate; AV: Anova; N/A: Not Applicable; A/T-test: Anova/T-test.

4.1.4 Project Change Performance

By definition, the level of the delivery performance or waste is quantified in total % change in contract. In order words, it is the time period in ratio of the total change order initiated due to deficiencies in both design and construction by contractor and the owner’s approval to the actual total cost of the change order.

$$\text{\% Change Order (\%)} = \frac{\text{Total Change Order}}{\text{Actual Total Cost}} \times 100$$

The study by Pocock (1996) on 90 DBB projects and 40 DB projects showed a higher rate of change in project at approximately 42% for DBB as compared to a 9.39% for DB. Col Debella and Ries (2006) study showed no significant difference between DBB and CMR with a p-value higher than 0.05 at a 95% confidence level. Likewise, Rojas and Kell (2008) studied 222 DBB procured projects and 6 CMR procured projects in Oregon also yielded a no statistically significant difference between CMR and DBB projects. Rajan et al. (2010) study on DBB, CSP, CMR, and DB projects showed a non-significant difference in project change among the various project delivery systems analyzed in the studies. The study also indicated that project change has a negative impact on the projects and the system used in its procurement. Kulkarni et al. (2012) study compared 17 IPD-like projects (CMR) and 13 non-IPD like projects (CSP) which showed a non-significant difference between CSP and CMR projects. Neidert et al. (2012) conducted a study on the use of CSP and CMR at the Texas A&M University System`s project. A total of 14 CSP and 19 CMR projects was analyzed with a statistically significant p-value of 0.018 and the result unfavorably showed a 19.64% rate of change for CSP projects as compared to 13.21% CMR projects. Finally, in a study conducted by El Asmar et al. (2013) on IPD and non-IPD project over different states in the United States, the study project change p-value (0.224) showed a non-statistically significant result in DBB/CSP projects across the studies as compared to the IPD project. Convincingly, the study also showed a non-statistical insignificant p-value (0.334) in project changes that are mainly attributed to alterations and deficiencies in project scope.

Though, these differences in design deficiencies proved statistically significant with a p-value of 0.029 at a 95% (0.05) confidence level (El Asmar et al. 2013).

Overall, most identified studies showed no significant difference between the four delivery systems within the study. Except for one study (Neidert et al. 2012), some reported study`s results were not statistically significant, while others did not report statistical significance. However, that the amount of change order request tends to be higher in DBB and CSP delivery method, which are often typically initiated by the owner or the constructor as a result of design errors.

Table 9: Delivery Method Quality Performance

				Quality (Q)	
Studies	Year	Sample Size/ Methods	Statistic Method	Statistics Significance	Findings
Pocock	1996	90 DBB, 40 DB	N/A	N/A	5.92 DBB vs 6.78 DB
Konchar M. and Sanvido V.	1998	116 DBB, 115 DB	N/A	N/A	5.8 DBB vs 6.5 DB
FHWA	2006	11 DBB, 11 DB	N/A	N/A	No significant difference
Rajan et al.	2010	DBB, CSP, CMR, DB	N/A	N/A	DB>CMR>DBB 4.0 Likert scale level CSP and DBB
El Asmar et al.	2013	DBB, IPD	N/A	N/A	3.2 for non-IPD (DBB and CSP) vs 4.0 for IPD

Key: Q: Quality; U/M: Univariate/ Multivariate; AV: Anova; N/A: Not Applicable; A/T-test: Anova/T-test.

4.1.5 Quality Performance

Quality is quantified in regards to owner`s overall satisfaction of the project. This could also be measured in terms of construction administrative burden and the user's expectations, while keeping an account of the owner`s intended outcome. For the purpose of this meta-analytic study, quality is also measured in terms of project sustainability measures and turnover. The quantification of quality in most project delivery systems literature has been widely based on customer satisfaction, in such a way that an owner qualitatively or quantitatively rates the level of satisfaction with the project. For most studies, this is determined using a Likert Scale level. However, the way the scale are reported also varies within studies. Some studies used a scale of 1-5 while others used 1-10 with 1(lowest quality ranking) being less satisfactory and 5 or 10 (highest quality ranking) being most satisfactory.

Looking at the various studies identified in table 9 above, higher project quality cannot be concluded to have leaned favorably to a specific project delivery method across the studies statistically. Pocock (1996) study concluded with a very slim difference in delivery quality performance between DBB (5.92) and DB (6.78). Conversely, Konchar and Sanvido (1998) study showed a less than 1 point value in project quality performance between DBB (5.8) and DB (6.5). In a study by the Federal Highway Administration (FHWA 2006) on highway projects showed that there was little to no difference in quality performance between DBB and DB projects. According to Rajan et al. (2010) study analyzing ENR best projects in Texas on projects procured using DBB, CSP, CMR, and DB; the study showed that DB scored higher than CMR and DBB in all categories of quality analysis. But when DBB and CSP where benchmarked against each other, the result showed an equal 4.0 Likert scale level. Finally, in a study conducted by El Asmar et al. (2013) on IPD and non-IPD project over different states in the United States, the study showed a 4.0 scale for IPD projects and a 3.2 scale for non-IPD (DBB and CSP).

All in all, the use of inappropriate delivery system for a specific project could result in owner`s biasness towards quality ranking. Similarly, some factors such project team communication, project team integration and involvement, project cost, as well as project complexity can all lead to very low overall project quality when this factors are not properly implemented and executed.

5. CONCLUSIONS, CONTRIBUTIONS, AND FUTURE RESEARCH

5.1 Conclusion

The meta-analysis of previously identified literatures that reported the levels of waste and performance between DBB, CSP, DB, and CMR project delivery quantitatively systems was studied. Due to lack of comparable literature and research studies on DBB, CSP, DB, and CMR collectively as an entity, the authors seeks to meta-analytically quantify the levels of waste and performance between all four delivery systems by benchmarking them against one and another. With the intentions of contributing to the body of existing knowledge in the AEC industry, the results of the contrasted analyzed studies showed inconsistences, notable trends and definable patterns among studies. These levels of waste and performance analysis was conducted on five key metrics namely: cost growth, time-schedule growth, construction speed, project change, and project quality. The notable trend and definable pattern seen across study shows that all the four studied delivery methods have a vast level of quantifiable waste, which is for the most part largely related to the delivery methods procurement process. For instance, the least collaborative DBB and CSP delivery methods resulted in large amount of construction days and schedule growth when compared with the more collaborative DB and CMR delivery methods, this was evident in the study analysis. However, there are factors that could be implemented into the product and process design that will potentially eliminate these wastes. Conversely, cost growth, project change and quality proved to be statistically insignificant for the most part between the four delivery systems.

Another way project procured using either DBB, CSP, DB, or CMR delivery methods can eliminate waste and yield higher performance rate is the level of team`s communication and integration in the delivery systems. According to Korkmaz et al. (2013), the early involvement of constructors is keen to project outcome and success. Using DBB projects constructed in New York, Colorado, and Missouri (see figure 9) that achieved a LEED Platinum as an exemplary example of successful usage of this type of project delivery system, these projects were constructed within schedule, budget, and with higher end user`s satisfaction. This was achieved through the early informal involvement of the contractor and project team`s commitment in the delivery process (Korkmaz et al. 2013). Similar results applied to the other project delivery systems as shown in the table. Conversely, CSP was also reported to save an approximate $4000 per student in Texas ISDs spending to have new schools constructed in Texas according to the study conducted by Reinisch et al. (2011), when it was compared with the typical CMR delivery method that has always been used as the ISDs procurement method.

Project codes	Location/ state	Project delivery method	Level of LEED certification	Approximate size (sq ft)
A1	New York	DBB	Certified	25,000
A2	Texas	CMR	Certified	7,000
A3	Colorado	CMR	Certified	90,000
B1	Colorado	DBB	Silver	60,000
B2	Colorado	CMR	Silver	7,700
B3	Alabama	DB	Silver	1,300
C1	Ohio	DB	Gold	14,000
C2	Pennsylvania	DB	Gold	35,000
D1	Colorado	DB	Platinum	186,000
D2	Arkansas	CMR	Platinum	94,000
D3	California	DB	Platinum	66,000
D4	Missouri	DBB	Platinum	120,000

Figure 9. Project delivery method performance (source: Korkmaz et al., 2013)

Concerning eliminating or quantifying waste and performance levels in project delivery systems, the adoption of best practices, best value procurement, and team integration (i.e. all primary project participants or stakeholders should be involved early enough in the project delivery) is also a key factor to project success (Lapinski et al. 2006, Kashiwagi 2008).

According to Ibbs (2003), well-defined project scope and project complexity are some key factors to be considered during the selection of a project delivery method. Figure 10 below shows an illustration of project schedule duration against the type of contract to be used for certain type of project. In order words, this means depending on factors such as overall project cost and time, certain project delivery system should be employed in order to eliminate wasteful activities and resources. For instant, in a situation whereby prototype projects (such as Walmart Stores, HEB Stores, or McDonalds etc.) with a well-defined project scope, clearer constructability, complete plans and specifications that are readily available for construction, the author suggest the use of “Lump Sum Fixed Price” contract, that is a DBB project delivery method. Similarly, in a situation with unidentified project scope, incomplete drawings and construction documents, the author suggest use of a “Cost Reimbursable W/ % Fee” contract type, which is the utilization a DB or related delivery system for the project procurement and execution.

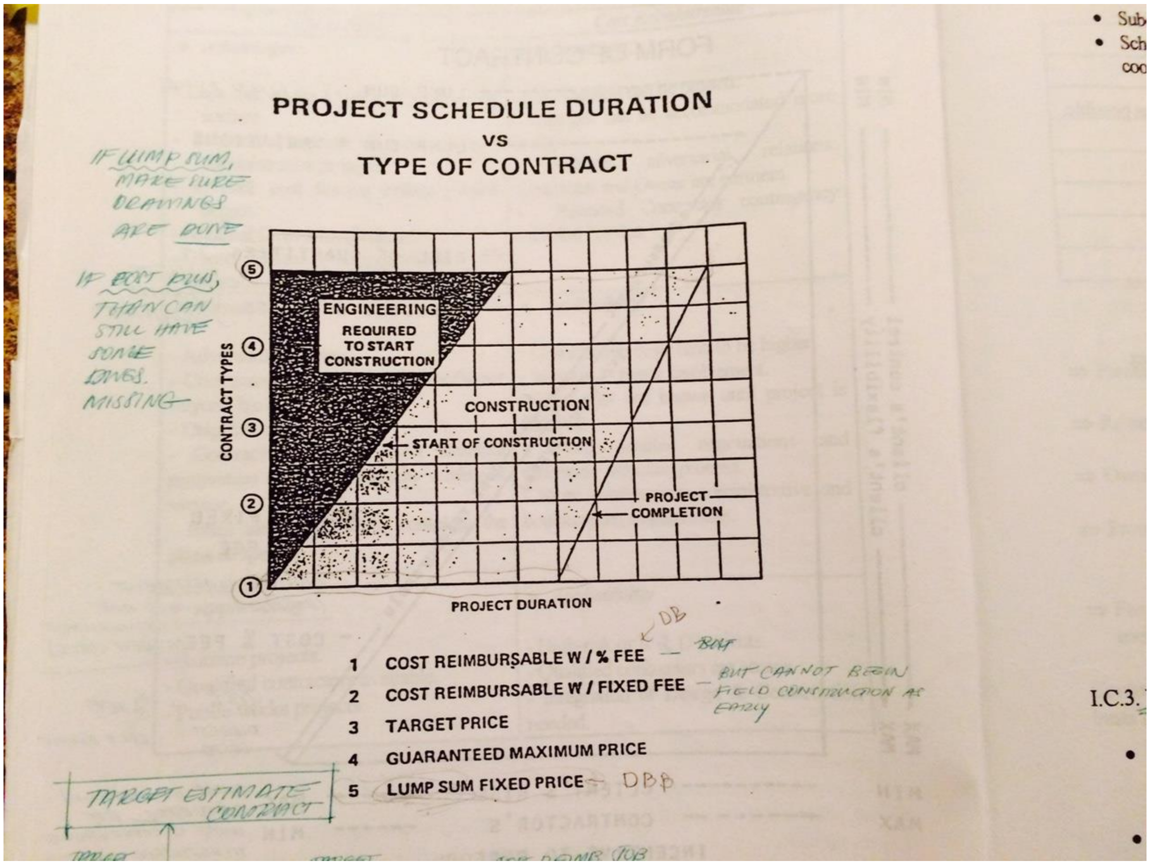

Figure 10. Project delivery method contract choice (source: Ibbs, 2003)

Finally, as identified across the literatures included in this meta-analytic studies, other project delivery characteristics such as owner involvement, project team preference, project team chemistry and experience, participant`s involvement and entry time, and overall team characteristics can have a very great effects on the levels of performance, waste, and benefit associated with the delivery system and project outcomes irrespective of the project delivery system adopted.

5.2 Contributions

The use of DBB or CSP and alternate delivery method has been proved beneficial over the years with the decades of existing literature and project outcome at various level. Using the Texas A&M University System as a typical example, majority of its constructions are procured by either using CMR or CSP delivery methods, this is due to the "best value" and higher flexibility (Texas Legislative Council 2012) procurement advantage that CMR and CSP delivery system possess. From a study of the list of past, current, and future projects on the Texas A&M University, College Station Campus, results showed that most CSP projects yielded positive results in terms of the metrics studied in this paper. DBB project (Wellborn Road Grade Separation) and CSP procured projects such as the Nuclear Magnetic Resonance (NMR), Liberal Arts and Arts & Humanities Building (LAAH), Corps Dorm Renovation FY 13 (Leonard Hall), Student Recreation Center Renovation, The Human Clinical Research Center performed well within schedule and budget, little or no project change, highly rated owner`s quality, and achieved LEED Silver accreditation (NMR), while other projects were designed to

LEED Silver but no certification. Similarly, other projects such as Mitchell Physics building (LEED Silver rating), YMCA building, Penberthy Intramural Complex, PEAP, MSC Renovation, Read Arena, and Veterinary Imaging Center were procured using CMR project delivery method. These projects for the most part yielded great end user quality rating (Wipke, 2014).

Ultimately, the need for an improved awareness and knowledge of the various project delivery methods as well as good industrial ethics and practices amongst project participants is keen to project success. Besides the owner`s factors of choice and implementation of delivery systems as mentioned earlier, the successful use and implementation of DBB or CSP on any project can also be determined by the industrial approach, culture, attitude, and the innovative approach of the industry`s product and process design as applied to such project from conception to completion.

5.3 Recommendations and Future Research

Limited resources was paramount throughout the study, this is due to the lack of identical studies and/or the way studies are reported. However, there are abundant of literature and studies that has been conducted on DBB when compared with other alternative delivery method. With the industry’s continual adoption of new and emerging innovative delivery systems and practices in the AEC industry, the authors see the need for more future research on quantifying and reporting the performance of more projects being delivered with CSP, DB, and CMR, while using most literatures identified project delivery performance metrics to help shed more light on the benefits or dis-benefits of the four delivery systems. Hence, this will also help minimize the effect variability across studies.

Based on this research findings, the following are the recommendations given for future research in this area of study:

1. There is a need for more research on individual project delivery system, especially in the case of CSP and CMR delivery method, while focusing on the most utilized performance metrics such as the ones identified in this study and other literature.
2. In order to reduce the effect of variability, the need for more research on projects delivered with the four project delivery systems (DBB, CSP, DB, and CMR) focusing on a specific project type.
3. In order to help project participants make a better choice in selecting an adequate project delivery method, the need for future research study on the trends and patterns associated with each delivery system`s selection should be study. For instance, the choice of selection with project scope, or project complexity.
4. For projects quality assurance and other sustainable factors, future research should be conducted to correlate each delivery systems with the finished project cost which should include items such as maintenance cost, optimization cost, and warranty cost.

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