Delivering Public Private Infrastructure Projects Using Integrated Project Delivery and Trending Technology

Barry Jones and Paul Weber

***Abstract*—The paper will discuss the common criteria between IPD and P3's that assist to create an integrating partnership for maximizing design and construction value when developing a healthy built environment. BIM and IPD form essential tools and strategies in this decision environment. IPD linked to the "Big Room" concept will be discussed. In particular, the system proposed will assist the design process to fully analyze criteria and constraints in a collaborative team environment resulting in more sustainable buildings and structures. Some key criteria of the final solution is to provide a design and construction methods that result in a healthy built environment using materials and building methods that are economic and sustainable.**

***Index Terms*—Integrated Project Delivery (IPD), Computer Integrated Construction (CIC), public private partnerships, collaborative engineering, intelligent agents, BIM, virtual design and construction.**

I. Introduction

The research method was conducted through interviews, and monitoring IPD projects in California and determining how this delivery process could be applied to PPP's then reviewing reports on the success or failure of past PPP strategies.

The research (first phase) built on earlier work that measured the processes and interactions that Architects, Engineers and Construction Managers (AEC) use when making key project decisions [1]. In that study research data was collected from 54 companies in the USA and 39 in the United Kingdom. Scenarios of typical design and production problems were used to measure the differences in making key decisions in the traditional method of project delivery (design-bid-build) compared to a system where there was a high incidence of collaborative decision making; such as Design-Build. Results were compared between the three participating groups (AEC) so that the consensus view could be obtained.

The second phase of this investigation measures the current state of AEC collaboration that is in progress on various projects in California through IPD strategies.

The third ongoing stage is to determine whether large infrastructure projects using PPP or PFI strategies might benefit from using IPD.

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II. Integrated Project Delivery (IPD)

IPD is a contract delivery system that helps create an integrating partnership for decision making at design and pre-construction stages through to the final project handover to the facility management team [2] defines IPD as the framework that defines the relationships among the project participants and the processes that guide their actions. It embodies the project goals and creates consequences for success or failure tied to their achievement. It puts control in the hands of the project participants and makes them responsible for total project outcome, not just their individual performance. Correctly designed, it stimulates behaviors that increase creativity, improve productivity, and reduce waste. A strong IPD Framework leads to better outcomes, whether measured in value, aesthetics, and sustainability or other project criteria.

III. Virtual Design and Construction (VDC) and Building Information Modelling (BIM)

VDC is a process that integrates the design and construction professionals into a collaborating team that build a BIM model of the project using 3D, 4D(cost), 5D(time), 6D (carbon footprint) CAD visualization. A virtual object is created before construction starts so that much of the criteria and constraints associated with the project under design are analyzed at an early stages of project development. As such, it serves as a shared knowledge resource for information about a facility thereby forming a reliable basis for decisions during its lifecycle from project inception onwards. For best results it is essential that VDC are implemented from the beginning of a construction project in order to increase the quality of the object, the organization, and the process, during the building life cycle [3]. In particular, the criteria and constraints of the various contributors need to be articulated and discussed as the model builds. For the approach to work effectively it is essential to include the experience of construction managers and specialist sub-contractors to maximize project benefits from the execution experience.

Software applications increasingly offer cloud-based solutions for design and construction collaboration. From conceptual design through commissioning teams increasingly have access to BIM models using cloud-based applications using varying devices (computers, tablets and smart phones) rather than using heavier and high-priced computer software used to create the model. Autodesk's BIM 360 Suite (BIM 360 Team, BIM 360 Docs, BIM 360 Glue, BIM 360 Layout, BIM 360 Plan, BIM 360 Field, BIM 360 Ops) offers cloud based project management application for real-time viewing,

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sharing, and markup in more than fifty 2d and 3d design file formats (including AutoCAD, Revit, and Navisworks) that can even be viewed on mobile devices. The BIM 360 Layout iPad app can connect with a total station.

After BIM models, drawings and specifications are converted to pdfs, a number of software allow cloud-based team collaboration. Bluebeam software offers Bluebeam Studio sessions that allow architects, engineers and contractors real-time collaboration tools for pdfs. Electronic annotations, and tracking these annotations, counts and measurements in pdfs, OCR features for hyper linking symbols to details and sheets in a pdf, and linking measurement total to Excel are some of the tools used in Bluebeam Extreme.

IV. VDC Used in the IPD Environment

It was found that using VDC in an Integrated Project Delivery (IPD) environment becomes the key to effective project delivery with the IPD team offering a solution-oriented approach. At a very early stage (project development, pre-draft phase) the entire planning (design) is carried out by a team that involves not only an architect and a structural engineer, but also specialists in the areas of construction management, MEP engineering, energy technology, environmental engineers, building physics, acoustics, façade construction and depending on the type of project further specialists. This work method leads to a collaborative, integrated and transparent construction process. All communication goes back to the central model. The model is shared among all project team members and it serves as a common, rich database where all information is structured managed and maintained. Therefore, the amount of redundant data is reduced and repetitive data that already resides in the model can be used by all participants. It also acts as an excellent team building tool. A shared, visual model to externalize and share project issues is a valuable team-building tool. This rich data model on the completion of the project can be handed over to the Facilities Management team who provides the experience for operating and ensuring economic building performance.

Research indicated that the "Big Room" concept can be used to facilitate the process, where all the key project participants, including the client, collaboratively work in the same room to define the methods, schedule, quality, performance and cost goals for the project. They then evaluate how to satisfy these goals often using 'lean' construction techniques. Multi-domain intelligent computer agents could be used here to search for alternative solutions [4]. For instance a goal might be use of local material resources by assessing the opportunities presented by the site itself, and selecting materials that are minimal polluters, sustainable and recyclable, etc. or the sustainability aspects can be analyzed with the goal to eliminate, reduce and change the use of materials and components that increase environmental inefficiencies. Similarly, the cost and time to build aspects are driven down by the collaborative team through many iterations of considering alternative materials, methods, layouts, component analysis, etc. Next, the functional requirements of the structure are reviewed to see if it is possible to reduce the demand from that standpoint, i.e. efficient envelope design, solar and efficient lighting, construction systems required to build, energy requirements, life-cycle maintenance costs, air quality health impact, design for safety, etc.

Within the "Big Room" collaborative design environment it can be supported by responsive decision analysis support tools such as intelligent search computer agents as discussed next that are used to refine the design by searching out suitable alternatives that add value to the project while satisfying the many criteria and constraints. The resulting design will bear a high degree of confidence that in regard to material and component efficiencies, sustainability, cost and time to build, it will achieve its objectives. Throughout the process, and during future use of the structure, continuous efforts will be made to reduce waste, improve health, use economical recycled and environmentally benign materials, and reduce the generation of pollutants.

V. Intelligent Computer Search Agents

Earlier research [5] found that the advances in the concept of an object as a high-level information source led to the paradigm of object-oriented modeling and the development of object-oriented computer languages. The premise is that a crucial element in the decision making process that human designers utilize to solve problems is the reliance they place on their ability to identify, understand and manipulate objects, e.g. architects develop solutions by reasoning about location, sites, buildings, floors, spaces, walls, windows, doors, and so on; the contractor does likewise. Each of these objects encapsulate knowledge about its own nature, its relationships with other objects, its behavior within a given environment, what it requires to meet its own performance objectives and how it might be manipulated by the designer within a given design problem scenario.

Within the computer agent environment proposed, problem solving is seen as a co-operative process with mutual sharing of information to produce a solution. Objects are information entities only whereas computer agents are active and have knowledge of their own nature, needs and global goals. Objects are accessible by agents but cannot take action. Within the computer environment agents also have the ability to communicate and take action. Typically, each agent is represented at the level of detail to which the collaborative team wishes to reason about the designed system in the building project. A coordinator should be capable of invoking a procedure for resolving conflict conditions based on consultation. The agents use their specialized expertise and available resources to work in parallel on different or coordinating tasks to arrive at a solution concurrently. They assist in searching out alternative solutions.

Complete families of computer-agents that represent a particular domain can be built e.g. architect, interior designer, civil engineer, landscape architect, safety manager, quality manager, environmental manager, mechanical and electrical engineer, construction manager, project manager, etc. and within each family specific agents would monitor and offer assistance regarding criteria and constraints imposed in the areas of environmental, quality, safety, cost, production time, etc. For instance there could be a 'Sustainability' agent residing in a number of domains i.e. Architect, Construction manager, Project Manager, Quality manager, each would be representing the criteria and constraints of that domain. It must be stressed that this design assistance using computer agent is not intended to automate the design process. Agents would assist the designer or collaborative partnership by acting as co-operative search agents having the ability to liaise with knowledge bases in the search for alternative solutions. They exist to express opinions about the current state of the construction solution. The intention is to change incrementally the current state of the design through the interaction among the various agents within the environment. This interaction enriches the environment with information about the current design state and how it relates to the design requirements. Each agent would provide two kinds of support; intermittent foreground responsiveness to requests for information initiated directly by the designer, and continuous background monitoring and evaluation of the evolving design solution.

VI. Public Finance Initiatives (PFI'S) and Public Private Partnerships (PPP's)

PFI's are a method of providing funds for major capital investments where private firms are contracted to complete and manage public projects. It is as a legally binding contract between a public sector entity and a private company where the partners agree to share some portion of the risks and rewards inherent in an infrastructure project. It is a long term contract between government entities, private investors, construction firms, and asset and operations managers. The project is delivered by a consortium and the risks involved are transferred to the party most qualified to manage it. Thoughtful allocation of project rewards and risks are the basis of a successful PPP [6] states that political dysfunction, a challenging fiscal environment, greater project complexity, and the sheer size of the need across different sectors are forcing leaders to explore new ways to finance the investments and operations that will grow their economies over the next decade. Part of this exploration means new kinds of agreements between governments at all levels and the private sector to deliver, finance, and maintain a range of projects. In particular, PPPs for infrastructure are complicated; they require robust economic analysis, complex negotiations, intense public scrutiny, long-term commitments, political leadership, and force public sector employees and policymakers to hone a relatively new skill set.

In the most advanced PPP markets, such as the United Kingdom, this risk and reward sharing structure more narrowly refers to agreements where the private sector designs, builds, finances, operates, and maintains (also known as DBFOM) an infrastructure asset for a pre-determined period of time. In exchange, the public sector provides a recurring payment based on the condition of the asset (known as an availability payment) or allows the private sector to collect tolls or fees generated from the project.

Four arrangements are recognized (i) Bid/Build; (ii) Design/Build; (iii) Design/Build/Finance; (iv) Design/ Build/ Finance/ Operate/ Maintain. Public and private sector collaboration from the outset of an infrastructure project, whether green-field or brown-field, can lead to a number of innovations. These may come in the form of new materials, faster project delivery, increased use of technology, operational efficiencies, or enhanced building techniques. One major advantage of the private sector is that it is often less tolerant of cost overruns and project delays than the public sector. Therefore, transferring construction, operational, and/or demand risk to the private sector can result in quantifiable savings for the public sector. These might not be the cheapest options in the short term, but have the potential to drive savings over the long term through decreased energy usage, lower maintenance costs, or enhanced resiliency

The U.S. Department of Transportation, as well as international leaders like Her Majesty's Treasury in the United Kingdom, recommends using a VFM (also referred to as a public sector comparator) analysis to econometrically evaluate the true costs and benefits of a PPP project. Private consultants or financially savvy internal review teams are capable of running these types of models, which can incorporate a number of different scenarios. Importantly, VFM analysis is predicated on quantifiable inputs and outputs in the project. These considerations often look at the cost of capital, demand projections, tax implications, social gains, risk transfer pricing, environmental externalities, and a range of other factors. Using a VFM, policymakers can start making informed decisions about entering into a PPP by comparing the costs and risks associated with different proposals and procurement models. It is so important to map out the full process before moving a project forward.

In the United Nations report ESCAP "A New Vision of PPPs in Asia Pacific" [7] it stated that above all, infrastructure bottlenecks have still prevented many countries from realizing their full potential, and are major obstacles to development and achieving real social equity. But for more than three decades, PPP's have mostly proven, that they can be effective tools to complement the efforts of Asia-Pacific governments in developing infrastructure and providing related services.

VII. PFI's/PPP's Facilatated Through IPD

Assembling a group with the right mix of finance, technical, managerial, legal, policy, and communications knowledge and experience is critical to the success of any PPP project. In the research this was found to be similar to the requirement of a successful IPD projects. In both cases creating this environment requires transparency, collaborative engagement strategies, and some form of profit and risk sharing linked to project success. Therefore PPPs and IPD share many of the benefits and are complementary to each other. Collaboration, teamwork, focus on delivering to time and budget, overall quality and performance, risk sharing built to profit all operating in a transparent system are the requirements of both.

VIII. Conclusions

The environment proposed from the first phase of research [1] is one that fully utilizes the strengths of intelligent collaborative computer agents that interact with the multi-discipline pre-construction team to interrogate and refine the design solution before construction commences. In the second phase of this research using families of domain specific intelligent agents linked to Virtual Design and Construction tools allows alternative design and construction solutions to be rapidly generated. Linking this model to IPD operating in the "Big Room" opens up new ways of exploring client solutions that satisfy the many criteria and constraints that are sought by the key stakeholders of the project. Further, the integrated model based approach will positively impact construction in the 21st century. Many positive experiences and case studies are beginning to exist and many of these new collaborative practices are becoming standard for some clients. . In this way a collaborative team has the tools and information to interrogate and solve many of the cost, constructability, time, quality, sustainability, environmental, safety, etc. issues before construction commences, and continue that monitoring throughout the construction process. Also, at the end of the project all captured information can be organized and passed to the facility operations team.

In the third ongoing phase of this research linking IPD to deliver PPP projects was found to be a two-way complementary model that benefit each other; similar issues exist to be resolved in both systems. Faster delivery times, increased certainty and accountability for the operational condition of the asset, process transparency, increased value, engagement of key stakeholders, diminished downside financial risk, budgetary certainty over a long period of time, lower lifecycle costs, and the use of innovative materials or technologies are all achievable through a well-structured PPP linked to IPD.

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