Investigation of the Relationship between Green Design and Project Delivery Methods

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Executive Summary

The selection of the project delivery method (PDM) for any project is critical – it establishes communication, coordination, and contractual issues between the owner, contractor, and designer. With an increase in the number of green design projects, understanding the relationship between the PDM and green design is paramount to project and contract management. It is reasonable to assume that a positive relationship between green design and design-build (DB) exists since both theoretically are intended to foster an integrated, holistic, and collaborative project. This research examines the relationship between the design-bid-build (DBB), construction management (CM), and DB PDMs and green design with the goal of establishing best practices and identifying potential synergies between them. The research collected information by conducting primarily telephone interviews with approximately twenty-five individuals, including owners, contractors, and designers involved in completed green design projects, mainly in the public sector. The interviews developed a general understanding of the current state of knowledge and experience and not a rigorous quantitative analysis. Upon completion of the interviews, the tabulated results were summarized and green project characteristics and project-PDM interactions emerged. Existing published research was evaluated to reveal aspects of PDMs independent of green design. Best practices were ascertained by combining information from the interviews and published research. Best practices are as follows:

1. **Project implementation features**. The decision to use DB as PDM on green design or other projects should be based on the specific project features; e.g., well-defined scope and adequate owner staffing. DB will not produce successful results on all projects.
2. **Collaboration**. Project team collaboration early in the design and construction process is an important aspect of green projects, and collaboration was considered somewhat more important in projects that used DB.
3. **Experience**. Team experience is important on all green design projects independent of the PDM. Owners should use a 'best value' selection process, which is more prevalent in DB projects, and include team experience as a criterion. The owner's role is critical with DB.
4. **Leadership.** Leadership is an important feature for all contracting parties involved in green design projects and it is a dominant success factor in DB projects.
5. **Scope of work**. A well-defined scope of work is important on all projects, independent of the PDM. In DB, improving the scope of work definition by developing a set of documents, typically comparable to the design development phase, as the basis for awarding a contract is called DB bridging. Using contracting techniques such as DB bridging can result in better identification of expected quality and improves the owner's level of control.
6. **Funding and Budget**. Having adequate funding and budget for the given scope of work is particularly important in a green design project. Public funding restrictions may not allow use of certain PDMs, and the nature of public funding streams may make non-traditional PDMs more difficult.
7. **Complexity and Flexibility.** Complexity and flexibility is a project feature that is more specific to green design projects and is more frequently associated with DB.
8. **Control and Accountability.** Control and accountability is a problem associated with DB more than with DBB. It is not specific to green design projects. DB Bridging can be used to offset the lack of control with traditional DB.

The use of green design and DB is increasing and understanding the linkage between the two is important. This research has found that while linkages do exist, the owner needs to carefully consider all aspects of a green design project before making the decision of the most appropriate PDM.

Introduction

Communication, coordination, and contractual issues between the owner, contractor, and designer are paramount in determining the relative project's success from all three parties' perspective. The selection of the project delivery method (PDM) establishes the basis of communication, coordination, and contractual roles throughout not only the life of the project, but also the future relationship between the parties. Selection of the PDM is based on many factors including the owner's experience; administrative constraints; funding restrictions; schedule and completion requirements; and legal boundaries.

Another criterion in the selection of the PDM can be its relative success in implementing the project's goals. With the increasing number of sustainable and green projects, as evidenced by the growing use of the United States Green Building Council's (USGBC) green building rating system Leadership in Energy and Environmental Design (LEED), the relationship between the PDM and green design goals need to be better understood by designers, owners, and the construction industry. Looking purely at the definition of green design and the design-build PDM, it is reasonable to hypothesize a positive relationship between the two. Both green design and design-build are intended to create an integrated, holistic, collaborative project. This research examines the hypothesis that a positive relationship exists between certain PDMs and green design.

Best practices for public sector agencies implementing green design projects were developed from the results of this investigation of completed projects. The research was conducted by interviewing owners, contractors, and designers with experience in both public sector projects and green buildings.

The document outline is as follows:

1. Description of common types of project delivery methods
2. Description of research methodology
3. Summary of best practices
4. Detailed project information and interview responses
5. Summary of relevant published research on PDMs
6. Conclusion and future research

Project Delivery Methods

While several types of project delivery methods (PDMs) and their respective variations exist, this paper focuses on three methods: design-bid-build (DBB), design-build (DB), and construction management (CM).

Design-Bid-Build

DBB is a traditional project delivery method prevalently used in public projects. With this method, the owner contracts separately with the designer and the contractor. A direct contractual relationship between the designer and contractor does not exist, although a working relationship is typically established. The schedule progression is typically linear; that is, the designer completes the design, the owner solicits bids for the project, and then the contractor builds the project. Perceived advantages of this approach are typically clearly defined roles; the owner has significant control over the process; and the checks and balances between the three parties lead to a higher quality project. Some variations of DBB include (Oyentunji 2006):

- **DBB with early procurement**: Owner begins procurement during the design phase; contracts established between owner, contractor, designer, and suppliers.
- **DBB with project or construction manager**: Owner begins procurement at the end of design phase; contracts established between owner, contractor, designer, and project or construction manager.
- **DBB with early procurement and constructor construction manager**: Owner begins procurement during the design phase; contracts established between designer, constructor construction manager, and suppliers.
- **DBB with staged development**: Owner begins procurement at the end of staged portion of the design phase; owner established relationships with designers, contractors, construction or project managers, and suppliers. One example of this approach may be starting the foundation construction while design continues.
- **DBB with multiple primes**: Owner begins procurement at the end of design; contracts established between owner, designer, suppliers, and multiple primes. Multiple primes are often used when required by state law.

While DBB is a frequently used method, several drawbacks exist. Since a contractual relationship does not exist between the contractor and designer, a non-productive adversarial relationship between the parties can develop because the individual entities are mainly protecting their respective interests. It is commonly believed that the DBB projects have extended schedules often caused by relatively long procurement processes; for example, most federal, state, and local projects require a minimum three week bidding period. Perhaps the greatest disadvantage of DBB is that the budget, schedule, and ultimately the perceived success of the project rely heavily on the completeness of the contract documents. Design omissions and errors equate to change orders and possibly schedule delays. Often for public projects, the use of DBB is dictated by the funding source, associated legislation, and procurement laws; public agencies may not have a choice regarding the project delivery method. Efforts to improve DBB include an owner's concerted efforts to ensure accurate contract documents, pre-qualifying bidders, and commitments through partnering (Mulvey 1998).

Design-Build

In the DB project delivery system the owner contracts with a single venture to perform both the design and construction phases of a contract, offering the owner a sole contract with a single point of contact and responsibility. DB use is increasing, especially in the private sector. DB often appeals to the owner due to a single-source of contact along with responsibility, decrease in contract administration efforts, and often a decrease in the project schedule due to the overlapping design and construction phases. Variations of DB are:

- **Multiple DB**: Design construction phases coincide; owner contracts with separate DB firms for different phases or aspects of the projects.
- **Turnkey**: Design and construction phases coincide; owner contracts with one turnkey contractor who is responsible for design, construction, and commissioning.
- **DB Bridging**: Detailed description below.

Some of the perceived disadvantages associated with DB include the owner's potential reduced level of control over the final project and quality. DB owners often believe that quality may be compromised because DB lacks the checks and balances typical in DBB. Most DB firms or joint ventures are headed by the contractor, possibly due to bonding capacity, with the designer as the subconsultant. With the contractor as the lead and ultimately responsible for the bottom line, the

designer's recommendation with respect to quality may be 'over-ruled' due to budget issues. Another important issue faced by owners in DB is the importance of the selection of a capable design-build team.

In an attempt to take advantage of positive elements of both DB and DBB, a hybrid known as 'Design-Building Bridging,' or simply, Bridging, was created in 1982 by George Heery (Brookwood 2006). In Bridging, the owner with a designer establishes a strong set of documents, typically comparable to the design development phase, and then works to award a contract with a DB firm. As will be subsequently discussed, several U.S. government agencies are using DB Bridging, along with additional modifications.

Construction Management

Several varieties of construction management (CM) exist with two common variations being CM at risk (CM@R) and agency CM. Both methods offer the advantages of engaging a contracting firm at the onset of a project and benefiting from the CM firm's expertise in scheduling, budgeting, and value engineering. CM@R is a method where the owner contracts with the both a designer and a construction manager. The CM firm, typically selected on qualifications, functions in a dual role responsible for both construction management services and construction activities. While definitions of CM@R vary, this method typically uses a Guaranteed Maximum Price (GMP). At a certain point in the design process, which varies according to project, the CM develops a GMP based on the contract documents. The CM and the owner enter into a contract based on the GMP. 'At-risk' depends on whether it is from the perspective of the owner or the CM. From the owner's perspective, 'at-risk' is any substantial changes to the design subsequently result in a legitimate change to the GMP. From the CM's perspective, 'at-risk' means that any minor changes in the contract documents do not change the GMP.

An agency CM functions as an extension of the owner's staff, and offers advice on budgeting, scheduling, and daily construction activities. While the owner typically holds both the design and construction contracts, the agency CM supports the owner to make educated and practical construction decisions. The contract between the owner and agency CM is often either a percentage of the construction contract or based on hourly staffing requirements.

The advantages of the CM methods are their flexibility, especially when the project scope and program is not well-developed; their control over schedule and budget when several contractors are involved; and a professional, single-source liaison with the owner. Some disadvantages are the number of people involved in resolving disputes, and disagreement over legitimate scope changes that may or may not affect the GMP. With an agency CM, if the agency CM is also a general contractor, then the agency CM may have difficulty understanding and protecting the owner's interest because of having more experience and perspective from the contractor's standpoint.

Survey Methodology and Data Collection

In order to determine best practices and the synergies between green buildings and PDMs, a strategy was developed to efficiently elicit responses from owners, designers, and contractors. The first step was to develop a database of contacts. The database was extensive due to the potential difficulty in identifying public sector green building projects that utilized different PDMs. The four main sources that comprised the database were the USGBC's (United State

Green Building Council 2006), the Design Build Institute of America's (Design-Build Institute of America 2006) website, contact with the Associated General Contractors (AGC), and web searches.

After the contact database was compiled, the methodology shown in Table 1 was used for the interviews and the survey. Flowcharts of interview questions are shown in Appendix 2 and Appendix 3. A questionnaire was developed that focused on quantitative aspects, and also asked questions regarding quality. The initial questionnaire can be found in Appendix 4. Although quantitative data collection with a survey was attempted, the main focus was to develop a general understanding of the current state of operations with respect to PDMs and green design through interviews and not rigorous quantitative analysis.

The telephone interviews were used to gather the main component of the research and to filter the projects to determine if sending a questionnaire was appropriate. In the interview process, approximately 75 contacts were called. During the initial phase of the telephone interviews, if a contact was available and the phone interview was conducted, often the interviewee either was not interested in the questionnaire portion and indicated that decision during the telephone interview or did not return the questionnaire. Therefore, a second case methodology was created that relied not on telephone interviews and supplemental questionnaire, but relied solely on an interview that included questions from the initial phone interview and quantitative questions from the original questionnaire. The second case questionnaire is located in Appendix 5.

In total, 88 individuals were contacted either via telephone or email, and 21 interviews were conducted. During the 21 interviews, several individuals discussed more than one project, so 26 projects are included in the study. The response rate is 24% on an actual interview basis, and 30% on a project basis. The individuals contacted were owners, contractors, and designers; however, owners represent about one-half of the respondents and in terms of PDMs, DB projects were about one-half, DBB about one-third, with the remainder being CM.

After the interviews were completed, responses were tabulated in a structured manner and evaluated. A comparison was made between green building features and successful project characteristics identified in the literature. The established green building project features were examined to establish best practices for green design project and then summarized.

Table 1. Overview of the Methodology and Data Collection Process

Methodology (1)	Logic (2)	Steps (3)
Initial	Collect qualitative information during phone interviews. Collect quantitative information in questionnaire.	1. Develop contact database 2. Develop phone interview questions 3. Develop questionnaire 4. Call contacts to conduct phone interview 5. Send questionnaire 6. Receive questionnaire responses
Revised	Collect quantitative and qualitative information in questionnaire.	1. Develop contact database 2. Develop revised questionnaire 3. Email questionnaire 4. Receive questionnaire responses

In the "Detailed Survey and Interview Response" section, detailed information for each of the interviews is summarized and when available, project information is provided. A detailed description of the study methodology is given in Appendix 1. The outcomes from the analysis of the responses are given in the following Recommendations for Best Practices section.

Recommendations for Best Practices

The interview and questionnaire responses were evaluated in a structured manner to determine common features or characteristics of green design projects in relation to PDMs. Seven categories of features were identified as important for successful green design projects:

1. Collaboration
2. Team experience
3. Leadership
4. Clear definition of the scope of work
5. Adequate budget and funding limitations
6. Complexity/Flexibility
7. Control/Accountability

The features are often not mutually exclusive; for example, an overly ambitious scope of work can strain a fixed budget. Each of these features have been examined in relation to the survey responses and other related published work to determine if the feature is more relevant or associated with a particular PDM, if it is generally regarded as a good practice, or if it is both. Figure 1 illustrates the Project Success Factors derived from existing research, green project success features derived from this research, and the shared features between the two sets. The following section outlines recommended best practices for PDMs and green design, beginning

with suggestions for the selection of a PDM based on project characteristics and then following with additional specific recommendations.

1. The decision to use DB as PDM on green design or other projects should be based on the recognition of the importance of features of the project's implementation process.

When owners or the members of the project team are considering the appropriate PDM, project features should be considered. DB will not produce successful results on all projects. Project features that emerged from the survey and were corroborated by the existing literature on PDMs, e.g., (Songer and Molenaar 1997), and project success factors, e.g., (Ashley et al. 1987) are collaboration among team members leading to a shared understanding among the project team, team experience, including the owner's experience, leadership, an adequate budget and manpower commitment, and a well-defined scope of work.

2. Project team collaboration early in the design and construction process is an important aspect of green projects, and collaboration was considered somewhat more important in projects that used DB.

Several interviewees strongly suggested that one key to project success for green design projects was collaboration. Collaboration is cooperation and common understanding of the project among the owner, contractor, designer, or design-builder. Successful collaboration results in an integrated project team. From the survey results, collaboration early in the project was recommended by six of the respondents; integrated team was recommended by four of the respondents. One respondent emphasized both collaboration and an integrated team.

With respect to this feature and PDMs, five DB projects, three DBB projects, and one CM@R project stressed collaboration was an important feature for project success. Collaboration was a slightly more prevalent feature in DB projects, but also considered important in DBB projects. The conclusion, therefore, is that collaboration is important on all green design projects, and is an important feature of green design projects that use DB.

3. Team experience is important on all green design projects independent of the PDM. Owners should use a 'best value' selection process, which is more prevalent in DB projects, and include team experience as a criterion. The owner's role is critical with DB.

The experience of the designer, contractor, and owner is an important feature of green design projects. From the interviews, six respondents believed that team experience was an important factor in a green design project. Of those six, four projects were DB, while two projects were DBB. Experience with the LEED rating system and its credits are important factors for all parties. One of the critical factors in a successful DB project is the role of owner. These findings are significant because they are contrary to the perceived belief that DB projects have a lower administrative burden for the owner. While this may be true when considered over the entire design and construction phase, the owner's experience is central early in the project, in particular, the owner's development of the RFP in the initial design phase (Molenaar and Songer 1998). The experience of the contactor's project manager was also noted as an important factor in this survey, and it is corroborated by existing research. Team experience is a shared project success factor (see Figure 1).

4. Leadership is an important feature for all contracting parties involved in green design projects and it is a dominant success factor in DB projects.

The importance of leadership was discussed during seven interviews. Six of those interviews were associated with DB projects, and one was associated with a DBB project. Leadership, as discussed during the interview process, was fairly broad and different depending on the person's perspective. For example, a contractor recommended that a contractor should lead the DB team. On the other hand, a designer recommended that the designer should lead the DB team. The contractor believed construction companies remained more focused on budget and schedule. The designer believed that they were able to guide the project to achieve higher LEED ratings and maintain a higher level of quality standards for the projects. One owner mentioned that he was considering a project delivery method that would put the contractor and designer on an equal footing, or have the designer as the lead. This owner explained that with DB, "…the contractor typically holds cost first, quality second. Conversely, the A/E firm holds quality first, and cost second. But, because the contractor typically holds the DB contract, the cost usually wins."

The owner's leadership is critical in setting the tone of the project and setting a clear direction, not only in the scope of work, but also during construction as issues arise. During three of the interviews, the importance of owner's leadership was discussed in terms of setting and remaining focused on the budget and LEED goals. For green design projects, it is most commonly the owner's decision that a project will have green design features, and then often will cite a LEED rating or state that the project will be a LEED silver, for example. One interviewee pointed out that one successful characteristic in his DB project was that the owner not only set an attainable LEED rating but also established a good/realistic budget to achieve the LEED goal. Another interviewee thought that the owner's focus on the budget helped to achieve a successful project.

Agencies that are using DB, such as the Pentagon, have found it effective to include award and incentive fees to the design-builder. An award fee, typically 10% of the contract award, provides the design-builder with an up-front incentive and starts the project in a positive manner. The award fee not only acts as an effective relationship builder, but also assists in paying some of the designer's fees. Further, it acts as one of the common construction 'rules' to always be the first player to extend your hand. With respect to the incentive, if there is a savings, then a split is shared between the DB firm and the owner. If there is an overrun, then an established not to exceed split is also shared between the DB firm and the owner. The Pentagon also uses quarterly progress reports which are associated with incentive fees. Contractual incentives in turn create contracts with complementary goals, all project success factors cited by (Chua et al. 1999), (Alkhathami 2004), and (Sanvido et al. 1992).

5. A well-defined scope of work is important on all projects, independent of the PDM. In the case of DB, bridging helps improve quality and the owner's control; and using performance specifications to attain a LEED certification has been an effective contract administrative technique.

Having a clear scope of work was mentioned during five interviews. Four of the five interviews were related to DB projects; the other interviewee discussed general experience. The significant themes that emerged during the interviews were the importance of a clear scope of work and the use of design-build bridging, performance specifications for LEED certification, and design competitions with DB as ways to define the scope. A clear scope of work minimizes change

orders and schedule delays in all PDMs. Clear scope of work is a project success factor as shown in Figure 1 and (Ashley et al. 1987) considered the scope of work a statistically significant factor for a successful project.

Design-build with Bridging is a PDM in which the owner produces a set of documents and establishes an RFP based on the bridging documents. The selected design-builder incorporates the bridging document into the final design and project. It should be noted that one interviewee mentioned that one potential problem with bridging is that the architect of record is the architect from the design-build company, and may become an issue when the bridging documents are incorporated from a different architectural firm. Bridging was mentioned during several of the interviews, and several respondents stated that bridging is recommended and used by the United States General Services Administration (GSA). DB bridging is used to maintain the owner's level of control and meet quality standards, two aspects of DB that are often cited as disadvantages. DB bridging appears to work well with green design because it allows the project team flexibility during the design and construction phases to experiment and meet LEED requirements, and ensures attainment of the owner's project goals and quality level. Similarly, specifying LEED rating as a performance specification also gives the project team the same flexibility to work within the LEED framework while achieving the owner's goals.

Regardless of the PDM, several interviewees mentioned that specifying green design elements as performance specifications, such as the project shall meet or exceed a specified LEED rating, was effective to realizing green design goals. Performance specifications set clear goals and shifted some of the responsibility from the owner and designer to the contractor. Since a relatively large number of LEED credits are driven by the contractor, this approach assisted in obtaining the owner's overall green project goals.

Some owners who use DB are having design competitions to assist them in the selection process. The owner gives the short-listed firms design fees or a stipend to compete in the selection process, which is a two-fold advantage because the firms are compensated for their proposals while the owner is given the opportunity to further define and solidify the project's scope of work before entering into a DB contract.

6. Having adequate funding and budget for the given scope of work is particularly important in a green design project. Public funding restrictions may not allow certain PDMs, and the nature of public funding streams may make non-traditional PDMs more difficult.

Often the funding source will dictate the project delivery method, which may inhibit the public owner's choice of PDM. Based on observations in this research, the use of non-traditional PDMs seems to decrease as one moves from federal, to the state, to the local levels. The federal government uses more DB than the local governments with the state's usage in between. On the other hand, one federal employee noted that the GSA's program requirements changed often, so DB may not work well due to shifts in the program. Also, the funding allocation is often separated between the design and construction phases making the option to pursue DB more administratively difficult. One interviewee noted that DBB was used due to funding and legal constraints.

Two respondents cited the importance of the owner's expectations in conjunction with the budget and LEED goals. Incorporating green design early in the design process in the Pentagon

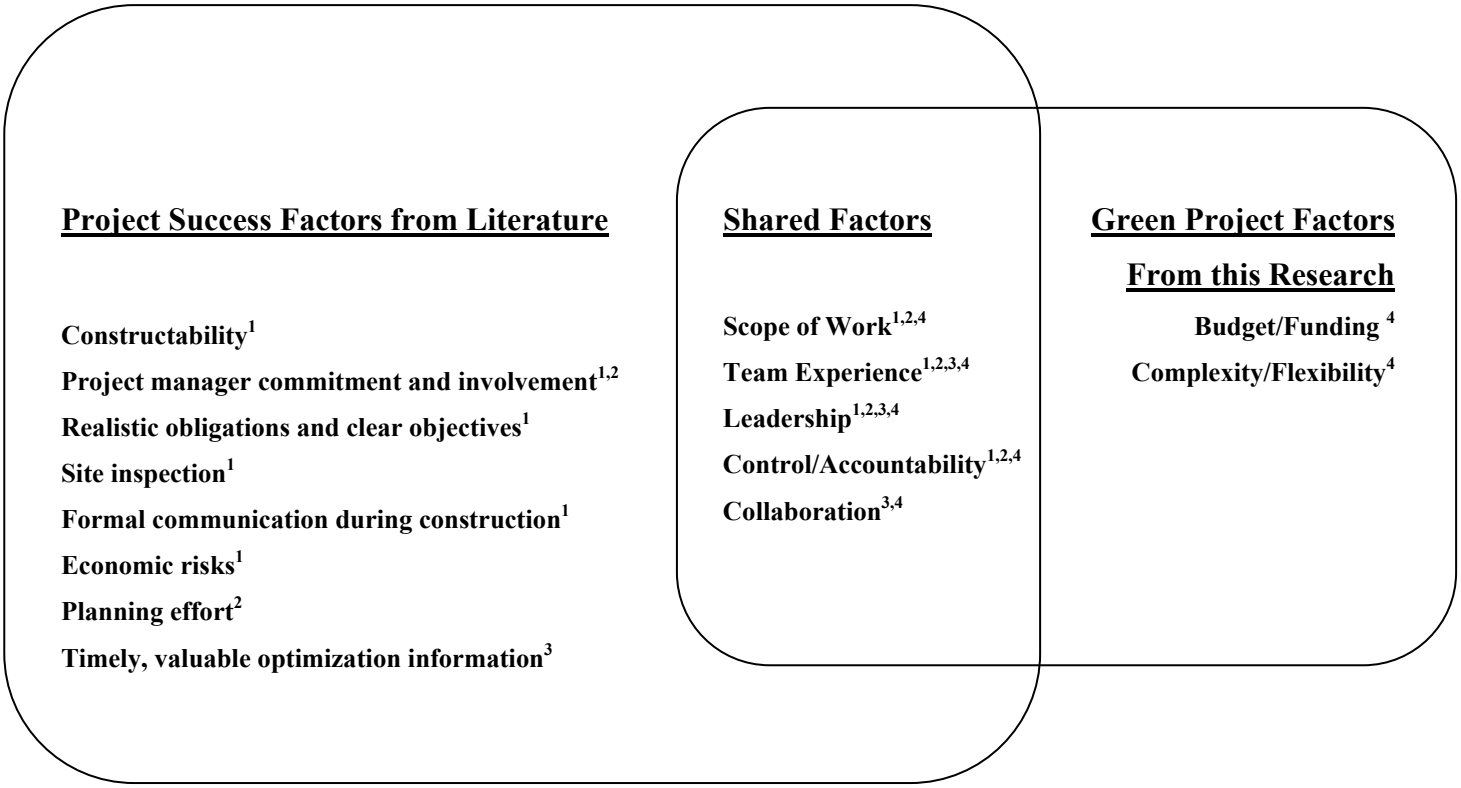
renovation projects resulted in no additional funds on the green aspects while achieving a higher LEED certification (Pulaski et al. 2003).

7. Project complexity and flexibility is a project feature that is more specific to green design projects and is more positively associated with DB.

Flexibility and complexity are included in the same feature category because during the interview process the two features were often intertwined; for example, a complex project required flexibility from all team members to produce a successful project. Complexity and flexibility were discussed in six of the interviews; three were associated with DB projects, two with DBB projects, and one interviewee based on experience. These combined features appear to be more prevalent in green design projects, as they are minimally mentioned in the existing research reviewed here. Interviewees said that they decided to use DB because it allowed them to be more flexible and allowed the team to refine the design without affecting the schedule. DB's flexibility fostered a collaborative effort that resulted in an end-product with many owner or tenant requested features. This aspect is important when the project is being built by a developer with a long-term lease tenant who has specific space requirements. Administratively, it was more difficult with DBB to make changes because the change order process was difficult and time-intensive causing additional costs and schedule delays. However, one interviewee believed that sustainable design was too complex to do as a traditional design-build.

8. Control and accountability is a problem associated with DB more than with DBB. It is not specific to green design projects. DB Bridging can be used to offset the lack of control with traditional DB.

One of the often cited problems associated with DB is the owner's lack of project control. With a lack of project control, accountability can be lost as well. This issue was discussed in four interviews; two were DBB projects, one was a DB project, and one was speaking based on experience. The two DBB interviewees both believed that DBB was the best option when the owner desired a great deal of project input and control. One architect interviewed believed that DB diminished owner's participation, and that the architect's access to the owner was limited. On the other hand, one interviewee that participated in a DB project thought that DB was the better approach when green design was involved because of the project team's continuity.



Notes:
1. (Chua et al 1999)
2. (Ashley et al. 1987)
3. (Sanvido et al. 1992)
4. Green features from this research.

Figure 1. Features of Project Success from both this Research and Literature

Detailed Survey and Interview Responses

Pentagon Renovation Projects (Penren)
PDM: DB or DB variation
Role: Owner

Overall Project Information
The Pentagon Renovation (PenRen) Project is a unique project that embodies elements of federal procurement, contract administration, sustainability, and constructability. (Pulaski et al. 2003) discussed the relationship between sustainability and constructability at the PenRen projects as complimentary, and when combined able to enhance both initiatives.

The Pentagon is the "world's largest building covering 29 acres of land and contains over 6.6 million square feet of floor space. There are more than 17.5 miles of corridors and 7,754 windows. The building has its own heating and refrigeration plant, water and sewage facilities, police force, fire station, heliport, childcare center, cafeterias, mini-mall, Metro station, and medical clinic. With a daily population approaching 25,000 people, it is larger than 9 out of 10 American towns (Pulaski et al. 2003)."

An Integrated Sustainable Design and Constructability (ISDC) team was established to integrate the mandated sustainability efforts, headed by Teresa Pohlman, and practical constructability efforts, conducted by Pennsylvania State University. Pohlman focused scattered sustainability efforts. The constructability team researched the first phase, Wedge 1, in order to make recommendations for the remaining work, Wedges 2 - 5, particularly in terms of highly repetitive work. The initiatives were combined to be a part of the ISDC.

Constructability and innovation were improved through PenRen's use of design-build, performance-based contracting, with incentives and award-fees. DB was used because of the belief that it fostered cross-disciplinary interaction among the owner, designers, and contractors. PenRen believed that DB allowed for better integration of building systems, and more efficient and sustainable designs. Performance-based contracting allowed design and specifications to be reduced from 3,500 pages for Wedge 1 to 16 pages for Wedges 2-5. Incentive and award-fees were established not only to elicit customer service and performance, but also to penalize the contractor if quality was compromised to maximize profit, a problem often associated with DB contracts. Contractors were awarded profit incentives based on quarterly progress reports determined by the owner. At the beginning of the project, the contractor was given an award fee. The Pentagon believed this approach was a 'win-win' for both themselves and the contractor (Pentagon 2006). In terms of green design, the Pentagon included LEED as criteria in the selection process and as a performance specification. PenRen provides an excellent example of a Federal agency that successfully and effectively implemented green design into a design-build framework.

Interview Response
The interviewee was involved in many projects at the Pentagon. The PenRen projects used DB with incentives and award fees. With respect to the incentive, if there was a savings, then a split was shared between the DB firm and the Pentagon. If there was an overrun, then a split was also shared between the DB firm and the Pentagon, but typically a maximum not to exceed amount

was established, such as 110% above the contract price. The award fee was typically 10% of the contract value. When asked why the Pentagon used DB, the interviewee said that the Program Manager, who is not an architect, engineer, or contractor, made this decision in an effort to cut costs and schedule.

Success with DB depends on an integrated project team, especially an A/E firm that does all of the work in-house, including green design. It is important to have all of the players aware of green design. If the green design component is a third party contract, then often the green aspects are 'additional' and not a part of the holistic design. Since the construction efforts at the Pentagon can be political, DB has the flexibility for changes without affecting the schedule. For example, if a high ranking official requires a change, with DBB the change order process takes time and subsequently money. With DB, the change can be made more quickly.

In terms of financing the projects, the Pentagon rents the space to the lessors, and this money funds the renovation efforts, along with money from Congress. The funds are typically not prescriptive. Two contrasting project examples were given. One project had an integrated team and another with a third party LEED AP professional. The integrated team's project was more successful in implementing the green aspects. If the green aspects are not integrated in the beginning, then there will be no additional costs or even less costs. If the green aspects are added on, then the project is likely to have cost increases.

The interviewee has been considering a 'joint venture approach' instead of using DB. With DB, typically the contractor holds the contract and subcontracts the work to the A/E firm. Additionally, the contractor typically holds cost first, then quality second. Conversely, the A/E firm holds quality first, and cost second. Because the contractor holds the contract, cost usually wins. If the project is a joint venture, then the contractor and the A/E firm are on a more equal footing, reducing the one-sidedness of the partnership.

Pentagon Athletic Center
PDM: DB
Role: Architect from DB team

Interview Response
The architect from the DB team for the Pentagon Athletic Center believed this to be a true DB project. The short-list of design-builders was based on qualifications, with the next step a design competition. The short-listed firms were each given a stipend of about $100,000 to compete in the design competition. Green design was a major part of the selection process. The Pentagon required quarterly reports from the DB team and if the team performed well, then the team was awarded a monetary incentive. This interviewee believes that DB and green design do complement each other because there is not a hand-off of project elements between the players.

Carl T. Curtis Midwest Regional Headquarters of the National Parks Service
PDM: Design-Assist or DB
Role: Architect and Owner

Project Information

The Carl T. Curtis Midwest Regional Headquarters of the National Parks Service, a commercial office and interpretive center, is located in Omaha, Nebraska. Situated in an urban setting, this 68,000 square foot building was completed in July 2004 with a LEED gold rating and a construction cost of $8,500,000 not including land cost. The regional headquarters is responsible for 13 states, along with the visitor's center for the Lewis and Clark National Historic Trail. The building is owned by Park Service Developers/Noddle Companies and is leased by the Federal government. The design-builder's on-site project manager and additional staff became LEED accredited professionals to be fully engaged in green design during the construction process. Some key green design features include:

- Alternative transportation with outlets for electric vehicles, carpooling, bike racks, and showers.
- Use of native, drought-tolerant plants; retention and detention pond; water efficient fixtures.
- Building's orientation increases daylighting and views and reduces solar heat gain.
- Material selections included low-emissivity insulated tinted glass, insulated precast concrete, certified wood, and local materials (United State Green Building Council 2003a).

Interview Reponses

Both the architect and federal representative were interviewed. While the federal representative considered the PDM to be DB, the architect considered it a 'design-assist.' The architect prepared drawings to a schematic design level with a LEED goal list, and then the contractor was selected through a process that included a long-list and a short-list. The short-listed firms advanced the design to a certain level, and the selection of the DB firm included the design with the LEED goal as one criterion in the selection process.

The architect and owner believe the project was successful. From the federal representative's perspective, it was a success mainly because the National Parks Service was delivered a project with the features that they wanted; further, the developer had the funds to deliver a quality project. From the architect's perspective, the project was also successful. When questioned about the relationship between green design and PDMs, the architect made a distinction between a building with green features and a LEED building. If the building is a LEED building, then this person believed that DB would be very useful. The architect cited the example on this project that the contractor was given project parameters and could not or did not obtain certain initial LEED points. The owner then in turn placed the responsibility on the architect to determine additional LEED points – resulting in additional architectural fees. If the contractor and designer were on one team, the efforts may have been more collaborative.

Rinker Hall and McGuire Center
University of Florida
PDM: Construction Manager at Risk
Role: Owner

Project Information – Rinker Hall

University of Florida's Rinker Hall houses the School of Building Construction which includes 1,500 students and 100 faculty members. This 47,300 square foot higher education facility was completed in March 2003, achieved a LEED gold rating, and had a construction cost of $6,500,000. The design of Rinker Hall has features that include:

- North-south axis orientation to use low-angle light for daylighting.
- Use of local materials and materials with recycled and renewable resource content, low toxicity, long and low maintenance, and end-of-life uses.
- Classrooms were designed with maximum flexibility to reduce churn costs for future uses.
- Two major areas were partly designed as indoor/outdoor spaces to take advantage of thermal shading (United State Green Building Council 2003b).

Project Information –McGuire Center
The McGuire Center for Lepidoptera Research is a 40,000 square foot addition to Florida's Museum of Natural History and includes a vivarium, museum space, display space for almost all known Lepidoptera species and the second largest butterfly collection, and lab space.

Interview Response
The University of Florida's Facility Management Department administers all projects with CM@R. None of the building projects use DB; however, all new University of Florida buildings are to be at least LEED certified. The first building, Rinker Hall, was the first LEED building on the campus, and due to its success, all buildings must meet the requirement. The University has LEED AP professionals on staff.

The main reason why the University uses CM@R is because it is, in their system, the easiest to manage administratively with the given funding. However, the interviewee noted that CM@R may not be the best approach. When asked about the relationship between DB and green design, this person thought DB may be the better approach given that 1/3 of LEED points are the responsibility of the contractor. The earlier the contractor is involved in the project, then the greater chance for success with a LEED certification. CM@R helped to manage the construction cost; but not the costs for designer errors and increases in the designer's contract. CM@R may be the best approach until the green market is more saturated.

US/Canada Shared Port of Entry (Sweetgrass Project)
PDM: DB Bridging
Role: Owner

Project Information
The United States and Canada Shared Port of Entry project, also know as Sweetgrass, is 100,000 square feet with one main building with six additional structures. It is the first project completed in accordance with the Shared Border Accord between the GSA and Canada Border Services. Many agencies from both countries were involved in this project, which created challenging coordination and administrative activities. The design-build cost of $31,200,000 does not include the cost of land. Sweetgrass is a LEED certified project and is an optimum green design learning facility since 1.3 million travelers and 413,000 shipments pass through the third largest crossing site in western U.S. and Canada (United State Green Building Council 2003d)

Interview Response
The Sweetgrass Project used DB bridging, a delivery system often used by GSA. This interviewee believes that the GSA prefers to use DB bridging because it helps to alleviate any problems that may be associated with quality on a DB project. With DB bridging, design

progresses to a certain percentage, and then a DB firm is procedurally selected. The remaining design and construction is completed by the selected design-builder. The original designer does not have to be a part of the selected DB team, and was not a part of the DB team that won the contract. For this project, the design was taken to 30% in total, but individual packages were advanced at different percentages. The architectural and structural packages were almost 100% designed, but the design of the HVAC and other systems were minimal.

When asked about funding restrictions with respect to PDMs, the interviewee responded that at the GSA, each region decides how funds are managed. For all projects above a certain threshold, Congressional approval is needed, and the Congressional approval is linked to scope, budget, and schedule. If any of those three items change significantly, then Congressional approval is needed again. Further, the GSA needs to prove that a project is economically viable. The scope, budget, and schedule are established through a development project plan conducted by the GSA. In addition, a project management plan is conducted to determine how to implement the project.

In addition to using DB bridging, the GSA used LEED criteria as performance specifications allowing the DB team flexibility to obtain LEED points. The interviewee believes that DB and green buildings are an excellent fit.

U.S. EPA National Computer Center and Child Care Center
PDM: DB
Role: Owner

Project Information – U.S. EPA National Computer Center
The U.S. National Computer Center is located in Research Triangle Park in North Carolina and was completed in January 2002. This 101,000 square foot commercial office building is a USGBC LEED silver rated facility which houses the U.S EPA's data processing and environmental modeling centers. Excluding land, the project's construction cost was $21,236,511. Environmental aspects include:

- Natural site feature preservation considered in selecting building site along with 10 acres dedicated as open space.
- A photovoltaic array to generate electrical energy and to act as a roof shade to minimize heat gain. The remainder of the roof is a white reflective membrane.
- South-facing windows for daylighting and passive solar gain in the winter and a central atrium for daylighting.
- Carbon dioxide sensors linked to the HVAC system to adjust and improve indoor air quality.
- 82% of all construction waste was recycled (United State Green Building Council 2003c).

Project Information – Childcare Center
Also located at Research Triangle Park in North Carolina, the Childcare Facility is 25,400 square feet and was built to replace the existing First Environments Early Learning Center (FEELC). The FEELC is now able to accommodate 188 children and 41 staff with 20 classrooms. The childcare facility is a LEED registered project that is attempting to achieve a silver rating by implementing features such as daylighting and energy efficiencies (U.S. Environmental Protection Agency 2006).

Interview Response
DB was used on both projects, the National Computer Center (NCC) and the Childcare Center. In this interviewee's opinion, DB is preferred to DBB because with DBB, the owner pays for the designer's mistakes.

This National Computer Center was a part of a larger project, but it was cut from the original project due to funding constraints. When the funds were available, the design was completed, but the needs of the EPA had changed. The EPA decided to use DB because it was more flexible and allowed the team to refine the design. Further, the GSA recommended using DB. Data processing capabilities improved allowing for a building size reduction of about 20% without sacrificing functionality. The DB firm was selected based on a negotiated best-value contract.

This interviewee believes that DB with LEED "…is the only way to do it." Since DB and LEED are about integrating design and construction processes, it is critical to have both the designer and contractor working together at the beginning. The contractor typically will subcontract the design work to the designer, probably because of bonding capabilities. It was recommended that it might be more beneficial for the designer to lead. Because of the success of DB on the NCC, it was also then used on the Childcare Facility.

Solano County Government Center
and
Caltrans District 7 Headquarters
PDM: DB
Role: Contractor

Project Information – Solano County Government Center
The Solano County Government Center is a six-story building, 300,000 gross square feet, designed to merge 18 county departments and divisions in to one common location to house 800 employees. The project procurement method was in accordance with a public contract code which was a two-step process including a Request for Qualifications (RFQ) to pre-qualify firms, and a Request for Proposals (RFP). The top three pre-qualified design-builders submitted their best value proposal. Solano County used Design-Build Bridging, and the bridging documents were prepared by the County's Master Architect/Engineer. The bridging documents addressed the scope of the projects including aspects such as size, type, context, design criteria, and performance specifications. This project is a LEED certified project with environmental aspects that include energy efficiency that exceed the minimum building energy-efficiency standards of California's building code; water conservation measures for the interior and exterior; diverting 75% of demolition and new construction waste from landfills; and sustainable materials (Solano County 2002).

Project Information – Caltrans District 7 Headquarters Building
California's Department of Transportation's District 7 Headquarters building is a $165 million project located in Los Angeles, California. This LEED registered building includes environmental features such as a photovoltaic system that meets 3% of building energy demand; east and west elevation shading systems; and a computer-controlled pneumatic system to open and close aluminum scrims over window openings with respect to the angle of the sun. Also,

this project used an internet-based project software, Constructware, to improve communication and reduce paper use (Constructware 2005).

Interview Response
The interviewee has worked on three green design projects, and all of the projects have used DB. This person's opinion is that green design and DB work well together. Since the Governor of California has mandated that all public buildings are to be LEED Silver, the increased use of DB and green design will continue. From the contractor's perspective, the delivery method is mandated by the owner. This contractor believes that the private developer is only driven by price and will only include green features if there is an associated monetary benefit.

Washington State Penitentiary Replacement Warehouse
PDM: DBB
Role: Architect

Project Information
The Washington State Penitentiary Replacement Warehouse is a 39,000 square foot building located in Walla Walla, Washington with a LEED silver certification. In the state of Washington, all public projects are required to obtain a LEED silver rating. Sustainable features focus on reducing infrastructure including traffic, water usage, and electricity usage. By constructing a new warehouse, operations were consolidated into one logistically centralized location reducing traffic and travel distances. Also, showers, bike racks, and car pooling promoted other transportation methods. In terms of energy conservation, low-e windows, ground source heat pumps, walk-in cooler heat recovery, and daylight sensors were installed. Lower water use was achieved by harvesting rain and site water and installing water conserving appliances (International Facility Management Association 2005).

Interview Response
This interviewee believes that DBB is the best option when the owner desires a considerable amount of input and control of the end product and that DBB offers the most involvement for the owner. If the project is conducted with DB, then the Owner can lose control and perhaps end up with a product that is not performing adequately. For this project, the final cost was within budget with less than 1.5% A/E initiated change orders. The commissioning took longer, and some of the systems were not performing adequately. This interviewee also worked on another project for the same owner and prepared the documents for DB bridging and believes the owner is not satisfied with using DB bridging on that project.

Pennsylvania Turnpike Commission's Central Administration Building
PDM: DBB
Role: Owner

Project Information
The Pennsylvania Turnpike Commission's (PTC) new Central Administration Building was completed in April 2001 as a renovation and expansion project. This 160,000 square foot, $33 million project obtained a LEED certification and included green elements of energy and water reduction, along with recycled materials (Strategic Building Solutions 2006).

Interview Response
DBB was used as a PDM because of the funding used on this project. This project was a multiple prime project as required by the Commonwealth of Pennsylvania's Separations Act requiring agencies to award separate contracts to specialty contractors such as mechanical, electrical, and plumbing. The PTC believes that DBB is a good approach because the responsibility is shifted from the owner to the designer. While the project outcome was relatively successful, the interviewee mentioned that it went "…as well as can be expected for a multi-prime contract project."

Duracell Project
PDM: DBB
Role: Contractor

Project Description
Duracell's building located in Bethel, Connecticut is a 310,000 square foot building with a construction cost of $70 million. While not listed as a certified LEED project, the building's green design features include a skylighted spine, additional skylights, and large windows to decrease lighting demand; use of 460,000 dark red bricks composed of manganese, a by-product of Duracell's battery production; and recycled or reclaimed materials like crushed rock from site preparation activities (Charles 1995).

Interview Response
The contractor believed this DBB project was successful because of the team approach developed between the architect and the contractor. As a PDM, DBB forced the architect and contractor to work towards a successful project.

When asked in general about the use of DB on green design projects even though it was not used on this project, the response was that in an ideal world DB would be the best method because it has everyone's interest in mind. However, there are problems associated with the DB method because either the contractor is working for the architect or the architect is working for the contractor and internal conflicts exists that are projected on to the final product. This interviewee believes that the best method is CM@R. For a successful project, the contractor and architect need to work as a team.

Washington D.C. Parks Department Project
PDM: DBB
Role: Contractor

Interview Response
The interviewee believed that the Washington D.C. Parks Department Project was successful because it was on schedule and under budget, but the success was not based on the DBB PDM. This person did believe that DBB allowed for more flexibility to meet LEED criteria. In terms of PDM and green design, the PDM has no effect on the success of a project because the PDM is chosen before the 'real players' are involved. Success is dependent upon the project team's adeptness within their profession and ability to adapt to different scenarios. Best practices for

using DB on green design projects include being flexible to meet the owner's requests while complying with LEED criteria. Also, remain focused on the schedule and budget.

Texas Instruments Project
PDM: DB
Role: Contractor

Interview Response
The interviewee believed the project was successful because of the collaborative effort between the owner, designer, and contractor. The designer and contractor were familiar with green design which contributed to project success. Since the Owner set a realistic budget and incorporated costs for green design elements into the budget, the team was able to respond effectively.

Regarding the PDM, the use of DB had a positive effect on the project because it helped to foster a more collaborative effort. This individual recommended using a contractor-lead DB team as opposed to a designer-lead DB team because he believed the contractor has a better handle on cost and schedule.

Oak Ridge National Laboratory
East Campus Revitalization Project
PDM: Varies
Role: Owner

Overall Project Information
- Most buildings were privately funded with developers totaling 376,000 gross square feet, all LEED certified, DB.
- One building was funded by the Department of Energy; 52,000 gross square feet; LEED certified; DBB.
- One building funded by the state, 52,000 gross square feet, LEED certified, DBB.
- One developer funded with an end-of-lease buy out, 210,000 gross square feet, LEED silver rated, DB.

Selected Project Specific Information
Several projects comprise Oak Ridge National Laboratory's East Campus Revitalization project, and this information focuses on detailed information for a portion of the project. The private development component consists of four buildings, which are considered one building for code purposes. The building types are commercial office, financial and communications, laboratory, and campus, totaling 376,000 square feet with a construction cost of $71,000,000. The project was completed in August 2003, and received a LEED certified rating. Some key environmental aspects include:
- Architectural design to reduce heat-island effect.
- Drought-tolerant landscaping.
- Alternative transportation is encouraged by installing showers and bike storage facilities along with car pooling parking spaces.
- Recycled materials with low VOCs.

- Carbon dioxide monitors with air filters.
- Energy efficient design with efficient lights, occupancy sensors, variable-frequency fan drives, and Energy Star office equipment.

The building is owned by developers and leased to the Federal government. This project used DB with a guaranteed maximum price (GMP) contract (United States Green Building Council 2003).

Interview Response
The selection of the PDM was made mainly according to the associated funding. This interviewee believed that DB with fast-tracking made more sense economically due to construction interest rates. Of the two methods, this person prefers DB fast-tracking because it saves time and money and allows the end-user little opportunity for changes, which in this person's opinion was a positive element. It was more challenging to implement green design principles with DB fast-tracking, but the challenge made the projects more interesting in comparison with DBB projects.

Scowcroft Building Renovation
GSA Leased property
PDM: DB
Role: Owner
This interviewee was not closely involved in the construction process because the building is a GSA leased property but noted that the developers selected a method most similar to DB. The interviewee indicated that for GSA leased buildings, the agency will issue an RFP to developers and it is the developer's prerogative to choose construction methods.

GSA Employee
This interviewee was responding based on experience, not a specific project. Interviewee believed that the GSA "…did not do a lot of DB projects, but the GSA was doing DB bridging." As the agency's requirements often changed, DB may not work well with shifts in a building's program and the interviewee was additionally aware of issues regarding accountability. A significant issue with using DB is related to the funding stream, because often funding is separately allocated for the design and construction phases.

Colorado Department of Labor and Employment
PDM: CM as GC
Role: Owner

Project Information
The Colorado Department of Labor and Employment (CDLE) received a LEED certification for its 40,000 square foot addition. The project has the following green design elements: high efficiency HVAC and lighting, lighting controls, natural daylighting, energy management system, reflective roof coasting, low flow faucets and toilets, high recycled content of ceiling tiles and carpet, recycled deconstruction materials, low VOC paint, locally purchased materials,

low toxicity of cleaning agents, and wind power contract. The construction cost for the addition was about $4,000,000.

Questionnaire Response Summary
From the second case survey information, the project was at the original budget amount and finished ahead of schedule. The CM/GC worked well to combine the efforts of the GC and the design team. Best practice recommendations are to start early with green design efforts, use a proper set of green specifications, work with local suppliers, and provide up-front documentation on materials.

Cambridge City Hall Annex
Role: Designer
PDM: DBB

Project Information
Cambridge City Hall Annex, located in Cambridge, Massachusetts, is a restoration project that received a LEED gold rating. This 32,000 square foot facility houses several of the Cambridge's public houses. Sustainable features are:

- Reuse of an existing building.
- Water efficient landscaping.
- Close proximity to public transportation; provisions to encourage cycling and carpooling.
- Efficient energy use; maximize daylighting; ground source heat pump system; low-e windows; daylight and occupancy sensors; displacement ventilation and heat recovery system; 28-kW solar power photovoltaic system.
- Recycling of 80% of construction waste.
- Use of recycled materials; 50% of wood from certified forests.
- Carbon dioxide sensors; minimize construction fumes; low-emitting materials (Oikos Green Building Solutions 2006).

Questionnaire Response Summary
Response in the questionnaire indicated that DBB had a negative impact on the overall project; in particular on the quality. In response to the relationship between green design and DB, the respondent believes that DB will not prove to be an effective PDM because the DB process "…diminishes the owner's participation and access." An alternative PDM that may be more successful is 'teaming.' In this approach the owner maintains independent contracts with designer and builder; teaming is more effective when the designer and builder have experience working together. This respondent believes that traditional DB with green design is too complex. "If the architect is working for the builder, his loyalty is compromised and if the owner is doing DB to save money he/she will not get a building that is cost-effective and easily maintained and operated."

Pennsylvania Department of Environmental Protection's
South Central Regional Office Building
Role: Designer
PDM: DBB

Project Information
Pennsylvania's Department of Environmental Protection's (PADEP) Southeast Regional Office Building was completed after the South Central Regional Office Building. PADEP's Southeast Regional Office Building was completed in 2005 and achieved a LEED gold rating with a construction cost of $12.5 million. This facility, which is located near an old railroad station in Norristown, Pennsylvania, has green features including an exposed network and cistern in a four-story atrium used to gather rainwater used in toilets and landscaping. By increasing daylighting, the energy consumption was reduced by 40 percent. Also, this facility uses 83 percent less water than a comparable conventional office building (L. Robert Kimball 2005).

Questionnaire Response Summary
The respondent's opinion for this DB project is that the PDM contributed negatively to the quality of the project, but positively to the overall project. This person's opinion regarding green design and DB is that "…typically DB can serve as an excellent construction delivery methodology as long as the construction professional remains committed to the same quality level as the owner." Best practice recommendation is "…very early involvement of construction professional and integration with design professional's efforts throughout the design and construction process."

Alfred A. Arraj Federal Courthouse
PDM: DBB
Role: Contractor

Project Information
The Alfred A. Arraj Federal Courthouse is a 320,000 square foot building that was completed in 2002. With a final construction cost of about $87 million, this Federal Courthouse has an extensive photovoltaic system and is anticipating a LEED gold rating.

Questionnaire Response Summary
Contractors, owners, and designers all need to understand green design. If the entire team does not understand green design, then commitments made by team members are often not met. Including the general contractor during pre-construction and design can help the owner understand the costs associated with green design.

Bachelor Enlisted Quarters MCPON Plackett Manor & Naval Hospital Lake Naval Station
PDM: DB
Role: Design-Builder

Project Information
The Bachelor Enlisted Quarters MCPON Plackett Manor & Naval Hospital Lake Naval Station is a 462,000 square foot special use facility. The facility cost over $65 million to construct and was completed in 1999.

Questionnaire Response Summary
The respondent agrees with green design, but thinks there is a cost associated with green. Green design must be explicitly made a requirement in the contract documents.

Literature Review

A relatively large amount of research has been conducted regarding PDMs in projects in general compared to research of PDMs with green design projects. Therefore, a literature review was conducted of project delivery systems irrespective of the relationship with green design. The literature review focuses on the following aspects:

- Quantitative studies related to PDMs to report advantages and disadvantages of the associated method;
- Project characteristics that complement DB;
- The owner's role in DB projects;
- The public sector's perspective on DB; and
- Characteristics of successful projects.

Quantitative Studies of Project Delivery Methods

Positive Research Findings on DB

(Konchar and Sanvido 1998) collected project specific data from 351 U.S. building projects to empirically compare cost, schedule, and quality with respect to CM@R, DB, and DBB. Univariate significance testing was used and multivariate linear regression models were created to determine highly influential variables. Univariate results indicated that DB projects performed equally or better than DBB and CM@R.

Multivariate comparisons were made to examine project performance variables with respect to project delivery methods. Reported multivariate results included unit cost, construction speed, delivery speed, cost growth, and schedule growth and of these results, unit cost, construction speed, and delivery speed are considered the results with the greatest certainty. The results for the variables with the respective R^2 are shown in Table 2.

Table 2. Percentage of Average Differences Between Project Delivery Systems by Metric (Konchar and Sanvido 1998)

Multivariate Model (1)	DB versus CMR (%) (2)	CMR versus DBB (%) (3)	DB versus DBB (%) (4)	R^2 (%) (5)
Unit cost	4.5 less	1.5 less	6 less	99
Construction speed	7 faster	6 faster	12 faster	89
Delivery speed	23 faster	13 faster	33 faster	87
Cost growth	12.6 less	7.8 more	5.2 less	24
Schedule growth	2.2 less	9.2 less	11.4 less	24

Negative or Neutral Research Findings on DB

Ibbs and co-workers examined the effectiveness of 67 projects related to DB and DBB (Ibbs et al. 2003). The study quantitatively analyzed the impacts different project delivery methods had on changes in cost, changes in schedule, and productivity. The projects mainly were located in the United States. This research differs from (Konchar and Sanvido 1998) in that (Ibbs et al. 2003) also included productivity, which leads to changes in cost and schedule. The research methodology involved a questionnaire which included basic information about the project and information about changes that happened. The authors concluded that the reported cost savings associated with the DB method are not fully substantiated by this set of data although only

univariate statistical analyses were performed to formulate this conclusion. It should be noted, however, that the definition of cost changes used 'final cost' and 'initial budget.' The use of the initial budget may prove to lead to inaccurate results because owners use different approaches with the initial budget number. For example, some owners may be conservative with the initial budget (estimate the project slightly higher), while other may not be conservative. The uncertainty with the initial budget may lead to uncertainty in the findings. Relative to schedule, DB projects experienced a 7.7% change whereas DBB were at 8.4%.

The authors note that while it is important to understand PDMs in concert with cost and schedule, the significant indicator is productivity. Productivity was analyzed as a function of cost and schedule changes by calculating best fit regression equations. The authors observed that the effects on productivity were difficult to predict and ultimately may depend on the functionality of cost or schedule versus productivity. To summarize, this study found that DB did not perform significantly better than DBB.

Understanding DB and Project Characteristics

Even though some discrepancy exists between the relative advantages and disadvantages of DB and DBB in (Konchar and Sanvido 1998) and (Ibbs et al. 2003), the use of DB is increasing in the public and private sectors. Understanding and defining not only characteristics of successful DB projects but also key project characteristics with respect to PDMs is critical for selecting the appropriate PDM for a project.

Songer and Molenaar examined 88 public sector projects to identify project characteristics that are critical for success (Songer and Molenaar 1997). The methodology included a literature review that identified a list of project success criteria and characteristics, unstructured interviews that further defined project characteristics, validation of results through a survey including the use of analytical hierarchy process (AHP), and additional structured interviews. Criteria of success are staying on budget, conforming to user's expectations, and staying on schedule. This study found that the top five DB characteristics for successful DB projects are:

1. Well-defined scope;
2. Shared understanding of the project scope;
3. Adequate owner staffing;
4. Owner's construction sophistication;
5. Established budget.

Owner's Role in Project Success and DB

(Molenaar and Songer 1998) tested the above characteristics by attempting to predict the relationship between the characteristics and project success for public sector projects using DB. Multi-attribute analysis was used with regression models in a hierarchical framework with retrospective case studies. Results indicated that the most critical element to project success is the owner. The owner's critical roles are developing accurate request for proposals (RFP) and active involvement in the design phase. These results are important because they are contrary to the perceived belief that DB projects have a lower administrative burden. While this may be true when considering the entire design and construction process, DB projects may require additional preparation by the owner early in the process.

The Public Sector and DB

Molenaar and co-workers investigated the owner's experience with DB, design completion, DB team selection, contract types, award methods, and variations on DB methods (Molenaar et al. 1999). The results of a survey of 104 completed public-sector projects showed that at the time of the survey, many public agencies had a relatively little experience with DB projects; for 35% of the projects, it was the public agency's first experience with DB. 67% of the projects employed a combination of price and qualifications to select the design-build firm. Most contracts, 88%, were lump sum and 57% were awarded through a competitive process. The rest of the contracts were a negotiated cost plus guaranteed maximum price. DB performed well in cost and schedule as evidenced by the results that showed 59% of the projects were within 2% of the project budget and 77% of the projects were within 2% or better of the established schedule. Quality was defined in three ways, namely conformance to expectations, administrative burden, and owner satisfaction. With the exception of administrative burden, the quality was high with an average score of 4.73 out of 6. The authors believe that the administrative burden may have been high given the agency's lack of experience with DB.

Three variations of DB, one-step, two-step, and qualifications-based, were investigated. One-step DB includes a competitive technical proposal with the award based on technical merit and lowest cost. The two-step DB separates the technical and price proposals; develops a short-list based on the technical proposal; then accepts the price proposals from the short-listed design-builders. The qualifications-based DB is conducted by selecting the design-builders through competitive negotiations. The results from the study found that the two-step process demonstrated the highest level of performance, but that many federal agencies continue to use the one-step approach because of its similarity with DBB.

Characteristics of Successful Projects

Several studies have attempted to define successful project characteristics. (Alkhathami 2004) summarizes several key project success factor studies, which will be described in this section.

(Ashley et al. 1987) developed a comprehensive list of approximately 2,000 factors through interviews with construction project personnel and literature review. The list was reduced to 46 categories and five major areas:

1. Management, Organization, and Communication
2. Scope and Planning
3. Controls
4. Environmental, Economic, Political, and Social
5. Technical

Construction project personnel subjectively rated the 46 success factors and from these ratings, eleven of the factors were chosen for additional investigation:

1. Planning effort
2. Project manger goal commitment
3. Project team motivation and goal orientation
4. Scope and work definition
5. Project manger capability and experience
6. Safety
7. Control systems
8. Design interface management

9. Risk identification and management
10. Technical uncertainty
11. Legal political environment

These eleven factors were used to statistically correlate the factors with project success, which was accomplished by conducting structured interviews with eight companies. The eight companies were asked to select one 'average' project and one 'outstanding' project for comparison. The results were analyzed by calculating percent differences between average and outstanding responses; performing two-sample hypothesis testing to see if the percent differences were statistically significant; and determining if any of the factors had a casual effect on the success of the construction project through correlation analysis. Results were given for the difference between the mean responses. The statistically significant differences between average and outstanding projects for the success factors were:

1. Construction and design planning effort
2. Project manager goal commitment
3. Project team motivation
4. Project manger technical capabilities
5. Scope and work definition
6. Control systems
7. Safety

Additional research on project success factors was done by (Sanvido et al. 1992) who defined success as "…the degree to which project goals and expectations are met. These goals and expectations may include technical, financial, educational, social and professional aspects." The goals and expectations are dependent upon the project participant's viewpoint. A list of typical success criteria from the owner, designer, and contractor viewpoints was developed by the researchers through brainstorming and literature reviews. The researchers were also interested in understanding if the critical project success factors were linked to construction type, building type, and project success perspective. The researchers found four critical factors that determine project success:

1. A well-organized, cohesive facility team to manage, plan, construct, and operate the facility.
2. A series of contracts that allow and encourage the various specialists to behave as a team without conflict of interests and differing goals.
3. Experience in the management, planning, design, construction, and operations of similar facilities.
4. Timely information from the owner, user, designer, contractor, and operator in the planning and design phase of the facility.

(Chua et al. 1999) used analytical hierarchy process (AHP) with subjective expert judgments to identify critical success factors (CSFs). Sixty-seven factors were identified and were grouped into four main areas: project characteristics, contractual arrangements, project participants, and interactive processes. A hierarchical system was developed with three levels – level one was construction project success; level two was budget, schedule, and quality performance; and level three were the four main project aspects previously mentioned. Sub-hierarchies for each of the main project aspects were created. A questionnaire was developed to collect data which was analyzed within the AHP framework. In addition to developing CSFs, the researchers also found

that the experts "…do agree that there are different sets of CSFs for different project objectives (Chua et al. 1999)." Also, it is important to include project characteristics and contractual arrangements to help determine if a project will be successful. The top ten success factors from both (Alkhathami 2004) and (Chua et al. 1999) are shown in Table 3.

Table 3. Critical Success Factors (Derived from (Alkhathami 2004) and (Chua et al. 1999))

Success Factors (1)	Budget (2)	Schedule (3)	Quality (4)	Overall (5)
Adequacy of plan and specifications	1	1	1	1
Constructability	2	2	2	2
Project manager commitment and involvement	8	3	4	3
Realistic obligations and clear objectives	3	6	5	4
Project manger competency	3	6	5	4
Contractual motivation and incentive	5	4	6	4
Site inspection	9	5	10	6
Construction control meetings	-	10	3	7
Formal communication during construction	-	8	7	8
Economic risks	3	-	-	9

Literature Review Summary

While some research has concluded that the hypothesized benefits of DB are questionable, the majority of research has reported that DB is an effective PDM given a project with appropriate characteristics. With respect to the public sector, as the use of DB increases and the owner's experience with DB increases, some of the reported administrative burden should be reduced.

A substantial amount of research exists on project success factors, and a representative sampling was described. An evaluation in (Alkhathami 2004) found the success factors in (Ashley et al. 1987) to be the most inclusive. The successful project characteristics from the studies were logically combined and then compared to features of successful green design projects and the common factors for traditional and green projects were identified.

Conclusion

The original intent of this research examined the relationship between project delivery methods and green design projects in search of common threads between the two to assist the public sector when selecting an appropriate PDM for a green design project. This research is relevant and timely given the recent Memorandum of Understanding between 17 Federal agencies and Executive Office of the President that commits federal leadership to sustainable buildings.

This research was a higher-level, mainly qualitative, analysis which survey about 25 green projects through relatively structured interviews. Further, a literature review was conducted to determine the effectiveness of PDMs and understand project success factors without considering green or sustainable aspects. Through the interview process and published research a series of best practices emerged which in some cases related to a specific PDM, but in other cases were independent of the PDM.

1. The decision to use DB as PDM on green design or other projects should be based on the project's features.

2. Early team collaboration is an important aspect of green design projects, and even more significant in DB project.
3. Not only is the experience of the designer and contractor important, but also the owner's role and experience is critical. This finding is independent of the PDM.
4. Leadership, a dominant success factor in DB projects, is an important feature for all contracting parties involved in green design projects.
5. A well-defined scope of work is important on all projects. DB bridging helps improve quality and the owner's control.
6. Adequate funding and budget for the given scope of work is significant in a green design project. Public funding restrictions may not allow use of certain PDMs, and the nature of public funding streams may make non-traditional PDMs more difficult.
7. Project complexity and flexibility is a project feature that is more specific to green design projects and is more positively associated with DB.
8. Control and accountability is a problem associated with DB more than with DBB. It is not specific to green design projects. DB Bridging can be used to offset the lack of control with traditional DB.

A relationship between DB and green design did not explicitly emerge but several broad features related to PDMs and green design did emerge to assist the owner in making the appropriate PDM decision. Further, when using DB on a green design project, the main recommendations were to use DB bridging with award/incentives fees and performance specifications.

While this research developed best practices though the interview process and literature review, more quantitative data is needed to further investigate the relationship between green design and PDMs. Further, because of the lack of quantitative data, this research focused on the factors of project success; additional quantitative research can also focus on the criteria for success such as budget, schedule, and quality.

Acknowledgements
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Appendix 1. Survey Methodology and Data Collection

In order to determine best practices and the potential synergies between sustainability and PDMs, a strategy was developed to efficiently elicit responses. The first step was to develop a database of contacts. The database was extensive due to the potential difficulty in identifying projects that practiced sustainable design, utilized different PDMs, and were public sector projects. The four main sources that comprised the database were the United States Green Building Council's website (United State Green Building Council 2006), the Design Build Institute of America's (DBIA) website [add references], the Associated General Contractors (AGC), and web searches. The USGBC website lists all certified and registered projects. Only completed projects were included in the database. Contact information was not consistently reported, so additional investigations were made to locate accurate contact information. The DBIA's website lists all DBIA registered projects which used DB as a PDM. All public sector building related projects were extracted and included in the database. The AGC was contacted and subsequently sent an email to applicable members. A list of the interested members was forwarded and included in the database. Finally, web searches were not only used to obtain information on contacts within government agencies, but also to provide additional knowledge on specific projects. For example, if an architect was contacted about Project X, then a web search was done on Project X to determine the owner and contractor so additional information could be obtained. The database, not including web results, includes about 250 contacts.

After the contact database was compiled, the methodology was established, as shown in Table 1. The intent behind the methodology and data collection was to obtain best practices and not rigorous quantitative analysis. Although, quantitative data collection with a survey was attempted, the main focus was to develop a general understanding through interviews of the current state of operations with respect to PDMs and green design.

The initial methodology included a two-step process of data collection. After creating the contact database relatively high-level qualitative questions were developed for telephone interviews. Two sets of questions were developed, one for USGBC's contacts and one for DBIA's contacts. Two difference sets of questions were needed because with the USGBC contact information it was known that the projects were green, but the PDM was not known; conversely, for the DBIA contact information it was known that the project used DB, but it was not know if the project was green. The web searches and AGC's contacts were a combination of the two. The flowcharts of questions are shown in Appendix 2 and Appendix 3. Next, a questionnaire was developed that focused on quantitative aspects, but also asked a question regarding quality. The original questionnaire can be found in Appendix 4.

The phone interviews were to be used to gather the main component of the research and to filter the projects to determine if sending the questionnaire was appropriate. If the project was appropriate, then the questionnaire was sent to the interviewee via the acceptable method of email, fax, or mail. Finally, the interviewee was to return the questionnaire.

For the telephone phone interview process, approximately 75 contacts were called. During the initial phase of the phone interviews, if a contact was available and the phone interview was conducted, often the interviewee either was not interested in the questionnaire portion and indicated that decision during the phone interview or did not return the questionnaire. Therefore,

a second case methodology was created that relied not on phone interviews, but solely on a questionnaire that included questions from the phone interview and quantitative questions from the original questionnaire. The second case questionnaire is located in Appendix 5.

After the interviews were completed, responses were tabulated and evaluated to determine common themes or features, identified in Figure 1. A comparison was made between green building features and successful project characteristics identified in the literature. The established green building project features were examined to establish best practices for green design project and then summarized.

Table 4. Overview of the Methodology and Data Collection Process

Methodology (1)	**Logic (2)**	**Steps (3)**
Initial	Collect qualitative information during phone interviews. Collect quantitative information in questionnaire.	7. Develop contact database 8. Develop phone interview questions 9. Develop questionnaire 10. Call contacts to conduct phone interview 11. Send questionnaire 12. Receive questionnaire responses
Revised	Collect quantitative and qualitative information in questionnaire.	5. Develop contact database 6. Develop revised questionnaire 7. Email questionnaire 8. Receive questionnaire responses

In total, 88 individuals were contacted either via phone or email, and 21 interviews were conducted. During the 21 interviews, several individuals discussed more than one project, so 26 projects are included in the study. The response rate is 24% on an actual interview basis, and 30% on a project basis. The individuals contacted were owners, contractors, and designers; however, owners represent about one-half of the respondents as indicated in Figure 2. In terms of PDMs, DB projects were about one-half, DBB about one-third, with the remainder being CM and Other as shown in Figure 3. The Other category included fast-tracking and a federal employee who did not discuss a specific project. Variations of DB and CM were used and these variations will be discussed in subsequent sections. Of the responses, 6 completed the questionnaire; 1 the initial survey and 5 the revised survey. Since only a small number of questionnaires were completed, the results are not reported. Detailed information for each of the interviews is summarized and when available, project information is provided. Analysis of the responses is given in the Best Practices section.

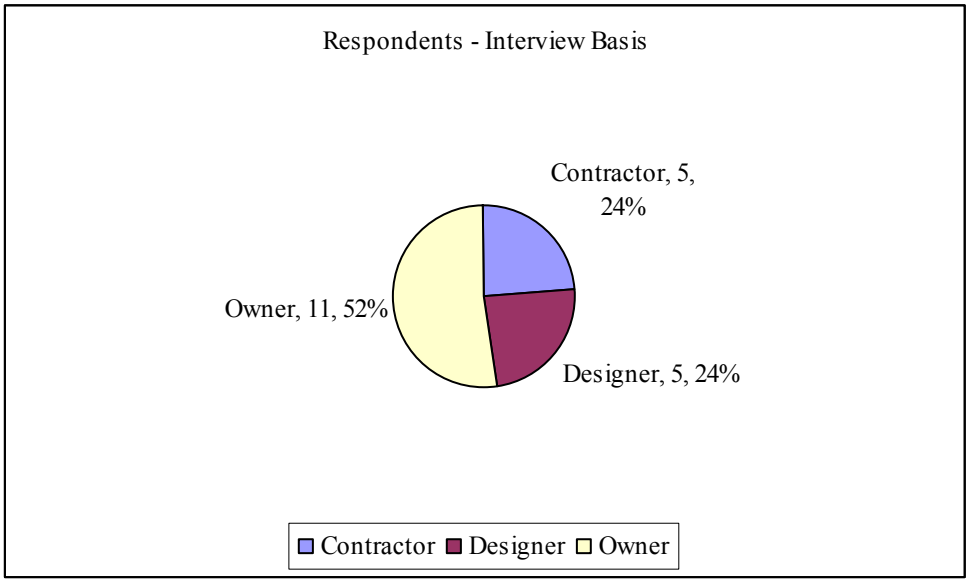


Figure 2. Number and Percentage of Respondents by Role in the Project Team

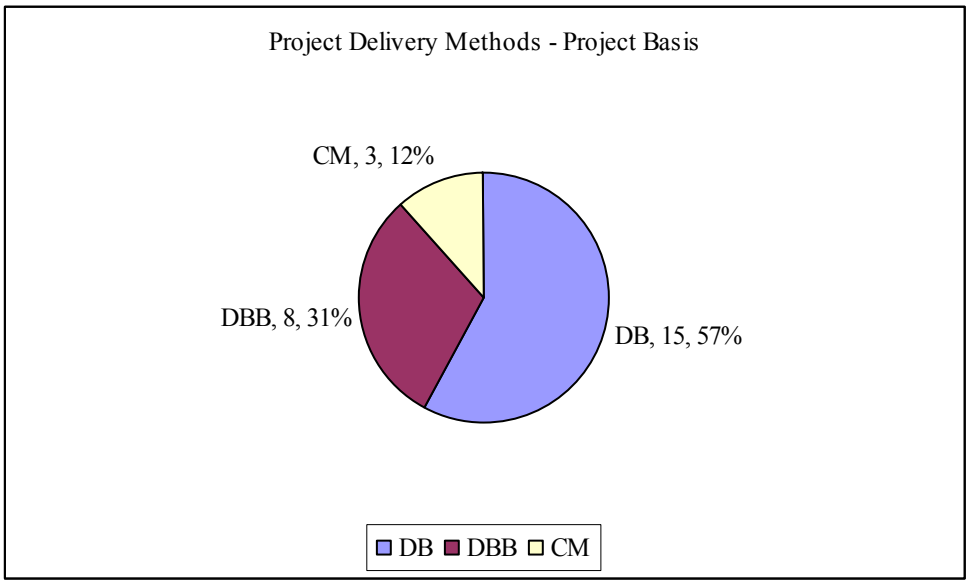
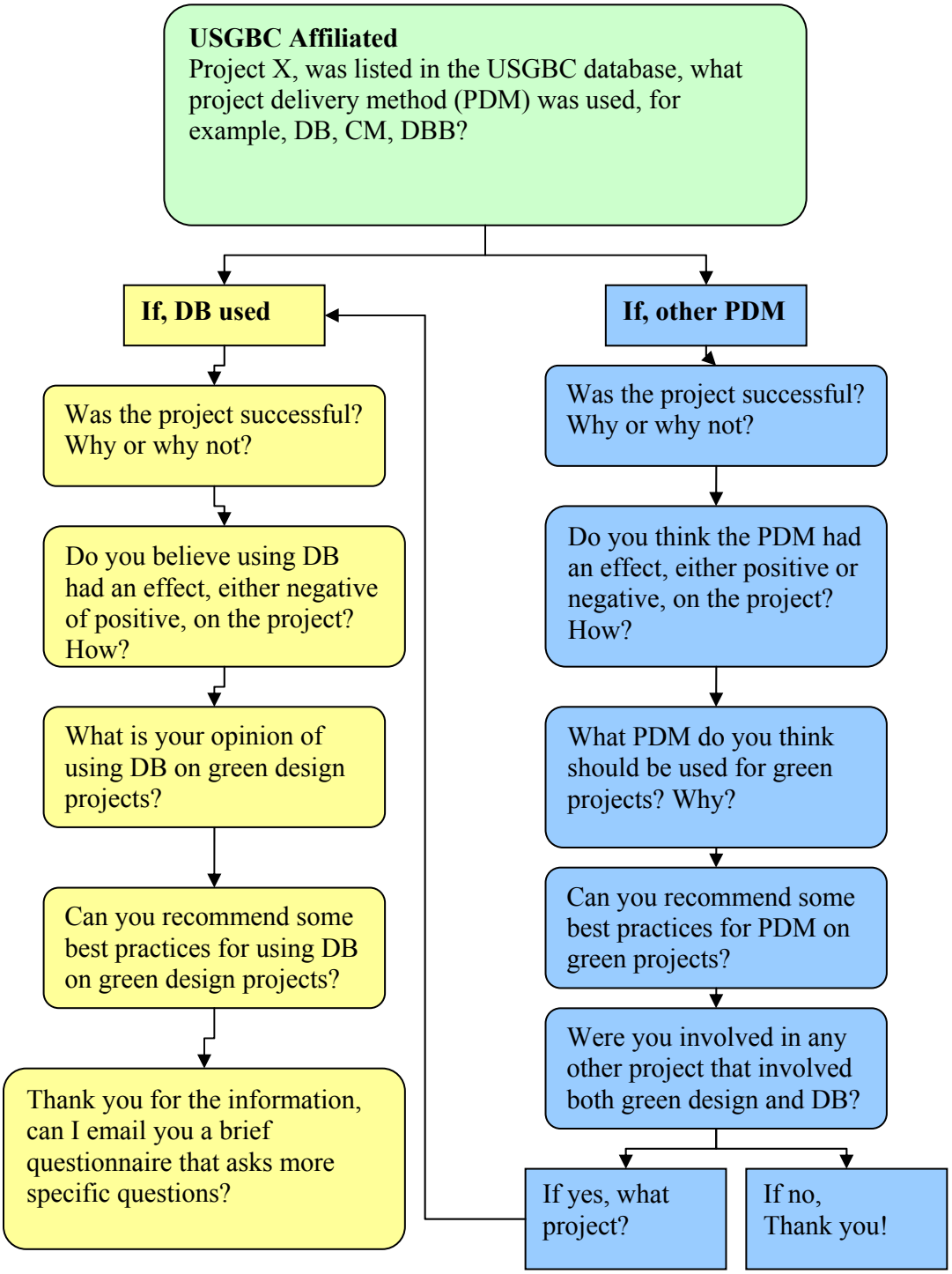
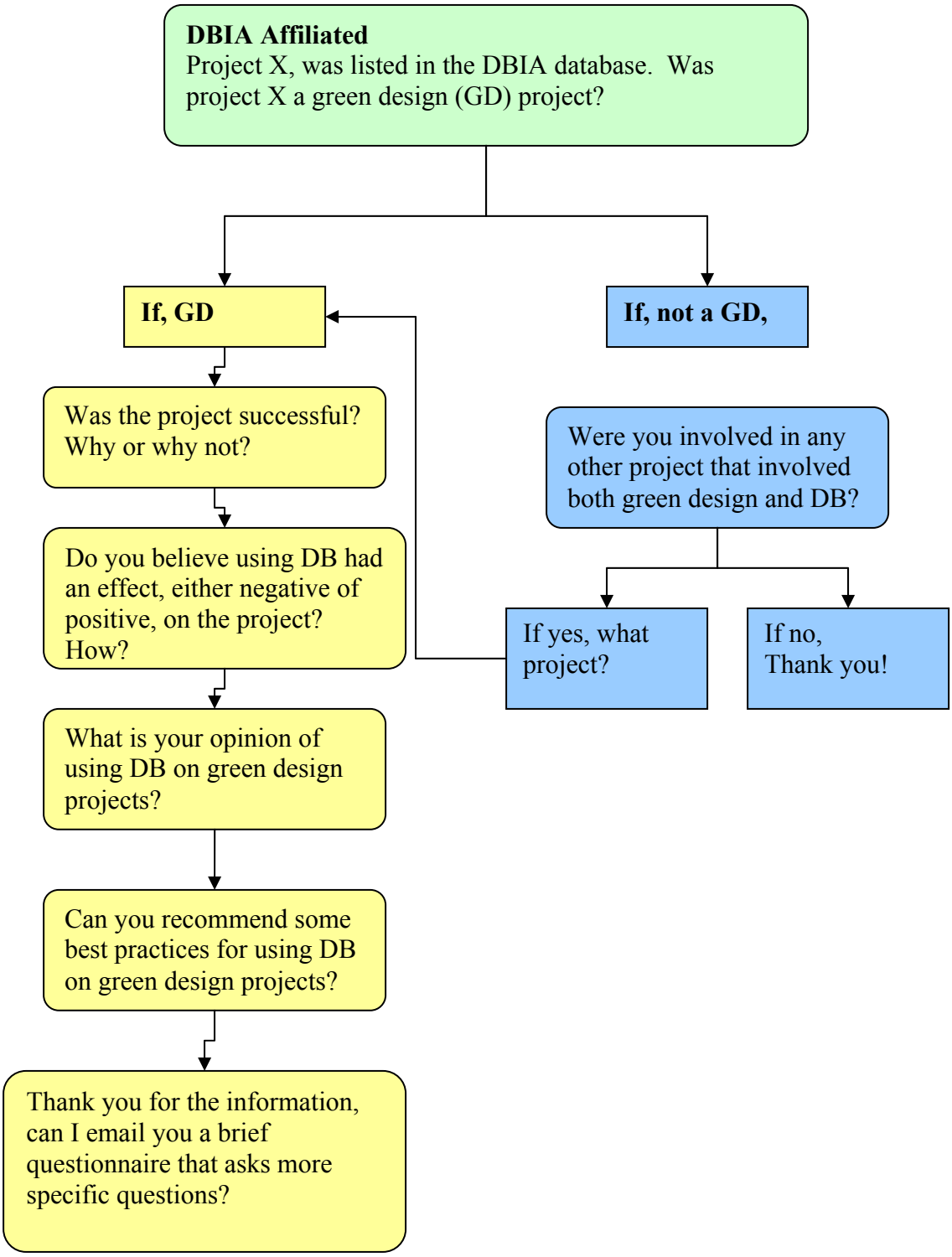


Figure 3. Number and Percentage of Responses by Project Delivery Method

Appendix 2. USGBC Phone Interview Questions



Appendix 3. DBIA Phone Interview Questions



Appendix 4. Original Questionnaire

Robert J. Ries, Ph.D., R.A.
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949 Benedum Hall
3700 O'Hara Street
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(412) 648-3255
Fax: (412) 624-0135
http://www.engr.pitt.edu/civil

Subject: Green Design and Project Delivery Systems

Dear Mr. Penson:

Thank you participating in the phone interview for our research into green design and project delivery systems. As a follow-up to our conversation, we are forwarding to you a questionnaire. Your input via the structured phone interview assisted in identifying industry's best practices and recommendations, a subjective component of this research. As the next step, the following questionnaire, will help us better quantify the relationship between project delivery methods and green design projects.

Project Scope and Hypothesis:
This project investigates owner, contractor, and design professional viewpoints relating the relative success of implementing sustainable design with various possible project delivery methods (e.g., design-build (DB) and design-bid-build (DBB). The study examines the hypothesis that design-build, by nature an integrated, team-based collaborative design and construction process, may be more conducive to sustainable design than other delivery processes. As there are strengths and weaknesses with project delivery systems in the context of sustainable design projects, identifying and documenting best practices will assist project teams with implementing green design projects.

Submittal Information:
The attached questionnaire can be filled out electronically or printed and filled out manually. If you are completing the form electronically, please simply type the information in the appropriate boxes and click on the shaded boxes as appropriate. Should you have any questions, please contact Melissa Bilec at 412.648.3255, or via email at mmp23@pitt.edu.

Please return the questionnaire by one of the following methods:
(1) Return via email to mmp23@pitt.edu or robries@pitt.edu
(2) Return via fax, attention Robert Ries, at 412.624.0135
(3) Return via mail to the above address, attention Robert Ries.

Thank you in advance for participating in our research.

Sincerely,

Robert J. Ries, Ph.D., R.A.
Melissa Bilec, Doctoral Candidate

Project Information

Please check applicable box for your stake in the project in question:

☐	Owner
☐	Design Professional
☐	Contractor
☐	Other:

Please fill in the following information:

Project Name:	
Project Type: (Commercial, Residential, etc.)	
Year Completed:	
Square Feet:	
Green Construction/Sustainable Design?	☐ Yes ☐ No

Please check project delivery method of above project:

☐	Design-Bid-Build
☐	Design-Build
☐	Construction Management
☐	Other:

Please select contract type of above project:

☐	Lump Sum
☐	Unit Price
☐	Cost Plus Percentage
☐	Cost Plus Fixed Fee
☐	Guaranteed Maximum Price
☐	Other:

COST

Original Budget Cost:	
Final Construction Cost:	
Change orders as a total dollar amount or percentage of final construction cost:	
Main reasons for change orders, if any (may select more than one)	
☐ Design Error/Omission	
☐ Owner Request	
☐ Contractor Generated	
☐ Unforeseen Condition	
☐ Other:	

SCHEDULE

Original Scheduled Completion (in date or duration):	
Final Completion (in date or duration):	
Main reasons for delays, if any (may select more than one)	
☐ Weather	
☐ Design/Scope Changes	
☐ Unforeseen Condition	
☐ Coordination Delays	
☐ Other:	

QUALITY

In your opinion, do you believe that the project delivery method contributed positively or negatively to the *quality* of the project?
☐ Positively
☐ Negatively

Appendix 5. Second Case Questionnaire

Robert J. Ries, Ph.D., R.A.
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http://www.engr.pitt.edu/civil

Subject: Green Design and Project Delivery Systems

Dear Participant:

Our research team from the University of Pittsburgh's Department of Civil and Environmental Engineering is investigating the relationship between the owner, contractor, and design professional viewpoints relating the relative success of implementing sustainable design with various possible project delivery methods (e.g., design-build (DB) and design-bid-build (DBB)). The study examines the hypothesis that design-build, by nature an integrated, team-based collaborative design and construction process may be more conducive to sustainable design than other delivery processes. As there are strengths and weaknesses with project delivery systems in the context of sustainable design projects, identifying and documenting best practices will assist project teams with implementing green design projects.

Your associated project was mainly obtained from the United States Green Building Council's website. After this introductory letter, you will find a brief questionnaire. Your participation and completion of the questionnaire will assist us by collecting both quantitative and qualitative data.

Submittal Information:
The questionnaire can be filled out electronically or printed and filled out manually. If you are completing the form electronically, please simply type the information in the appropriate boxes and click on the shaded boxes as appropriate. Should you have any questions, please contact Melissa Bilec at 412.648.3255, or via email at mmp23@pitt.edu.

Please return the questionnaire by one of the following methods:

(4) Return via email to mmp23@pitt.edu or robries@pitt.edu
(5) Return via fax, attention Robert Ries, at 412.624.0135
(6) Return via mail to the above address, attention Robert Ries.

Thank you in advance for participating in our research.

Sincerely,

Robert J. Ries, Ph.D., R.A.
Melissa Bilec, Doctoral Candidate

Project Information

Please check applicable box for your stake in the project in question:

☐	Owner
☐	Design Professional
☐	Contractor
☐	Other:

Please fill in the following information:

Project Name:	
Project Type: (Commercial, Residential, etc.)	
Year Completed:	
Square Feet:	
Green Construction/Sustainable Design?	☐ Yes ☐ No

Please check project delivery method of above project:

☐	Design-Bid-Build
☐	Design-Build
☐	Construction Management
☐	Other:

Please select contract type of above project:

☐	Lump Sum
☐	Unit Price
☐	Cost Plus Percentage
☐	Cost Plus Fixed Fee
☐	Guaranteed Maximum Price
☐	Other:

COST

Original Budget Cost:	
Final Construction Cost:	
Change orders as a total dollar amount or percentage of final construction cost:	
Main reasons for change orders, if any (may select more than one)	
☐ Design Error/Omission	
☐ Owner Request	
☐ Contractor Generated	
☐ Unforeseen Condition	
☐ Other:	

SCHEDULE

Original Scheduled Completion (in date or duration):	
Final Completion (in date or duration):	
Main reasons for delays, if any (may select more than one)	
☐ Weather	
☐ Design/Scope Changes	
☐ Unforeseen Condition	
☐ Coordination Delays	
☐ Other:	

QUALITY

In your opinion, do you believe that the project delivery method contributed positively or negatively to the *quality* of the project?
☐ Positively
☐ Negatively

PROJECT DELIVERY METHOD

In your opinion, do you believe that the project delivery method contributed positively or negatively to the *overall* project?
☐ Positively
☐ Negatively

GREEN DESIGN

What is your opinion of green design projects implemented through the design-build delivery system?

Can you recommend some *best practices* for a green design project with respect to the project delivery method? *(For example, design-build bridging contributes to project success.)*