Multi-Tiered Selection of Project Delivery Systems for Capital Projects

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ABSTRACT

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In this thesis, a decision support system (DSS) for selecting the most suitable project delivery systems (PDSs) for capital projects is proposed. Project delivery systems continue to evolve, to meet challenging project objectives. Selecting a PDS is an early project decision, which can greatly affect the project execution process and its outcomes. The proposed DSS encompasses a multi-tiered process; designed on the basis of an in-depth analysis of 15 case studies of projects constructed in the USA and 207 projects in Canada which utilized public-private partnership delivery methods. The selection criteria were developed utilizing related literature and the findings of the analysis of the case studies. The developed system operates in two distinct modes; elimination, first, to narrow the search field, and ranking, second, to find the most suitable delivery method. In the first mode, the suitability of public-private partnership (PPP) is identified and a number of PDSs are eliminated based on a set of key project characteristics. In the second mode, evaluation and ranking of the remaining PDSs are performed using multi-attributed decision method (MADM). The MADM model utilizes relative effectiveness values (REV) of PDS's in the evaluation process. These values build upon those developed by CII (2003) to account for PDSs and selection factors beyond those considered in the CII study. The proposed DSS is intended for decision makers of owner organizations, and their consultants. It incorporates knowledge about PDSs and their suitability in meeting a set of targeted project objectives. The decision maker provides project-specific inputs including project information and judgments regarding the importance of specific evaluation and selection criteria. An automated software tool was developed to facilitate the use of the proposed DSS. Three case projects were analyzed using the proposed DSS, including one private sector project and two public sector projects. Two of these cases where also analyzed in the CII study. The results obtained by the proposed DSS were identical to those of the CII study, under the same criteria and the same set of alternative DSSs. The two cases were further analyzed to consider the expanded set of PDSs and the developed criteria. In the latter case, the results revealed a more suitable PDS method. This also applies to the third case. In two of the three cases, the selected PDS was recently developed and known as an integrated project delivery (IPD). The developed method, aside from expanding upon the CII study in the criteria and in the number of PDSs, introduces and makes available newly developed PDSs including IPD and the family of PPPs. The developed method is expected to be useful to owners of capital and public projects.

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NOMENCLATURE:

A/E	architecture and engineering, architect and/or engineer
ADM	Aéroports de Montréal
AGC	Associated General Contractors of America
AHP	analytical hierarchy process
AIA	American Institute of Architects
ANP	analytical network process
APPA	APPA - Leadership in Educational Facilities (formerly Association of Physical Plant Administrators)
BIM	building information modeling
BF	build-finance
BFM	build-finance-maintain
BOO	build-own-operate
BOOT	build-own-operate-transfer
CM	construction manager
CMA	construction management agency
CMc	construction manager constructor
CMR, CM@R	construction management at-risk
COAA	Construction Owner's Association of America
C.R.	Consistency ratio
DB	design-build

DBB	design-bid-build
DBE	disadvantaged business enterprise
DBF	design-build-finance
DBFM	design-build-finance-maintain
DBFMO	design-build-finance-maintain-operate
DBFMOO	design-build-finance-maintain-own-operate
DBFO	design-build-finance-operate
DBFR	design-build-finance-rehabilitate
DBMO	design-build-maintain-operate
DBO	design-build-operate
DBOO	design-build-own-operate
DNB	design-negotiate-build
DSS	decision support system
ECI	early contractor involvement
EMP	estimated maximum price
EPA	Environmental Protection Agency
EPC	engineering procurement construction
EPCM	engineering procurement construction management
FDBOMSD	finance-design-build-operate-maintain service delivery
FDOT	Florida Department of Transpiration
FM	facilities management
FTA	Federal Transit Administration (part of U.S. Department of Transportation)

GC	general contractor
GMP	guaranteed maximum price
GSA	General Services Administration (part of U.S Federal Government)
IDBB	integrated design-bid-build
IDc	integrated design construct
IPD	integrated project delivery
IT/ICT	information technology/information communication technology
LDO&PPA	lease-develop-operate and power purchase agreement
LOA	letter of authorization
MADM	multi-attributed decision method
MAUT	multi-attribute utility theory
MCA	multi-criteria analysis
MO	maintain-operate
NASFA	National Association of State Facilities Administrators
NTP	notice to proceed
OB	owner build
ODC	owner's design consultant
P3, PPP	public private partnership
PBS	Public Building Service
PDCS	project delivery and contract strategy
PDS	project delivery system
PFI	public finance initiative (a U.K term for DBFM or DBFMO)
PMA	project manager agent

PSC	public sector comparator
QA/QC	quality assurance/quality control
QBS	qualifications-based selection
RFQ	request for qualifications
RFP	request for proposals
SPE	single purpose entity
TBD	to be determined
USACE	United States Army Corps of Engineers
USAF	United States Air Force
VFM	Value for money

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1 CHAPTER ONE: INTRODUCTION

1.1 Delivery of Capital Projects

Delivery of capital projects includes planning, funding, design, construction, commissioning, operation, maintenance and de-commissioning. The owner initiates a project, having established a need or having identified an opportunity to create value through a capital project. The owner engages other parties to take specific roles and responsibilities to deliver the project, and the relationships between the parties are defined through contracts. Project delivery system (PDS) represents arrangements of roles and responsibilities among the project participants, including the timing of major participant involvement and of major events in project delivery. The responsibilities that the owner assigns to other parties are most often design and construction, but they may also include financing, maintenance, operations, and ownership. The concepts related to project delivery are principles of contractor selection, contract types and compensation methods.

A number of project delivery systems have evolved over time. The three most widely known categories are Design-Bid-Build (DBB), Construction Management at Risk (CMR) and Design-Build (DB). According to Primer in Project Delivery 2nd Edition, a joint publication of the American Institute of Architects and Associated General Contractors of America (2011), these three along with Integrated Project Delivery (IPD), which has evolved more recently, are the only distinct project delivery systems, whereas many other subcategories exist. The construction industry has been striving to improve project delivery. Negative project outcomes, including poor performance and claims, have been associated with poor management (Forbes and Syed, 2010), which includes the application of project delivery systems. Improvements are based on experience and also by learning from other industries.

How important is PDS selection? Disastrous project outcomes are never the result of a PDS itself, but a PDS may represent a potential for success or a potential for problems, in specific project circumstances. If an unsuitable PDS is selected, it is more challenging for the project team to meet the project goals of cost time and quality. The adverse effects could also include a higher than expected demand on owner's staff, misalignment between owner expectations, contract documents and the completed project, high lifecycle costs, or the need for further interventions after the project is completed. If a suboptimal PDS is selected, the team may miss opportunities to achieve the best value. The greater the project size, complexity, and level of risk, the more important the suitability of PDS for the project. According to Touran et al. (2009b), for transit projects, "selecting the wrong project delivery method is often a significant driver of project failure."

PDS selection does not always require a decision support system (DSS). The owner may regard the decision as relatively straightforward, without the need to expand time and effort towards applying a structured process. This is usually the case for small and simple projects, or if a project bares similarity to a previously positive experience. A decision support system for PDS selection can be of greatest benefit in the following situations:

1. Decision is complex; multiple factors are at play with opposing tendencies.
2. Decision maker is a committee, a board or similar group.
3. Decision maker is accountable to a constituency such as the general public, an overseeing committee or to management and every decision must be substantiated and the decision process documented.
4. Decision maker prefers to use a highly systematic process.
5. Decision maker is interested in trying less familiar PDSs and would like to evaluate its suitability for the project.

The following factors contribute to the importance of a rational and structured decision making process:

- project size, primarily in terms of cost
- public awareness of the project and its importance
- project's perceived and anticipated impact on the local, regional or larger economy
- need for transparency in decision making and in handling public finds
- stakeholders in the community are affected

More than one PDS may be most suitable for the project, but it is important to establish this through a rational evaluation process, based on knowledge. In some cases, it may be appropriate or necessary to change from one PDS to another during the project planning stages. For example, in CMR delivery system, if the owner wishes a fixed price contract, but it is not possible for the owner and CM to agree on the guaranteed maximum price (GMP), the owner has the option to pay the CM for his pre-conduction services and bid the project competitively, thus switching to DBB delivery system (Minchin, Thakkar and Ellis, 2007). Within the public-private partnership category, the owner may issue a request for expression of interest (RFEI) for one delivery method, but subsequently chose another method, as was the case with Hotel-Dieu Hospital in Quebec City. Ballard, Cho, Kim and Azari, (2012) promote the idea that project delivery systems should themselves be designed rather than selected from a list of available choices, to suit the unique characteristics of project and owner. They suggest that 'slow, simple and certain,' projects may not justify the costs of designing, non-traditional delivery methods.

1.1.1 Motivation for the study

The motivation for this research is to facilitate the selection of the most suitable PDS for a project. A considerable body of knowledge and decision tools already exist in this area. However, very few PDS selection methods have been used in practice (Ng and Cheung, 2007, Ibbs and Chih, 2011). Ng and Cheung (2007) suggest that decision-makers are generally reluctant to employ tedious computational models and to rely on such models. Moreover, a number of PDSs have been introduced recently and applied to a set of capital projects and institutional facilities beyond those considered in existing decision support systems. In view of the complexity of the selection, this research aims at circumventing the limitations of previous work, and the inability of the previously developed decision support systems to appropriately consider the full range of available PDSs. The intention is to expand on prior work, by incorporating recently developed PDSs such as Integrated Project Delivery (IPD) and various models of Public-Private Partnership (PPP) as available alternatives within one decision support system, and by improving the applicability of the system.

1.2 Scope and Objectives

The primary objective of this thesis is to study various project delivery systems and the factors that determine the suitability of each PDS to specific project conditions, and develop a decision support system (DSS) which ranks the available PDS alternatives in order of suitability. The sub-objectives of the study are:

1) Understand the nature of a PDS selection decision.
2) Identify the project delivery systems being used and understand the characteristics of each.
3) Identify and understand the factors, or criteria for PDS selection.
4) Evaluate methods for multi-criteria analysis, including methods of weighing selection criteria and propose a suitable method.
5) Examine how well various PDSs satisfy specific selection criteria, i.e. determine preliminary relative effectiveness values (REV) of each PDS with respect to each criterion.
6) Implement the developed DSS in a computer application.
7) Analyze case studies by applying the proposed DSS and compare the results with the results of previously developed methods of PDS selection to test the proposed DSS.

8) The envisaged DSS should be adaptable to future developments and allows user customization.

1.3 Research Methodology

The methodology of this research is essentially based on an in-depth review of case studies and a literature review, along with an automated method developed by the CII for selection of PDSs for capital projects. The research methodology is tailored to the selection process and aimed at providing a flexible tool that operates through multi-tier selection and evaluation that utilizes multi-attributed decision support for ranking the selected PDSs. The methodology is outlined in Figure 1-1.

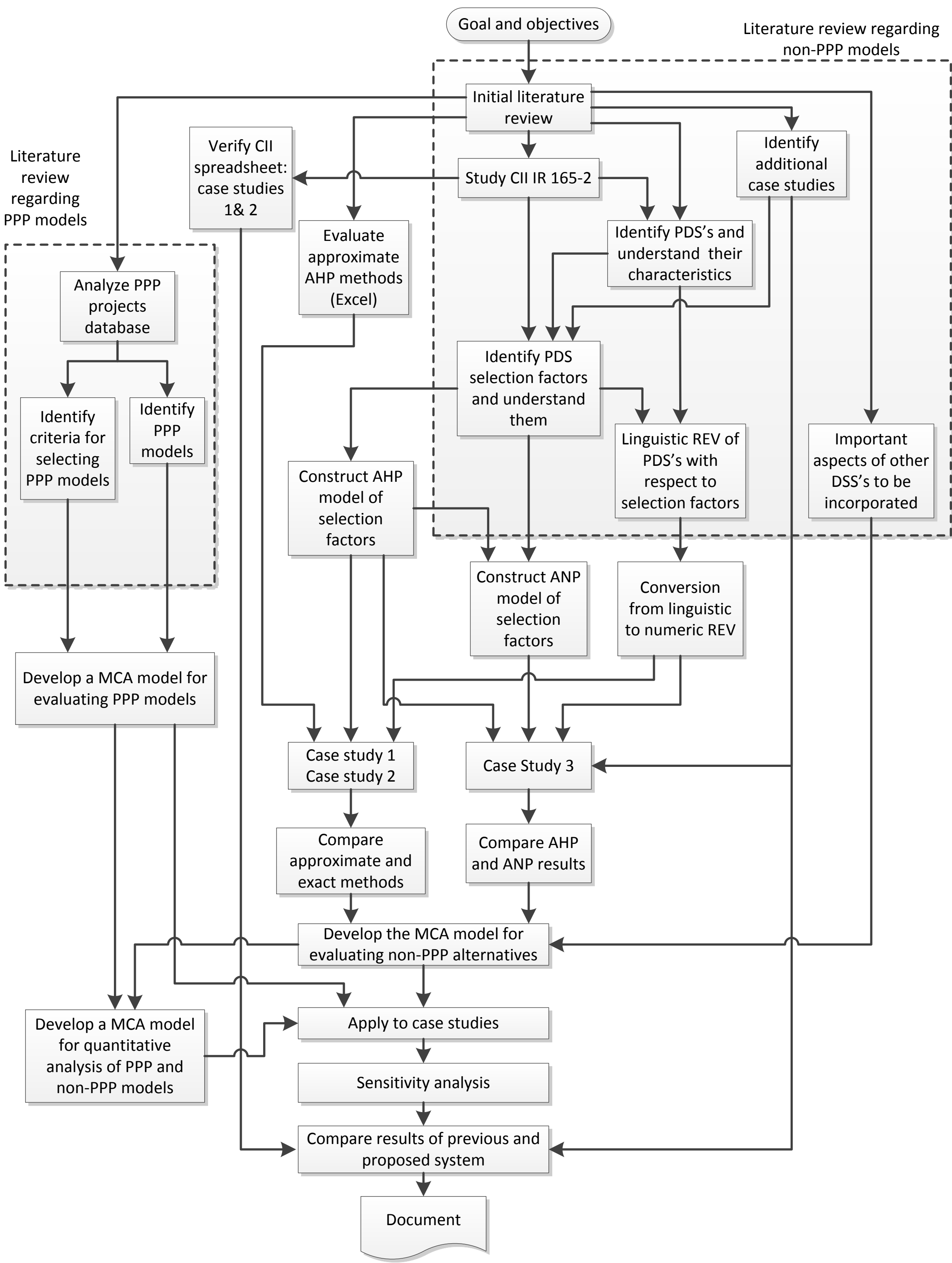

Figure 1-1 – Research Methodology

1.4 Thesis Organization

Chapter two is the review of the literature. The term project delivery system is defined and the historical development of PDSs is briefly presented. PDS alternatives are described. There is an overview of prior research and practice of PDS selection process. General methods of decision science that apply to this topic are described. Chapter three explains the development of the proposed decision support system, as a multi-tiered decision process. It describes the development of selection criteria and the method of determining relative weights of selection factors for the multi-criteria analysis, which includes structuring the AHP and ANP models. The development of relative effectiveness values of PDSs with respect to selection factors is also described. The development of the automated tool and its interface are presented. Chapter four provides examples of implementation of the proposed DSS through three case studies. Chapter five states the conclusions and outlines the contributions to the body of knowledge and the recommendations for future work.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Definition of Project Delivery System

Clough (1981) defines a project delivery system as "a method for procurement by which the owner's assignment of 'delivery' risk and performance for design and construction has been transferred to another party (parties). These parties typically are a design entity who takes responsibility for the design and a contractor who takes responsibility for the performance of the construction," (Clough, 1981, Mahdi and Alreshaid, 2005). Gordon (1994), uses the term 'construction contracting method' and defines it as a combination of scope, organization, contract and award. Scope refers to the duties assigned to the contractors, which may be design, construction and financing. Organization refers to the business entity that holds the contract for construction, such as a general contractor or construction manager. Contract refers to the method of compensation for the work performed under contract for construction, which can be either fixed price or reimbursable, and award refers to method used to select the contractor – competitive bidding or negotiation, (Gordon, 1994). Koncahr and Sanvido (1999) state that "a project delivery system defines the structure of the relationships of the parties, the roles and responsibilities of the parties and the general sequence of the activities required to deliver the project" (Konchar and Sanvido, 1999, Moore, 2000).

2.2 History of Project Delivery Systems

The earliest buildings and infrastructure were designed, engineered and constructed under the sole responsibility of a master-builder. The ideas of separate roles of architect and builder emerged in Renaissance. The development of technology and the increased sophistication of buildings, particularly after the industrial revolution, lead to the specialization and differentiation between design and construction disciplines. The body of knowledge in design and engineering grew, expectations and demands on design practitioners increased, and this led to further differentiation and specialization of design and engineering disciplines. Professional organizations emerged which regulated practice of specific disciplines (Ballard, Cho, Kim and Azari, 2012). The separation of roles brought about concerns over accountability and responsibility of various project participants. In late 19th century the U.S. government responded to concerns over objectivity and integrity of project development process on large infrastructure projects by instituting contracting regulations, which led to the development of the sequential delivery process known as design-bid-build (U.S. Department of Transportation, 2006). This system is intended to provide fair competition among bidders, but it allows little interaction between designers and constructors during the design phase, which can lead to inefficient designs, errors and disputes, often resulting in longer delivery. In the 1970's the construction manager system was introduced to overcome these disadvantages and to improve the quality and constructability of design through builder's input. (Konchar and Sanvido, 1998). Meanwhile, the delivery of projects with single point of responsibility for design and construction had not disappeared from practice in private sector, and it came to be known as design-build (DB). The first documented uses of design-build on U.S. public sector project was at school districts throughout Midwest in 1969, (Molenaar, Songer and Barashh, 1999). DB allowed the owners to minimize the demands of the project on their in-house staff (Konchar and Sanvido, 1998). Initially, a large portion of public sector was restricted from using design-build. However, in 1996 the U.S. Federal Acquisition Reform Act authorized its use for Federal projects, which gave impetus to its growth (Molenaar, Songer and Barash, 1999).

The origin of what has come to be known as the Integrated Project Delivery (IPD) was in the North Sea oil exploration projects in the U.K. (Forbes, L. and Syed, 2010). The company BP pioneered the concept of alliancing on these projects, in the early 1990's in an effort to reduce the high development costs of drilling in the North Sea. The remaining fields in this area were relatively small compared to those elsewhere in the world, and it was challenging to make such projects economically feasible. Since the engineering solutions did not result in cost reductions desired, the BP sought to improve the efficiency of project delivery by eliminating the adversarial relationships between the major participants. The first project with the new approach was Andrew Filed. The company management recognized that, in order to create an environment conducive to teamwork and trust, the interests of each project participant should be aligned with the project outcome. They developed a "painshare–gainshare" compensation program, which involved open-book accounting, sharing all uninsurable risk and setting an initial target cost by the entire team. The under- and over-runs from this target cost would be shared by all alliance members. The alliance member companies were selected based on virtue rather than competitive prices. The success surpassed the expectations. The final cost was £290 million compared to the engineering estimate of £450, made prior to the alliancing effort, and the project was completed six months ahead of schedule, (Sakal, 2005).

The alliancing concept was next applied to major infrastructure and building projects in Australia (Forbes and Syed, 2010). A partnership of companies in Florida including design professionals and construction practitioners, named Integratedprojectdelivery Collaborative, trademarked the term Integrated Project Delivery (submitted for trademark in 2000 and registered in 2005), and they claim to have developed the IPD process during the 90's (Integratedprojectdelivery collaborative, 2013). On their design-build projects, this collaborative employed relational contracting internally within the DB team (referred to as the IPD team) and transactional contracting externally with the client (Matthews and Howell, 2005). According to AIA (2012), the Sutter Field Fairfield Medical office building in Fairfield California, begun in 2005 and completed in 2007 was "the, or close to the, first 'true' IPD project in the country." On this project, an Integrated Form of Agreement (IFOA) bound three parties: the owner the architect and the builder.

In 2007, the American Institute of Architects and the AIA California Council published the 1st version of *Integrated Project Delivery: A Guide*. The same year, Consensus DOCS, a large coalition of construction industry associations representing mostly contractors and owners published the first standard form of agreement for IPD, Consensus DOCS 300 Tri-Party Agreement for Integrated Project Delivery. The AIA C191 – Standard Form Multi-Party Agreement for Integrated Project Delivery followed in 2009. In 2010, the Joint Committee of the National Association of State Facilities Administrators (NASFA), Construction Owners Association of America (COAA), APPA: The Association of Higher Education Facilities Officers, AGC, and the AIA, published "Integrated Project Delivery for Public and Private Owners." The AIA developed a family of standard contract forms for the IPD, including *the* AIA *A295™– 2008 General Conditions of the Contract for Integrated Project Delivery*. Additionally, in 2010, the AIA and the Associated General Contractors of California jointly published the first set of six IPD case studies, and in 2012 AIA, AIA Minnesota and Minnesota School of Architecture published another edition with six additional case studies. In January 2012, the Construction Industry Institute published *Starting from Scratch: A New Project Delivery Paradigm*, a research report calling on the industry leaders to work on changing the existing paradigm and to go even beyond IPD.

Public private partnership (PPP) was developed out of the need of governments worldwide to overcome shortage of funding for public projects. This need initially led to privatization of certain public assets and projects in many countries in 1970's and 1980's. The legislation that allowed such privatization opened the possibilities for private sector to participate in financing and ownership of traditionally public projects. In 1992, the U.K first introduced the Public Finance Initiative (PFI) for public projects as an alternative for privatization, followed by Australia and New Zeeland. A critical development in the 1990's was the requirement to demonstrate that PFI would not be more expensive over the project life than traditional delivery, thought the value-for-money analysis. The term PPP gained favor over the term PFI emphasizing the partnership aspect of this delivery method. PPP has been implemented in many countries including Canada, China, Czech Republic, Finland, France, Hong Kong, Germany, Greece, India, Ireland, Israel, Japan, Malaysia, Netherlands, Norway, Portugal, South Africa, Singapore, Spain, Turkey and United States (Ghavamifar, 2009).

The development of project delivery, along with related contract language, government regulations and the mindsets within the industry continues, with the goal of improving performance and increasing value of participating in projects to all parties. The drivers of evolution in project delivery are desire to improve efficiency of the process, minimize potential for disputes and improve outcomes, both short term and long term, as well as the larger trends in the industry and in the society, such as scarcity of funding, environmental sustainability concerns, and opportunities offered by technological advancements.

2.3 Description of Most Common Project Delivery Systems

2.3.1 Design Bid Build (DBB)

Design-bid-build, also known as traditional project delivery, is characterised by a sequential order of design and construction activities. Owner has separate contracts with one or more design professionals and the contractor. There is one general contractor (GC) for the entire project, who usually in turn contracts with various subcontractors and suppliers, for specific portions of the work. The GC is selected based on the lowest responsive bid. The GC also usually selects subcontractors and suppliers based on their lowest responsive bids. In many jurisdictions DBB is mandatory for public projects. The owner may prequalify subcontractors. The owner may include in the contract documents the qualifications that specific trade contractors must have or he may include a list of acceptable trade contractors. However, this limits competition. The design process involves extensive owner input, review and approval. At design milestones, the design professional is required to provide construction cost estimates and often milestone schedules along with drawings and other instruments of service. It is customary for design professional to consult with construction management professionals for cost and schedule estimates, but in such cases, those professionals are prohibited from participating in teams competing for the project, to ensure fairness of the bidding process. The owner is responsible to the contractor for design errors. The contractor is responsible for construction and material defects and the quality of workmanship. After the contract is signed, any changes in scope and quality and any other changes that affect cost and schedule must be agreed to by both parties and become incorporated in the contract.

The main advantages of this PDS are competition among contractors, leading to lower price, familiarity of this PDS within the industry, including well established standard forms of contract, owner's strong control of design and selection of designer, considerable time for design iterations and the design professional's duty to act in the owner's best interest. The disadvantages are the absence of constructor's input in design, relatively slow process of delivery, conditions conducive to adversarial relationships, and low potential for innovation. This PDS is quite forgiving to changes during design, as the cost of design services is relatively low. DBB is prevalent in the industry (CMA, 2012), particularly in the public sector.

2.3.2 Construction Management-at-Risk (CMR)

Construction Management at Risk, also known as construction manager constructor (CMC) and construction manager/general contractor (CM/GC) is characterized by separate contracts for design and construction, where the entity responsible for construction (at-risk construction manager) is also hired during the design to provide pre-construction advisory services (CSI, 2011, Joint Committee of the AIA and AGC, 2011). When design has progressed to a stage when the owner and the CM can reach an agreement regarding major parameters such as scope, schedule and pricing principles, the CM takes on the financial obligation for construction, (Joint Committee of the AIA and AGC, 2011). Guaranteed maximum price (GMP) is the most common pricing principle. GMP usually includes a base cost along with several allowances and a contingency, so the final cost may be lower and the savings may be shared between the owner and the CM, (CMAA, 2012). It is in CM's interest to ensure that a GMP is realistic, before committing to it. After the GMP is agreed to, CM continues to ensure through detailed design phases and construction that GMP would not be exceeded. The CM-at-risk may perform a portion of the work with his own forces but this is less and less common.

The main advantage of CMR is constructor's input in design and reliable cost estimates before design is complete, while the owner's does not lose control of design. Another advantage is owner's ability to select a contractor based on qualifications, which is very important for complex projects. The GMP reduces the owner's exposure to cost increases due to subcontractors' claims for changes (Minchin, Thakkar and Ellis, 2007).

CMR has a potential for conflict of interest as one party is both advising the owner and selling him a product (constructing the project). CM has the ability to influence the design and he may advise the use of less expensive product without ensuring that it satisfies owner's performance standard. During construction, if the CM is performing portion of the work, he has a financial interest in making profit on that work (CSI, 2011). In determining the contingency to be incorporated in the GMP, subjectivity is involved and the interests of the owner and the CM are opposed. Even if a shared savings clause exists, the owner might not realize savings. According to Pishdad-Bozorgi and Bowen (2013), in some cases of shared-savings/overrun provision, the early price given by a contractor is actually inflated and includes a higher contingency to increase potential profit for contractor. The contractor and subcontractors may also add hidden contingencies in various cost items, to further protect themselves from the uncertainty of partially complete design at time of bidding. Another disadvantage is lack of competition for the general contract for construction. The owner may consider and negotiate with multiple contractors at an early stage of design, but throughout the design process, when the selected CM is estimating costs, and when the owner and the CM negotiate the price, the contractor is not facing any competition. Competitive bidding of subcontracts that the owner may require, means that most of the direct cost is subject to competition (Minchin, Thakkar and Ellis, 2007).

Some public agencies are restricted from using CMR, or they may be allowed to use it through special pilot programs, (Minchin, Thakkar and Ellis, 2007). CMR delivery system requires owner's involvement and resources. Selection of CM firm is extremely important. CMR includes additional costs compared to DBB: cost of CM's professional services, higher cost of design professional services (as CMR delivery system requires more of design professional's time, especially with a fast-track schedule), and possibly higher demand on owner's staff and higher administrative cost for the owner. These costs should be justified by project size, complexity, or challenging schedule (CSI, 2011).

The following conditions may lead to selecting CMR delivery system:

- A project is large, schedule sensitive, difficult to define, and subject to change (Walewski, Gibson and Jasper, 2001)
- The owner wishes to control the design, and the selection of designer and contractor (Minchin, Thakkar and Ellis, 2007)
- The owner wishes to select a contractor based on qualifications rather than price, or the owner wishes to use a particular contractor/construction manager with whom the owner has had a positive experience and good relationship.
- Overlap of design and construction is necessary.
- The owner does not have resources to manage multiple prime contract packages and/or is not able to accept the risk of managing and coordinating multiple contracts.
- The owner requires a high degree of confidence in the total cost of the project, at an earlier stage, before design is complete.

A study of project delivery systems cost performance in Pacific Northwest Public Schools by Rojas and Kell (2008) revealed that GMP is not necessarily an effective guarantee for maximum control of construction cost. The study of 222 DBB school projects and 6 CMR school projects found that the CMR projects experienced bid cost growth and project cost growth observably higher than the DBB projects, which was unexpected,(Rojas and Kell, 2008).

2.3.3 Design-Build (DB), Engineer-Procure-Construct (EPC)

In design build project delivery system, single entity is responsible for both design and construction. The contract is signed between the owner and design-build contractor, also referred to as design-builder, based owner-defined scope of work. DB requires intense owner's effort in early stages - defining scope, budget and schedule, devising the process to select a contractor, and the selection process itself. Project scope includes performance requirements, and may include schematic design prepared by the owner or his consultant. Engineering Procurement and Construction (EPC) is the term used for design-build applied to industrial projects (CII, 2002, CII, 2003).

DB contractor is most often selected based on best value - a combination of technical merit and price (Molenaar, Songer and Barash 1999, Touran, et al., 2009a), but selection based on price only or qualifications only are also common (CMAA, 2012). Selection is often a two-stage process, consisting of request for qualifications (RFQ) to shortlist bidders, and request for proposals (RFP). The RFP usually requires both price and technical proposal, including schedule, quality levels of specific components and design developed to a certain stage. The owner negotiates with the preferred proponent prior to awarding the contract. On private projects, contract may be awarded based on direct negotiations with one or more prospective contractors, without a formal solicitation process.

The method of compensation is usually lump sum (Graham, 1997, Ibbs, Kwak and Odabasi 2003, El Wardani, Messner and Horman 2006), whereas guaranteed maximum price and, rarely, reimbursable compensation methods are also used (CMAA, 2012). After the fixed contract price is established, owner's ability to influence design is limited as the owner's input may be regarded as initiating a change in contract. DB contractors may be companies with both design and construction capabilities, general contractors hiring design firms, design firms hiring construction contractors, and joint ventures of design and construction firms (CSI, 2011, CMAA, 2012,). A design-builder must have the bonding capacity and accept risks for construction similar to or greater than the risk that a general contractor would accept on a comparable DBB project.

The owner or his representative review the design for compliance with requirements (CMAA, 2012) and oversee QA/QC activities of the design-builder (CSI, 2011). The AIA A141 *Standard Form of Agreement between Owner and Design-Builder* requires the owner or his consultant to review submittals and proposed changes to the documents, make periodic site visits, reject non-conforming work, inspect and certify substantial and final completion and review pay applications, (Quattaman, 2005). As the owner is not in control of detailed design, he must be able to have great mutual professional trust with design-builder (Beard, Loulakis and Wundram, 2001, Gnavamifar, 2009).

The USDoT *Design-Build Effectiveness Study* (2006) indicates that the greatest motivation and realized benefit of DB over DBB for highway projects is faster overall delivery, achieved by eliminating the process of construction contract procurement (USDoT, 2006). Owner has less risk as he does not have the responsibility for the quality and completeness of construction documents. This system benefits from builder's input in design as design and construction teams work within one entity. Also, DB contractor controls the budget and schedule, and any overruns not resulting from owner initiated changes are the responsibility of the contractor. Because the performance requirements can be met in multiple ways, DB encourages innovation (USDoT, 2006).

However, the reduced risk means less control for the owner. Performance specifications, if they are not carefully thought through, may allow products that do not meet the actual owner expectations, which can affect the functioning of the facility or lifecycle cost. Unless stated otherwise in the contract, materials are selected by design-builder (CSI, 2011). Similarly, the owner does not have control over trade contractor selection, unless this is agreed to prior to contract signing. This may result in inferior quality. Potential for conflict of interest exists as there are no checks and balances within the DB team to protect the owner (CMAA, 2012). Owner should not expect that his interests would be protected to the same level by the design professionals within the DB entity, as they would be when owner contracts with a design professional directly (CSI, 2011). This highlights the need for careful selection of design-builder and for a relationship of trust.

This project delivery system is the most appropriate for the projects that do not require significant owner involvement and control of design, where the scope can be well defined prior to design process. This would be the case with projects where aesthetic appearance, expression and image are not among primary drivers, conventional projects (CMAA, 2012) such as parking garages, warehouses, manufacturing plans, office buildings and road construction, but also for projects of high technical complexity, where requirements can be clearly defined.

A study of the CII Benchmarking and Metrics (BM&M) database found that, overall, there were fewer DB than DBB projects, but the share of DB projects grew with project size. 47% of owner submitted and 79% of contractor submitted projects costing over $50 million were DB (CII, 2002), and the average cost of DB projects was significantly larger than that of DBB projects (CII, 2002). According to this study, DB is used more often on industrial projects than on building projects.

Some governments do not authorize the use of DB for public projects, or allow it only for special pilot projects, but such restrictions are gradually going away (Touran et al, 2009a). Availability of qualified contractors is important for desired level of competition competition (USDoT, 2006, CSI, 2011,), and preparation of DB proposals is expensive. In order to encourage competition, and to be able to utilize ideas from all proposals, the owner may offer stipends to unsuccessful bidders (CSI, 2011). DB creates greatest constraint on competition due to qualifications based selection. There is typically no requirement to competitively bid subcontracts. DB projects are of greater scale, speed, and complexity than projects in general, which precludes firms with no DB experience from participating (Touran et al., 2009a, b). According to Forbes and Syed (2010), DB is the fastest PDS and can be expected to contain cost better than other PDSs but can result in lower quality when unchecked.

To overcome the major drawbacks of DB while maintaining its advantages, variations to DB have been evolving. In Design-build 'Bridging,' the owner develops design to a schematic level and solicits DB proposals for more detailed design and construction. This enables the owner control of design and greater confidence that requirements have been defined and communicated through the contract documents, while providing early price commitment and reduced exposure to risk (CMAA, 2012).

In 'Progressive DB' or 'DB progressive GMP' the contract is initially signed without the cost of work, but it may include price for design, pre-construction services, general conditions and a construction fee as a percentage of direct cost of construction. After design has sufficiently progressed (usually 50-75%), GMP is established (CMAA, 2012). This reduces contingency for uncertainty, incorporated in firm price DB contracts, by delaying the price commitment (Touran et al., 2009a). Design-builder is selected primarily based on qualifications, and can be involved as early as possible. The owner controls the design details collaboratively with design-builder until the GMP is established. This approach reduces the risk that the scope is not sufficiently defined in the RFP, and also the time and cost of preparing the RFP and evaluating proposals (Loulakis, 2013). Similar to the CMR method, if GMP negotiations are not successful, the owner can keep the design and complete the project through DBB delivery. The primary disadvantage is reduced competition (Loulakis, 2013).

2.3.4 Public-Private Partnership (PPP)

The World Bank defines PPP as "*A long-term contract between a private party and a government agency, for providing a public asset or service, in which the private party bears significant risk and management responsibility"* (World Bank Institute, 2012). In the Canadian context, PPP is defined as "a cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards," (CCPPP, 2005-2014). The difference is the inclusion of short term contracts in the PPP category in Canada.

The advantages to the public include transfer of risk, including price, schedule and performance certainly and private sector efficiencies. Innovation and increased utilization of assets may also occur. PPP models that integrate design, construction and long-term, responsibilities, encourage long-term performance. The ability to overcome budget constraints by spreading capital cost over long term is often perceived as the most significant advantage of PPP. Certain costs are inherently higher for PPP and therefore governments require that, if a PPP is to be used, it must be demonstrated that greater value for the public funds can be expected, over the term of the agreement, while taking risk into account.

Lack of public funds and decision for PPP

Lack of public funds is often mentioned as a primary reason for PPP. Unavailability of funds may be overcome by long-term private financing of capital cost, or by private ownership of the asset, which may or may not be transferred to the public at the end of agreement term. For several projects in the CCPPP Database (2013), unavailability of sufficient funds, or a desire of a public agency to avoid seeking public approval for the capital cost of a project were motivators for PPP (Prospera Place Sports and Entertainment facility DBFMO, BOOT, Moncton Water Treatment Facility DBFMO, Nova Scotia Schools DBFMO). However, this is not considered as a sufficient reason, as the value for money principle, explained further in section 2.4.5, must also be satisfied.

PPPs may lead governments to over commit long-term. It can be more difficult to assess the true long-term cost, as the payments may depend on uncertain elements such as demand, exchange rates and costs (World Bank Institute, 2012). World Bank Institute (2012) warns that "public resources may go into projects that don't really provide value for money, since costs are higher or benefits lower than first thought." Governments may take significantly more risk than they realize, when they provide guarantees for loans, accept risks for demand for service, or when they bail out a project in distress, out of concern that public service may deteriorate to unacceptable level (World Bank Institute, 2012).

PPP models as alternatives

Aside from construction, with or without design, responsibilities transferred to a private partner through a PPP agreement may include short or long-term financing, maintenance, operations or ownership. Combinations of responsibilities represent different PPP models. The use of PPPs has considerably grown in Canada in the last two decades, with 21 PPP models mentioned in the Canadian PPP Project Database (CCPPP, 2013). The range of PPP models considered as alternatives in the proposed decision support system described in Chapter 3 was established based on the models occurring in the CCPPP (2013) Canadian PPP Project Database, which included 207 projects at the time of this writing. Information available on each project in this database was studied to understand which duties were transferred to private partner on particular projects. Based on this, the PPP model categories were consolidated. The PPP models that don't include construction and the projects for which there was not enough information to understand which responsibilities were transferred were removed for the purpose of this analysis. The remaining dataset had 191 projects.

Regarding specific project responsibilities, in PPP, the differences between transferring and not transferring design are less than they are among the non-PPP delivery models. In models that don't transfer design (BF and BFM) the private partner still usually has significant responsibility for design coordination. For example, the VFM Report for the Roy McMurtry Youth Centre, delivered as BF, states that "the builder is now responsible for: inconsistencies, conflicts, interferences or gaps in the contract documents and particularly in the plans, drawings and specifications; and design completion issues which are specified in the contract documents but erroneously left out in the drawings and specifications," (Infrastructure Ontario, 2007d). The main difference in transferring or not transferring design is the level of development of design by the owner, provided in the RFP, and the freedom the proponents are given in interpreting and enhancing the reference design. Financing may be short-term (construction financing), or a long-term repayment of all or portion of capital cost. BF and DBF include only short-term financing. BFM, DBFM, DBFMO and DBFMOO include long-term financing. DBMO does not include long-term financing, but it may or may not include short-term financing.

The operations responsibilities of the private party can vary greatly, depending on the nature of the underlying asset and associated service, (World Bank Institute, 2012). When core operations are entirely public, 'O' is usually not included in the acronym, whereas when core operations are by private partner, or shared between the public and private partners, 'O' is included in the acronym. On projects where operations are transferred, there was no indication that maintenance is not transferred. According to World Bank Institute, 2012) 'Maintain' is usually implied if 'operate' is included.

When it comes to transfer of ownership, there are two basic types. One is transfer to private partner for the term of the agreement and back to public ownership at the end of the term, and the other one is that the asset remains in private ownership. BOOT is often used interchangeably with BOT and these models usually include maintenance and some or all operations. When ownership is by private partner, whether the private agency needs to lease back all or parts of the facility depends on the nature of operations, and project's potential for revenues. On environmental and energy projects, core operations may be by private partner, and in those cases the public does not lease the facility. In the Moncton Law Courts project (GNB, 2009); the city leases the space, whereas in some of the cultural and recreation facilities, public and private partners share the use of the facility and the opportunities for revenues. The summary of the consolidated delivery model categories is shown in Table 2-1.

Table 2-1 Summary of CCPPP Canadian PPP Project Database, consolidated

		Sector										
PPP model	All	Hospitals and Healthcare	Education	Justice/Corrections	Recreation and Culture	Energy	Environmental	Transportation	Real Estate	IT Infrastructure	Defence	Government Services
BF	33	31		1	1							
BFM	3	2	1									
DBF	16	5	2		4	1	1	3				
DBFM	63	30	6	14				10	2		1	
DBFMO	62	10	1	1	7	1	11	29		1		1
DBFMOO	4			1		1	2					
DBMO	4						4					
DBFMOOT	4				4							
DBFMOO-lease-back-T	1			1								
DBFM-own-lease-back	1				1							
Total	191	78	10	18	17	3	18	42	2	1	1	1

Table 2-1 includes the terms that have not been used in the literature. DBFMOOT denotes that ownership is private for the term of agreement, after which it transfers back to the public. This is usually referred to as DBFMO and also BOOT. The term DBFMOO-lease-back-T pertains to the Moncton Law Courts project, where core operations are public and therefore the public leases the space (GNB, 2009). 'T' designates the transfer of ownership back to the public at the end of term. The term DBFM-own-lease-back pertains to the project Maison Radio Canada, which is at the RFP stage. For this project, the private partner is expected to provide maintenance and soft FM services, but the core operations remain public. Radio Canada intends to lease the space, and does not intend to hate the ownership transfer back (CBC, 2013).

Among the Canadian PPP projects, the most represented sectors are Hospitals & healthcare (41%) and Transportation (22%), followed by Justice/Corrections, Environmental and Recreation & Culture (9% each) and Education (5%). Other sectors are represented by one to three projects. The most represented PPP models are DBFM and DBFMO, accounting for a third of the projects each (33% and 32.5% respectively). They are followed by BF (17.28%) and DBF (8.38%). Other models are represented by one to four projects. There were 10 projects (5.24%) that transfer ownership to private partner. Hospitals and healthcare projects are most often delivered as either BF (39.74% of the sector) or DBFM (38.46% of the sector). BF projects usually included renovations of existing facilities. This can be explained by the fact that it is more difficult to transfer the risk for maintenance and to some degree the risk of design, when existing facilities are significant part of the project for hospitals. On the other hand, for Transportation and Environmental projects that include upgrades of existing assets it is less uncommon that design, maintenance and operations are included in a PPP. The reason could be that there is not much uncertainty associated with maintenance of assets in these sectors. DBFM was most often the delivery model for Justice/corrections projects (77.78% of the sector) and Education projects (60% of the sector), and it was also used significantly for transportation projects (23.81% of the sector). DBFMO was the most frequent model for transportation projects (69.05% of the sector) and environmental projects (61.1% of the sector). Out of ten projects that included ownership by private partner, five were Recreation & culture; two were Environmental, two Justice/corrections and one was in Energy sector. These most common PPP models are described next.

Build-Finance (BF) is the most similar to traditional DBB, as it allows the owner to maintain control of design, and the bids are based on completed design. However, this mode shares a defining characteristic of PPP – greater transfer of risk. This model is largely used on healthcare facilities in Canada - 31 out of 78 projects (CCPPP, 2013). Hospital projects involving significant renovation and physical interfaces with existing facilities have used BF model. (CCPPP, 2011b, CCPPP 2013). Delay of payment to private partner until the handover represents an incentive to meet the schedule. Since this model has the least amount of integration of responsibilities it offers least advantages of the potential related synergies.

Design-Build-Finance (DBF) is the most similar to design build, with added responsibility for financing during construction. This approach does not specifically incentivize the whole life approach to project delivery. According to PPP Canada, this model is the most suitable when no significant gains in operations efficiency can be expected from a private party and also in cases of refurbishment or expansion projects, when it is difficult to reassign operations and maintenance risks. The project types delivered in Canada under this method include assisted living facilities, sports facilities, transit maintenance facilities and hospitals. Similar to BF, this approach encourages the private partner to deliver on time and to meet specifications.

Design-Build-Finance-Maintain (DBFM) assigns long-term maintenance to private party. According to Canadian Council for Public Private Partnerships (2011c) this method may also include limited operations by private party, such as cleaning, but the operations remain largely the responsibility of the public entity. This model encourages the whole life approach to design, construction and maintenance. The project types executed include bridges, transit projects, schools systems, hospitals and correctional facilities. This option is more suitable for large, new construction projects. It is the most common PPP type for Canadian health care facilities (30 out of 78) projects (CCPPP, 2013).

Design-Build-Finance-Operate and Maintain (DBFOM) transfers greater operational responsibilities and risks to private sector. This approach is suitable when the delivery of the public service is not compromised or perceived to be compromised if a private party is responsible for operations of a facility or delivering the service. This is the case on municipal recreation projects, such as arenas and community centers, where the private entity may be responsible for security, cleaning, waste management, food services, facility operations and scheduling, and program development and delivery. Transportation projects inducing mass transit facilities, roads and bridges are also suitable for DBFOM. What is acceptable or what is in the best interest of the public varies by country or by community.

2.3.5 New Project Delivery Paradigm, IPD and Lean Project Delivery

The CII Research Team 271 expressed a vision that an ideal PDS, suited to the majority of today's capital projects which are complex, quick, and uncertain, would be a PDS that can deliver predictable outcomes and defect-free projects and retain positive competition (Ballard, Cho, Kim and Azari, 2012). Furthermore, in an ideal PDS everyone feels valued, relationships survive the project, the whole is optimized rather that its individual parts, there is financial transparency and alignment of compensation, individuals can develop their full potential, and learning from each project is utilized on subsequent projects. The CII RT 271 sees the prevalent 'common sense' approach based on mistrust, as the major obstacle to the ideal PDS, and they call the industry participants to create conditions where the ideal PDS can be realized (Ballard, Cho, Kim and Azari, 2012). CII RT 271 refers to Integrated Project Delivery as an effort towards the principles of operational integration (OI), alignment of interests (AI) and management by means (MBM). Forbes and Syed (2010) define relational contracting/lean design and construction as a category of project delivery systems and they consider integrated project delivery (IPD) to be one of the interpretations of lean project delivery and one type of relational contract. CSI (2011) qualifies IPD as a recent step in the evolution of project delivery to accommodate the growing project complexity. IPD integrates the two broad activities traditionally associated with two groups of individuals and companies – 1) decide, design and determine, and 2) supply, construct, and install – to capitalize on the unique contributions of each individual and company to the delivery process (CSI. 2011).

There is a distinction between IPD as a project delivery system and the IPD as a philosophy (Joint Committee of the NASFA, COAA, APPA, AGC and AIA 2010, WBDG 2012, Joint Committee of the ACI-NA, ACC and AGC, 2012). IPD as a delivery system is characterized by a multi-party contract between the owner, lead designer and constructor, and possibly other project participants. IPD as a philosophy represents a higher level of team integration among the project participants within any of the project delivery methods, under the contract agreements that the parties may chose. Joint Committee of the NASFA, COAA, APPA AGC and AIA (2010) formally defines three levels of collaboration. Level 1 and Level 2 represent IPD as a philosophy, whereas Level 3 represents IPD as a delivery system. Common procurement methods are the same for all three levels: qualifications-based selection (QBS) of designers and QBS or best value selection of constructors.

IPD as a project delivery system may also be referred to as: Multi-Party Contracting, Lean Project Delivery, "Pure" IPD, Relational Contracting and Alliancing (Joint Committee of the NASFA, COAA, APPA, AGC and AIA 2010). AIA published several versions of definition of IPD since 2007. A definition of the Joint Committee of the AIA and the AGC (2011) states that:

> "IPD is a method of project delivery distinguished by a contractual arrangement among a minimum of the owner, constructor and design professional that aligns business interests of all parties. IPD motivates collaboration throughout the design

and construction process, tying stakeholder success to project success, and embodies the following contractual and behavioural principles:

Contractual Principles

• Key Participants Bound Together as Equals

• Shared Financial Risk and Reward Based on Project Outcome

• Liability Waivers between Key Participants

• Fiscal Transparency between Key Participants

• Early Involvement of Key Participants

• Jointly Developed Project Target Criteria

• Collaborative Decision Making

Behavioral Principles

• Mutual Respect and Trust

• Willingness to Collaborate

• Open Communication"

In IPD as a delivery system collaboration is required by a multi-party contract. The contract may include open–book accounting and shared financial risk and reward tied to project outcomes, whereas compensation is usually cost-plus without a GMP (Joint Committee of the NASFA, COAA, APPA, AGC and AIA 2010). Throughout this thesis the terms 'integrated project delivery' and 'IPD' have the meaning IPD as a project delivery system, unless noted otherwise.

IPD as a philosophy is an application IPD principles and practices while using any contractual arrangements. It is also referred to as hybrids of IPD and other delivery methods, “IPD-ish” or “IPD-lite.” Regulatory restrictions may prohibit applying IPD with a multi-party contract. U.S. Army Corps of Engineers, when faced with a legislative requirement to deliver several large complex projects, including three hospitals and one National Geospace Agency facility, in a short time, devised an Integrated Design Bid Build (IDBB) pilot program. The goal was to optimize the project delivery process and meet the challenging schedule, through the principles and tools of Integrated Project Delivery, within the constraints of the government contracting regulations, which mandate separate contracts and award processes for design and construction (Brennan, 2011). Brennan (2011) defines IDBB as a “delivery method where separate contracts for A/E and construction services are awarded concurrently to allow collaborative simultaneous design and construction activities to be executed.” Kelleher, Aberhathy, Bell and Reed (2010) qualify IDBB, also referred to as ECI (early contractor involvement) as the Government’s version of the CMR delivery method. In the ECI, two separate entities are contracted for design and construction. The constructor is engaged in the early stage of design for the pre-construction services, and his proposal includes an “initial target cost, initial target profit with incentive provisions, and a ceiling price that is the maximum to be paid to the contractor, absent an adjustment under a contract clause providing for an equitable adjustment” (FAR 16.403-2). Designer and constructor collaborate to achieve a mutually acceptable design and final price. However, the contractor’s commitment is not secured until the design has progressed substantially (Kelleher, Abernathy, Bell, and Reed, 2010).

IPD employs relational contracting, as opposed to transactional contracting. Relational contracting "apportions responsibilities and benefits of the contract fairly and transparently, based on trust and partnership between the parties so that cooperation and dependency between the parties leads to mutual benefit" (Forbes and Syed, 2010). According to Forbes and Syed (2010), relational contracts are suitable for complex uncertain project. Characteristics of relational contracting are the following. Team interests have equal or greater weight than the legal agreement; parties share values and common goals; business model acknowledges interdependence between the parties; mutual trust is essential; sharing of knowledge and ideas is required; financial benefits and losses are apportioned between parties; and values, behaviors and actions extend beyond any project to the industry as a whole. Limitations of relational contracting are that some goals remain different between the parties, tension may occur, and parties may be justified in not trusting each other in every aspect and in withholding certain information. Relational contracting may be used regardless of whether the owner is party to the contract (Mathews and Howell, 2005). According to Matthews and Howell (2005) in IPD, unlike previous approaches, all parties take full responsibility for all terms, conditions and requirements of the contract and for the success or failure of a project.

IPD as a PDS may use one of the three types of multi-party contracts: Project Alliances, Relational Contracts and Single Purpose Entities (SPE) (AIA/AIACC, 2007b). In Project Alliances, the owner guarantees the payment of direct cost to the other parties, but their overhead, profit and bonuses depend on project outcomes. Significant decisions are made by facilitated consensus, and parties mutually waive claims, except for wilful misconduct.

In relational contracts compensation includes project based incentives, but there may or may not be collective responsibility for overruns. Decisions are made by the whole team, but if there is no consensus the owner makes the final decision. Parties may agree to limit but not completely wave liability to each other. Single purpose entity (SPE) is a legal form created specifically for a project, where key participants have an equity interest in the entity based on their skill, creativity, experience, services, access to capital or financial contribution. Equity owners are paid for the service they provide, and additional compensation is tied to project success. SPE raises additional issues such as taxation and insurance (AIA/AIACC 2007b).

Advantages of IPD are the following:

- Aligns interests of project participants
- Best interest of the project is above any party's best interest
- Risk is managed in the best interest of the project
- Intense collaboration starts early and continues throughout the project
- Problems are identified early and collectively resolved
- Changes are reduced or eliminated entirely
- Conflict is avoided and disputes are resolved by the core group
- Fosters real-time communication
- Reduces waste
- Decisions made by consensus
- Everyone is focused on the project

- Improved schedules
- Better satisfaction of participants

(Joint Committee of the NASFA, COAA, APPA AGC and AIA 2010)

According to CMAA (2012) IPD combines the advantages of DB and CMR, and offers a high chance of success as the entire team's interests are aligned with project goals.

The disadvantages, according to the Joint Committee of the NASFA, COAA, APPA, AGC and AIA (2010) are the following:

- Relatively new approach with little precedent to look for guidance
- The contract requires significant trust, which may not develop in every situation
- It may be difficult to change mind-sets in order to reach best for project decisions
- Owners may not be comfortable in giving up command and control they typically have with more traditional approaches
- Owner risks to not get what he is looking for after huge investment of time
- Measuring the benefit is difficult to prove

CMAA (2012) lists the following disadvantages:

- It may take a lot of time and effort for the key stakeholders to agree on the project parameters and sign a contract. The owner may be paying for this.
- Behaviour of individuals in a team may damage collaborative relationship, which is critical, and therefore cause failure.
- If positive working relationships don't already exist between the key stakeholders, it is difficult to put together a team in an objective manner.

Relatively few projects have been executed using multi-party IPD contracts. Out of the twelve IPD case studies documented by the AIA (2012) nine projects used a multi-party contract, and the remaining three applied one or more of the following IPD legal and commercial strategies: shared risk/reward, financial incentives tied to goals and fiscal transparency. According to a 2010 survey of 47 projects in the U.S. using or planning to use an IPD agreement, the majority are in healthcare sector (27 projects). The largest group (14 projects) cost over $100,000, and most of them (8 projects) are in health care sector. This is consistent with statements of IPD proponents that IPD is best suited for quick, complex and unpredictable projects (Brennan, 2011), as large hospitals are among the most complex building types. Lower cost categories and other market sectors are also well represented; see Table 2-2 (AIA, 2012). At this stage, IPD is being tested by the industry, and many projects are small.

Table 2-2 Summary of Sept. 2010 survey of projects using or planning to use an IPD Agreement (AIA, 2012)

Project type	# of projects
Healthcare	27
Office	7
K-12 education	3
Higher education	2
Residential	2
Other	2
Retail	1
Gov't civic	1
Transportation	1

Cost (in million USD)	# of projects
<5	8
5-10	2
10-25	7
25-50	8
50-100	7
>100	14

Situations when IPD can be used and when is most suitable

According to the Joint Committee of the NASFA, COAA, APPA AGC and AIA (2010), IPD when used as a synonym for collaboration is always advantageous, and more collaboration is better. Conditions to use IPD as a delivery system are the following:

- Owner is open to using a new method of project delivery and willing to develop the IPD agreement in collaboration with other parties, and to educate his staff in working within the IPD.
- It must be possible to assemble an IPD team. Other participants, contractors, design professionals and others, must also be open to a less familiar PDS, and also otherwise competent for the project. There must be trust in companies' capabilities to deliver the project and strong professional values.
- The time and effort of finding the right team and negotiating the agreement should be justified by the project size, complexity, challenging schedule or other special characteristics or circumstances.

Brennan (2011) outlines the following characteristics of projects that can most benefit from the IPD:

1. Large
2. Complex
3. Short schedule considering size and complexity
4. Program is not clearly defined
5. High project risks

6. Owner needs to be involved with the design and have a substantial amount of control.
7. Project involves evolving technologies, and flexibility for future modifications and growth has to be planned. Significant user input in design may be required.
8. Long lifecycle
9. High operating expenses
10. Participants, particularly the owner are interested in innovating in project delivery.

Brennan (2011) developed and tested a hypothesis that IPD is a project delivery system superior to design-build and design-bid-build in creating value for large complex medical projects. He surveyed key stakeholder participants of the IDPP pilot projects, who were also experienced with other project delivery methods (Brennan, 2011). IPD may not be appropriate for small projects which may not justify the cost premium for IPD, projects for which owner cannot commit staff resources to the IPD process, and owners who are not comfortable with the unfamiliar, (Brennan, 2011).

Merrow (2011) expresses strong criticism of alliance contracts, the term that he considers interchangeable with IPD in the U.S. and Project Alliances in Australia. His conclusions are based on the research of industrial mega projects (projects costing more than 1 billion USD) in various regions of the world, but he expresses scepticism regarding the use of alliance type contracts on any project, based on the very principles of those contracts. Merrow (2011) defines alliance contracts as the grouping of all (or almost all) of the contractors working on a megaproject under a single compensation scheme, with the goal of aligning the goals of the contractor with those of the owner, though a shared destiny approach. He criticizes the principle of incentives, as undermining contractor professionalism. Moreover, when the same party or parties are advising the owner on the project targets, based on which the incentives would be triggered, and also executing the project with hopes of exceeding those targets and receiving the incentive rewards, this represents a high potential for conflict of interest. Merrow (2011) states that alliance contracts do not fulfill the basic purpose of a contract, which is to define the responsibilities of each party, and that such contracts, therefore, are damaging. According to the research performed by IPA (Independent Project Analysis), a consulting company of which Merrow is a founder and CEO, industrial mega projects using alliance contracts failed by far most often, among the four contract types occurring on industrial megaprojects. Projects were deemed as failed in case of serious time or cost overruns or operational problems, and also if the owner paid more than a fair market price. The projects that would seem successful from the standpoint of time, cost and operability, were deemed as not successful if, according to the IPA assessment, the contract was based on inflated targets, (Merrow, 2011). Merrow (2011) points out that some of the projects that used alliance contracts initially inspired enthusiasm, but later proved to be disappointing due to operability problems.

Merrow (2011) attacks some of the basic principles of alliance contracting, of which IPD is a type, as damaging. Based on his research of performance of industrial megaprojects, he criticizes the principle of incentives, arguing that it leads to inflated estimates, and the principle of shared risk, as undermining accountability. Others, on the other hand point to evidence that relational contracting and IPD lead to superior results (Matthews and Howell 2005, Sakal 2005, Joint Committee of the NASFA, COAA, APPA, AGC and AIA 2010). Further applications of IPD principles and multi-party contracts on various project types will test them, provide lessons learned and allow a more substantial evaluation IPD project performance and of suitability of IPD for various project circumstances.

2.4 Project Delivery System Selection Process

Two tendencies exist in literature regarding project delivery system selection. Numerous sources offer specific decision support systems for project delivery system selection. Most often, they consider the most widely known and utilized PDSs: DBB, DB and CMR, and some sources consider additional systems. Another stream of recent publications since around 2010, promotes a new approach to project delivery, using the terms, ‘integrated project delivery,’ ‘lean project delivery’ or a ‘new project delivery paradigm.’ (Forbes and Syed, 2010, Brennan, 2011, Ballard, Cho, Kim, and Azari, 2012) This camp sees the future of construction as transitioning towards that new proposed approach, and believes that it would eventually become prevalent for most project types, and there would rarely be a question of which PDS to choose.

Ibbs and Chih (2011) provide a guide to the owner for first selecting the appropriate method for PDS selection before embarking on the PDS selection process itself. Selection methods are grouped into four major categories:

1. guidance (decision charts and guidelines)

2. multi-attribute analysis (e.g. multi attribute utility theory and analytical hierarchical process)
3. knowledge and experience-based (e.g. case-based reasoning)
4. mix-method approaches

These methods vary in levels complexity of implementation, the amount of information required from the user, and in how they elicit, measure, and express the decision makers' preferences.

Guidance methods provide general information about different PDSs and rules for selecting an appropriate PDS. They increase decision maker's understanding of performance of different PDSs, but don't provide a clear decision. (Ibbs and Chih, 2011)

The multi-attribute analysis methods include

a. The weighted sum
b. The multi-attribute utility/value theory (MAUT/MAVT)
c. The analytical hierarchy process (AHP); and
d. The fuzzy logic approaches

2.4.1 Guidance Methods

Konchar and Sanvido (1998) compare performance of DBB, DB and CMR in cost, schedule and quality, based on analysis of 351 building project completed between 1990 and 1996 in the U.S. The results are summarized in Figure 2-1 and Table 2-3

Facility Type \ Metric	Unit Cost	Cost Growth	Schedule Growth	Construction Speed	Delivery Speed	Intensity	Turnover Quality	System Quality	Equipment Quality
Light industrial	DB, CMR < DBB ●	○	CMR < DB, DBB ●	DB, CMR > DBB ●	DB, CMR > DBB ●	○	○	DB > DBB ●	○
Multi-story dwelling	○	○	○	○	○	DB > DBB ●	○	○	○
Simple office	○	○	CMR < DBB ●	○	CMR > DBB ●	DB > CMR, DBB ●	CMR > DB, DBB ●	○	○
Complex office	○	○	DB < DBB ●	○	○	DB > DBB ●	DB > CMR, DBB ●	○	DB > CMR ●
Heavy manufacturing	○	○	○	○	○	○	○	○	○
High technology	○	DB < DBB ●	○	○	○	DB > CMR ●	DB, CMR > DBB ●	DB > DBB ●	○

Legend	
Significant differences called out	< or >
No significant differences between systems	○
Significant differences	●

Figure 2-1 – Matrix of significance by Facility Type Unadjusted for other Explanatory Variables (Konchar and Sanvido, 1998)

Intensity is defined as the unit cost of design and construction work put in place in a facility per unit time.

Table 2-3 – Percentage of Average Difference between Project Delivery Systems by Metric (Konchar and Sanvido, 1998)

Multivariate model (1)	U.S. DB versus CMR (%) (2)	U.S. CMR versus DBB (%) (3)	U.S. DB versus DBB (%) (4)	R^2 (%) (5)	Reading DB forum: DB versus DBB (%) (6)	R^2 (%) (7)
Unit cost	4.5 less	1.5 less	6 less	99	13 less	51
Construction speed	7 faster	6 faster	12 faster	89	12 faster	90
Delivery speed	23 faster	13 faster	33 faster	87	30 faster	80
Cost growth	12.6 less	7.8 more	5.2 less	24	NA	NA
Schedule growth	2.2 less	9.2 less	11.4 less	24	NA	NA

Note: DB = design/build; DBB = design/bid/build; CMR = construction management at risk; NA = not applicable.

The CII Design-build Research team (1999), developed a 'Project Delivery Systems Selector,' which provides information on relative performance of the three PDS's with respect to 8 performance metrics, based on facility type (Figure 2-2) and the user evaluates importance or those performance metrics numerically.

Metric / Facility Type	Unit Cost	Construction Speed	Delivery Speed	Cost Growth	Schedule Growth	Turnover Quality	System Quality	Equipment Quality
Light industrial	○	DB, CMR > DBB ●	DB, CMR > DBB ●	○	○	○	DB > DBB ●	○
Multi-story dwelling	○	○	○	○	○	○	○	○
Simple office	○	○	DB > DBB, CMR ●	○	CMR < DBB ●	CMR > DB, DBB ●	○	○
Complex office	○	DB > DBB ●	DB > DBB, CMR ●	○	DB, CMR < DBB ●	DB > CMR, DBB ●	○	DB > CMR ●
Heavy industrial	○	○	○	○	○	○	○	○
High Technology	○	DB > DBB ●	DB > CMR ●	○	○	DB, CMR > DBB ●	DB > DBB ●	○
Optimum Delivery System								

Figure 2-2 CII (Design-build research team, 1999)

There are many situations when the matrix in Figure 2-2 would not result in a PDS selection. In such a case the order of suitability of PDSs suggested by this system is DB, followed by CMR followed DBB, as this ranking is the same for all five cost and time related performance metrics, when facility type is not considered, as shown in Table 2-3. Therefore DB would be selected, unless there are constrains to using this delivery system.

2.4.2 The weighted sum approaches and MAUT

Both weighted sum approaches and the multi-attribute utility theory are quantitative methods in which weights are assigned to selection criteria to reflect their relative importance, specific to each decision, and each alternative gets an overall score, as a weighted sum. In the weighted sum approach, each PDS is scored with respect to each criterion on a certain numerical scale, whereas in MAUT, utility functions are fist defined for each evaluation criterion, and based on those functions, utility scores are derived for each alternative with respect to each criterion. (Ibbs and Chih, 2011).

An example of a MAUT approach is CII Implementations Resource Owner's Tool for Project Delivery and Contract Strategy Selection User's Guide (CII, 2003), which will be referred to as the CII IR 165-2. CII IR 165-2 uses the term Project Delivery and Contract Strategy (PDCS) for a project delivery system. The decision process is represented in the Figure 2-3. The CII defines twelve PDCS's listed in Table 2-4, and 20 selection factors, listed and defined in Table 2-5.

CII IR 165-2 provides relative effectiveness values (REVs) of each PDCS with respect to each selection factor on a scale of 0 (lowest) to 100 (highest), in the increments of 10 (CII, 2003). These REVs are considered as industry-wide and independent of specific circumstances. The range of project delivery systems and selection factors were established through a survey of 45 owner organizations and 45 contractor organizations, from twelve different industries, and refined through analysis by the CII research team, (Anderson and Oyetunji, 2004). The relative effectiveness values were developed through a two-part data collection and analysis exercise, validated by consensus of 32 experienced project managers, (Oyetunji and Anderson, 2006).

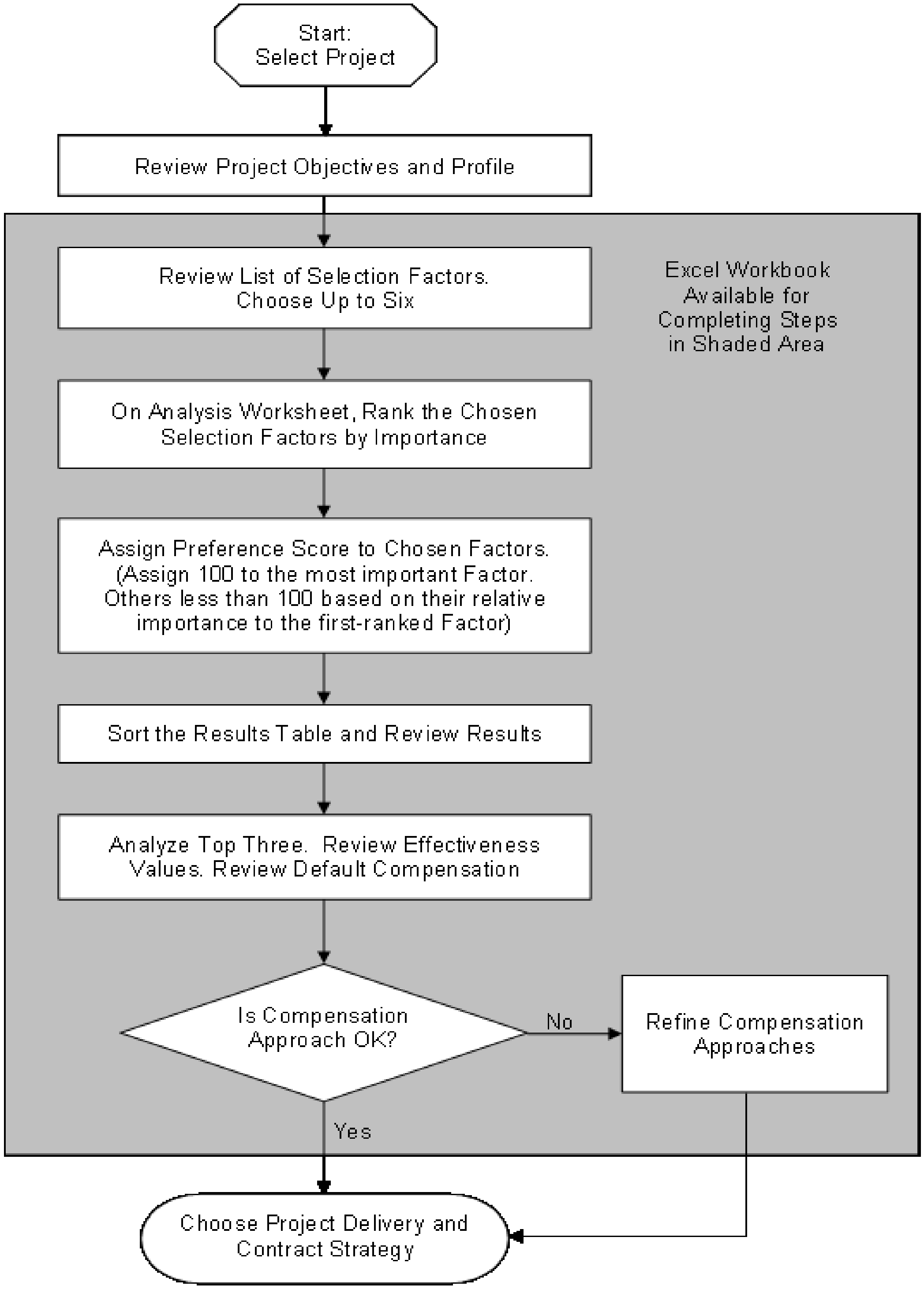

Figure 2-3 Project Delivery and Contract Strategy Selection Process Flowchart (CII, 2003)

Table 2-4 Project Delivery and Contract Strategy Descriptions (CII, 2003)

PDCS Number	PDCS Name	Description
PDCS 1	Traditional D-B-B	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor.
PDCS 2	Traditional with early procurement	Serial sequence of design and construction phases; procurement begins during design; owner contracts separately with designer, constructor, and supplier.
PDCS 3	Traditional with PM	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor; PM (Agent) assists owner in managing project.
PDCS 4	Traditional with CM	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor; CM (Agent) assists owner in managing project.
PDCS 5	Traditional with early procurement and CM	Serial sequence of design and construction phases; procurement begins during design; owner contracts separately with designer, constructor and supplier; CM Agent assists owner in managing project.
PDCS 6	CM @ Risk	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts separately with designer and CM @ Risk (constructor).
PDCS 7	Design-Build (or EPC)	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with Design-Build (or EPC) contractor.
PDCS 8	Multiple Design-Build	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with two Design Build (or EPC) contractors, one for process and one for facilities.
PDCS 9	Parallel Primes	Overlapped sequence of design and construction phases; procurement begins during design; owner coordinates separate contracts with designer and multiple constructors (or D-B contractor(s).
PDCS 10	Traditional with Staged Development	Multi-stage, serial sequence of design and construction phases; separate contracts for each stage; procurement begins with construction; Project Manager (Agent) assists owner with project management.
PDCS 11	Turnkey	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with Turnkey contractor.
PDCS 12	Fast Track	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts separately with designer and constructor.

Table 2-5 Selection Factors for Project Delivery and Contract Strategy (CII, 2003)

Factor Number	Factor Action Statement	Selection Factor	Factor Description for Comparing PDCS
Cost-related factors			
1	Control cost growth.	Completion within original budget is critical to project success.	Project delivery and contract strategy facilitate control of cost growth.
2	Ensure lowest cost.	Minimal cost is critical to project success.	Project delivery and contract strategy ensure lowest reasonable cost.
3	Delay or minimize expenditure rate.	Owner's cash flow for the project is constrained.	Project delivery and contract strategy delay or minimize rate of expenditures.
4	Facilitate early cost estimates.	Owner critically requires early (and reliable) cost figures to facilitate financial planning and business decisions.	Project delivery and contract strategy facilitate accurate early cost estimates.
5	Reduce risks or transfer risks to contractor(s).	Owner assumes minimal financial risk on the project.	Project delivery and contract strategy reduce risks or transfer a high level of cost and schedule risks to the contractor(s).
Schedule-related factors			
6	Control time growth.	Completion within schedule is highly critical to project success.	Project delivery and contract strategy facilitate control of time growth.
7	Ensure shortest schedule.	Early completion is critical to project success.	Project delivery and contract strategy ensure shortest reasonable schedule.
8	Promote early procurement.	Early procurement of long-lead equipment and/or materials is critical to project success.	Project delivery and contract strategy promote early design and purchase of long-lead equipment or materials.
Other factors			
9	Ease change incorporation.	An above-normal level of changes is anticipated in the execution of the project.	Project delivery and contract strategy promote ease of incorporating changes to the project scope during detailed design and construction.

10	Capitalize on expected low levels of changes.	A below-normal level of changes is anticipated in the execution of the project.	Project delivery and contract strategy capitalize on expected low levels of changes.
Factor Number	**Factor Action Statement**	**Selection Factor**	**Factor Description for Comparing PDCS**
Other factors (cont.)			
11	Protect confidentiality.	Confidentiality of business/ engineering details of the project is critical to project success.	Project delivery and contract strategy protect secrecy of business objectives and proprietary technology.
12	Capitalize on familiar project conditions.	Local conditions at project site are favorable to project execution.	Project delivery and contract strategy capitalize on familiar project conditions.
13	Maximize owner's controlling role.	Owner desires a high degree of control/influence over project execution.	Project delivery and contract strategy increase owner's role in managing design and construction.
14	Minimize owner's controlling role.	Owner desires a minimal level of control/influence over project execution.	Project delivery and contract strategy minimize owner's role in managing design and construction.
15	Maximize owner's involvement.	Owner desires a substantial use of own resources in the execution of the project.	Project delivery and contract strategy promote greater owner involvement in detailed design and construction.
16	Minimize owner's involvement.	Owner desires a minimal use of own resources in the execution of the project.	Project delivery and contract strategy minimize owner involvement in detailed design and construction.
17	Capitalize on well-defined scope.	Project features are well defined at award of the design and/or construction contract.	Project delivery and contract strategy capitalize on well-defined project scope prior to award of design and/or construction.
18	Efficiently utilize poorly defined scope.	Project features are not well-defined at award of design and/or construction contract.	Project delivery and contract strategy efficiently utilize poorly defined project scope prior to award of design and/or construction.
19	Minimize number of contracted parties.	Owner prefers minimal number of parties to be accountable for project performance.	Project delivery and contract strategy minimize the number of parties under contract directly with the owner.

20	Efficiently coordinate project complexity or innovation.	Project design/engineering or construction is complex, innovative, or nonstandard.	Project delivery and contract strategy facilitate efficient coordination and management of non-standard project design/engineering and/or construction.

The CII IR 165-2 utilizes the simple multi-attribute rating technique with swing weights (SMARTS), a variant of the multi-attribute utility theory. It recommends that between four and six selection factors be chosen for each particular project, and that no two factors should be based on the same objective or idea, to avoid double counting. The chosen selection factors are ranked in importance and then assigned relative weights (preference scores), such that the most important gets the score of 100 and the remaining factors get lower scores in the increments of 5 or 10, but not less than 5 (CII, 2003). An automated spreadsheet contains the REVs and enables calculation of ratings and ranking of alternatives, based on user's input of preference scores of factors. The CII IR 165-2 does not suggest a specific method for determining preference scores of selection factors.

2.4.3 AHP and ANP

Analytical Hierarchy Process (AHP) (Saaty, 1980) and Analytical Network Process (ANP) (Saaty, 2003) provide methods of weighing selection criteria with a higher level of objectivity, as items are compared two at a time. Judgements are expressed either numerically or verbally, as in Table 2-6. Judgements are organized and recorded in an n x n matrix, where n is the number of items compared, Consistency can be checked by calculating consistency ratio (C.R.), which should be kept below 0.1 (Saaty, 2003). To reach a decision through AHP, one constructs a hierarchy pertaining to the problem. The top of the hierarchy is the goal of the decision process, the sub-objectives are immediately below, the alternatives or possible outcomes at the bottom, and there may be several intermediate levels (Saaty, 1980). Elements are compared to each other within clusters, with respect to elements higher in the hierarchy. Constructing a decision hierarchy or network relies on an understanding of the problem, and a certain level of subjectivity is inherent in the AHP/ANP method (Saaty, 1980).

Table 2-6 (Saaty, 1980)

1	A and B are equally important
3	A is weakly more important than B
5	A is strongly more important than B
7	A is demonstrably or very strongly more important than B
9	A is absolutely more important than B

The AHP considers the elements of each group as only affecting the elements of one other group and being affected by elements of one other group, whereas the ANP also considers additional dependencies between elements of various groups. A network may be generated by adding connections to a hierarchy (Saaty and Vargas, 2006). According to Saaty and Vargas (2006) decision from a network can be significantly different than decision from a hierarchy. Creative Decisions Foundation (2010) points that "although many decision problems are best studied through the ANP, one may wish to compare the results obtained with it to those obtained using the AHP or any other decision approach with respect to the time it took to obtain the results, the effort involved in making the judgments, and the relevance and accuracy of the results." Rosan Saaty (2003) suggests that both the use of AHP and ANP are justified, depending on the case at hand, and that one or the other may be more accurate for specific decisions.. There are many more examples of AHP than of ANP in PDS selection.

Both the AHP and ANP utilize mathematical operations with matrices to compute the relative importance of the selection criteria. Exact priorities are obtained by "raising the matrix to arbitrarily large powers and dividing the sum of each row by the sum of elements in the matrix," (Saaty, 1980). Software, such as Super Decisions, automates the AHP/ANP matrix calculations. Priorities of elements within the same set of comparisons, i.e. the elements that are all compared to each other with respect to another element, are referred to as local priorities. Among the approximate methods for calculating local priorities, a method that represents the best approximation consists in finding the geometric mean of each row of the local decision matrix and normalizing the resulting numbers - the method referred to as 'Good' by Saaty (1980), (Popic and Moselhi, 2013). This approximate method also includes a method for calculating consistency ratio. To calculate the overall priorities of elements, local priorities of elements that are connected to each other along the same branch of a hierarchy are multiplied with each other, going from highest to lower levels of hierarchy, (Saaty, 2003).

Most examples of AHP in PDS selection have three levels of hierarchy, including the goal but not including the level of alternatives (Mahdi and Alreshaid, 2005, Ghavamifar, 2009). They have three to seven elements on the second level, of which at least one is related to owner and one to project. Al Khalil's (2002) model includes a 4th level of hierarchy, at which two extreme states of each factor of the 3rd level are compared

(Figure 2-4). Most models include pairwise comparisons of alternatives and they usually consider the three major PDSs; Design-Bid-Build, Design-build and Construction Management at Risk. Mahdi and Alreshaid (2005) consider Construction Management Agency in addition to the three most common PDSs. Almazroa (2003) provides an AHP model tailored to projects in Saudi Arabia, whereas Ghavamifar's (2009) model is tailored to transit projects, (Figure 2-5).

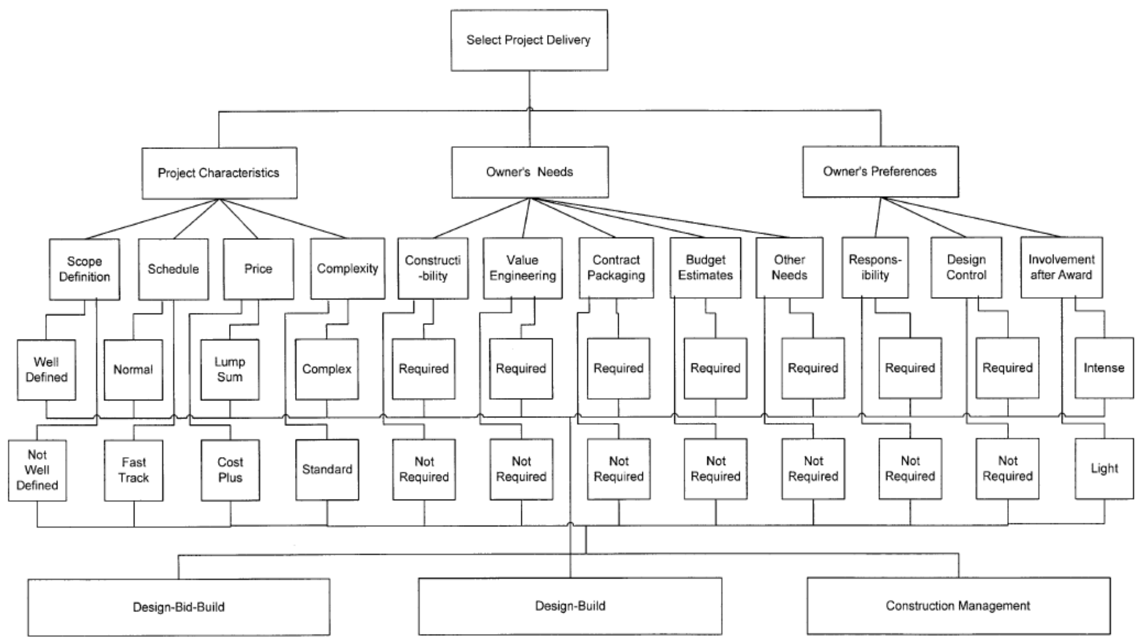

Figure 2-4 Hierarchy design for the project delivery method selection model (Al Khalil, 2002)

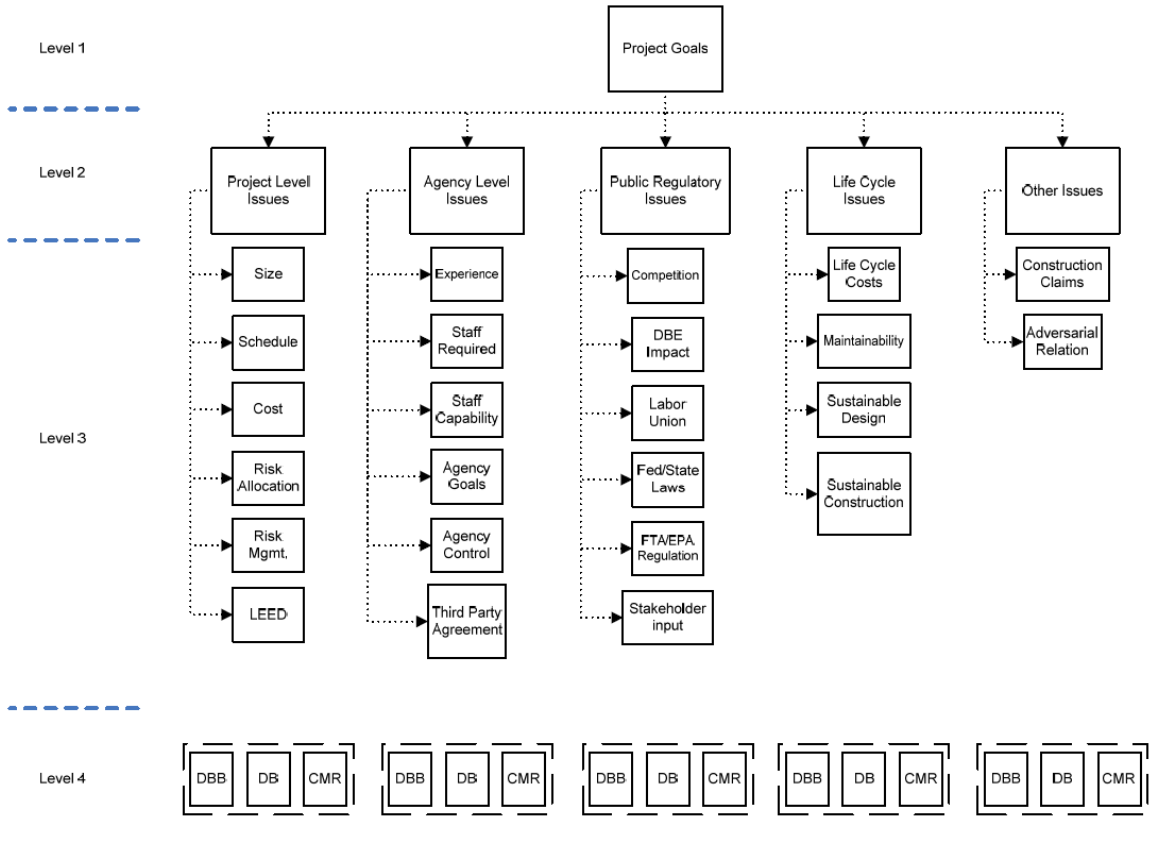

Figure 2-5 – (Hierarchy of Factors Used in AHP Application to PDM Selection, Ghavamifar 2010)

Pooyan (2012) proposed a PDS selection system for post-conflict construction projects, and structured a model which closely resembles a hierarchy (Figure 2-6). However, the three elements in the Main criteria cluster are also influencing each other, making that system a network rather than a hierarchy.

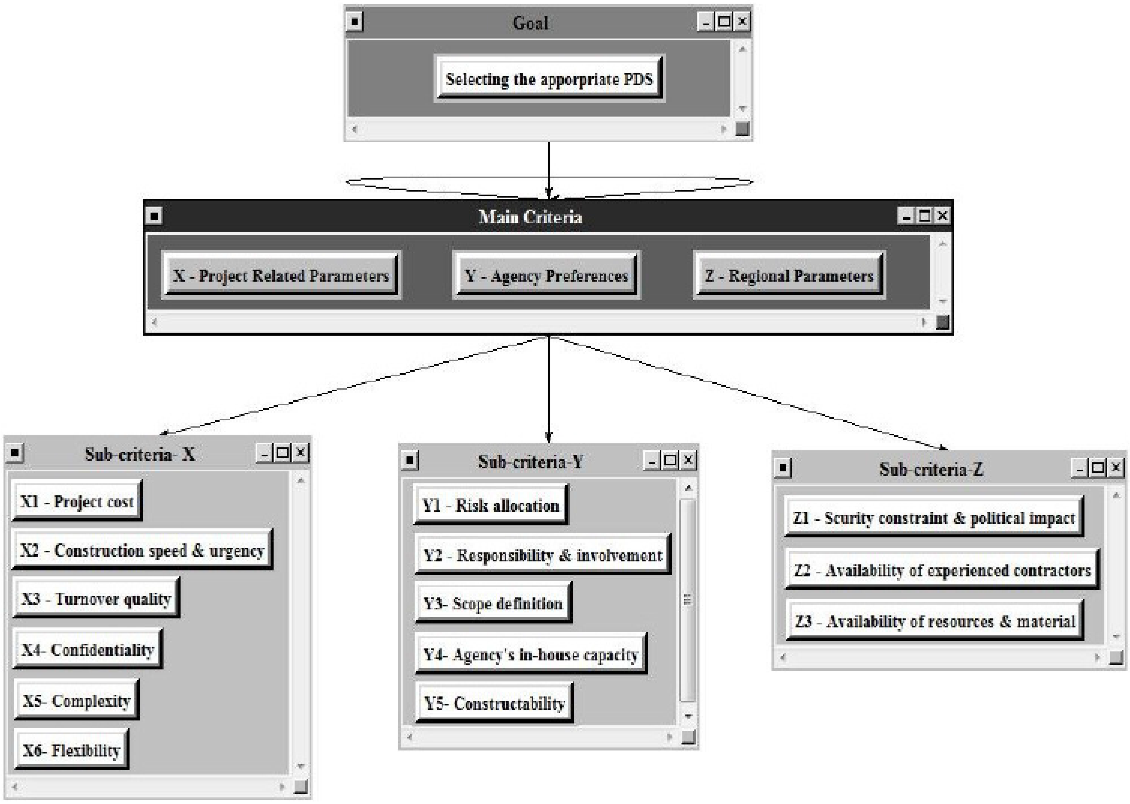

Figure 2-6 - Screenshot of the ANP Model in Super Decision (Pooyan, 2012)

The limitation of including the alternatives in the AHP model is that only a small number of alternatives can be considered in one decision problem. Also, the knowledge of the nature of various PDS's related to their relative effectiveness with respect to specific criteria, which may be regarded as independent of specific projects, is not incorporated in the AHP decision models, but each decision relies on decision-maker's knowledge of PDSs.

2.4.4 Multi-tiered Methods

Multi-tiered methods include one or more steps of eliminating alternatives to select a PDS. Alhazmi and McCaffer (2000) developed a model which includes four levels of screening relevant to PDSs found in construction industry of Saudi Arabia. That decision support system relies on user knowledge, as user evaluates PDSs at each stage of screening. Also, user should develop criteria relevant to the project, and not necessarily only rely on the criteria suggested by the system.

Transportation Research Board of the National Academies, published two sets of guidelines, one for airports and the other one for transit projects, developed in parallel (Touran et al., 2009a, b). Both guidelines have similar first two tiers, whereas the guidebook of transit projects includes a third tier. A higher tier is triggered only if a lower tier does not lead to a clear decision. Alternatives are the three most common PDSs: DBB, CMR and DB, and, in addition, Design-Build-Operate and Maintain (DBOM) is considered for transit projects. First tier eliminates PDSs unsuitable for the project based on any of four categories as shown in Table 2-7 and Table 2-8.

Table 2-7 Go/no-go summary for airports (Touran et al, 2009a)

Issues	DBB	CMR	DB
Project Schedule Constraints	✓/X		
Federal/State/Local Laws		✓/X	✓/X
Third-Party Agreements			✓/X
Others	✓/X	✓/X	✓/X

Table 2-8 Go/no-go summary for transit projects (Touran et al, 2009b)

Issues	DBB	CMR	DB	DBOM
Project Schedule Constraints	✓/X			
Federal/State/Local Laws		✓/X	✓/X	✓/X
Third-Party Agreements			✓/X	✓/X
Labor Unions				✓/X

✓ = Applicable for Further study.
X = Not applicable (discontinue evaluation of this method)
Shaded areas do not need to be considered by the user

First tier also includes review of the advantages and disadvantages of each PDS, as shown in Table 2-9.

Table 2-9 - Project delivery method advantage/disadvantage summary (Touran et al, 2009a)

Airports				Transit Projects				
	DBB	**CMR**	**DB**		**DBB**	**CMR**	**DB**	**DBOM**
Project-Level Issues Rating								
1. Project Size/Complexity				1. Project Size				
2. Schedule Compression								
3. Schedule Growth Control				3. Schedule				
4. Early Cost Precision								
5. Cost Control				2. Cost				
6. Risk Management/Allocation				4. Risk Management				
				5. Risk Allocation				
7. Lifecycle Costs				6. LEED Certification				
8. Maintainability								
Airport-Level Issues Rating				Agency-Level Issues Rating				
9. Airport Experience/Staff Capability				7. Agency Experience				
				8. Staffing Required				
				9. Staff Capability				
10. Airport Control of Project				11. Agency Control of Project				
11. Security								
12. Control of Impact on Passengers and Operations								
13. Third-Party Stakeholder Input to Design and Construction				12. Third-Party Agreement				
Public Policy/Regulatory Issues Rating								
14. Competition and Local Talent				13. Competition				
15. DBE/Small				14. DBE Impacts				

Business Impacts								
				15. Labor Unions				
16. Legal and Statutory Constraints				16. Federal/State/Local Laws				
				17. FTA/EPA Regulations				
				18. Stakeholder/ Community Input				
				Lifecycle Issues Rating				
				19. Lifecycle Costs				
				20. Maintainability				
17. Sustainability and LEED Certification				21. Sustainable Design Goals				
				22. Sustainable Construction Goals				
Other Issues Rating								
18. Adversarial Relationships				24. Adversarial Relationship				
19. Construction Claims				23. Construction Claims				
Other				Other				

PDS alternatives are evaluated as: most appropriate, appropriate, least appropriate and not applicable. A clear winner should be apparent without counting evaluations. Otherwise, second tier follows, which is a weighted-decision matrix. Selection factors are defined based on project goals and pertinent issues, four to seven most important factors are ranked and weighed, and PDS alternatives are scored with respect to those factors. Several methods are suggested for weighing selection factors, including AHP. Third tier Optimal Risk-Based Approach, may be applied to transit projects. Its first phase is a qualitative risk allocation matrix, which may lead to selecting a PDS. Otherwise, quantitative risk analysis may follow, in which only the risk factors affected by the choice of PDS should be considered.

2.4.5 PPP decision

Decision for PPP is delicate as there is controversy regarding PPP advantages. Governments around the world recommend that PPP candidate projects should be screened for suitability, before detailed analysis, which includes market sounding and value for money analysis (VFM). HM Treasury VFM Assessment Guidance (2006) offers a method for evaluating PFI versus traditional delivery, which includes a quantitative and qualitative assessment. Qualitatively, the delivery alternative must satisfy three major criteria: viability, desirability and achievability. Viability means that "suitable long term contracts can be constructed, and strategic and regulatory issues can be overcome." Desirability means that "PFI would bring sufficient benefits that would outweigh the expected higher cost of capital and any other disadvantages." Achievability refers to favorable assessment of the market, the public agency's resources and attractiveness of the proposal for the market. PPP procurement process is usually longer than that of traditional delivery and it requires greater engagement and knowledge of both the public and private sector. Public owner must understand the extent and complexity of the process and be able to dedicate knowledgeable staff and consultants so that the project requirements may be well defined for all aspects of the project, and proposals properly evaluated. Also, there must be enough time for the multiple stage competitive process, evaluation of proposals and negotiations. (HM Treasury, 2006)

PPP Canada recommends the screening criteria listed in Table 2-10. Public-Private Partnerships Guide for Municipalities (CCPPP, 2011c) lists similar screening criteria.

South Africa PPP Manual lists the screening listed in Table 2-11 and value drivers in Table 2-12 (World Bank Institute, 2012). Ghavamifar (2011) focused on transit projects proposes the screening criteria, in Table 2-13.

Table 2-10 – High Level P3 suitability screening criteria (PPP Canada, 2011), Canadian Council for Public-Private Partnerships, 2011c)

	Screening criterion*	Relevant consideration(s)*	Project condition	Suitability for PPP **	Meaning of factor in screening the project for PPP ***
1	Project size	Is the project's size sufficient to support the P3 costs?	Yes	+	Critical
			No	-	
2	Contract bundling	Is there potential to bundle a number of contracts into a single long term contract?	Yes	+	Critical if projects are otherwise too small for PPP
			No	-	
3	Nature of the project	Is the project a new build or a refurbishment?	New	+	Suitable for PPP
			Refubr.	-	Some models not suitable
4	Project integration	Is the project separated or integrated with existing assets or networks?	Separ.	+	Suitable for PPP
			Integr.	-	Some models not suitable
5	Consistency	Will the performance requirements and use of the project be relatively stable over time?	Yes	+	Suitable for PPP
			No	-	Some models not suitable
6	Performance Measurement	Can service performance be easily described and measured?	Yes	+	Suitable for PPP
			No	-	Some models not suitable
7	Asset life	Does the asset have an expected useful life greater than 20 years?	Yes	+	Enhanced PPP potential
			No	-	
8	Maintenance requirements	Does the project have significant maintenance requirements?	Yes	+	Enhanced PPP potential
			No	-	
9	Refurbishment requirements	Is the refurbishment cycle for the project relatively predictable and	Yes	+	Enhanced PPP potential
			No	-	

		stable?			
10	Limiting Factors	Are there stakeholders and/or other factors that influence transferability of the project's maintenance and operations?	Yes	-	Some models not suitable
			No	+	Suitable for PPP
11	Innovation	Is there scope for innovation in design construction or operations?	Yes	+	Enhanced PPP potential
			No	-	
12	Revenue	Is there scope for the private partner to generate additional ancillary revenues?	Yes	+	Enhanced PPP potential
			No	-	

* PPP Canada, 2011

** Canadian Council for Public Private Partnerships, 2011c
*** Interpretation by the author based on Canadian Council for Public Private Partnerships, 2011c

Table 2-11 PPP Potential Screening Factors in South Africa (South Africa National Treasury. 2004, World Bank Institute, 2012)

	Screening criterion	Explanation
1	Scale of the project	Are transaction costs likely to be justified?
2	Outputs capable of clear specification	Is there reason to believe we can write a contract that will hold provider accountable?
3	Opportunities for risk transfer (and other PPP value drivers)	Is there good reason to believe that a PPP will provide value for money compared to the alternative of traditional public procurement? That is: to achieve appropriate risk allocation—so risks are largely allocated to the party best able to control or bear them—and capitalize on the PPP value drivers*?
4	Market capability and appetite	Is there a potentially viable commercial project and a level of market interest in the project? Assessing market appetite may require initial market sounding with potential investors.

*PPP value drivers are explained in the same resource and listed in Table 2-12

Table 2-12 PPP Value Drivers (World Bank Institute, 2012)

PPP Value Drivers	
Risk transfer	Portion of risk of owning and operating a facility may be transferred to a private party
Whole of life costing	Integration of design, construction and operation is an incentive to minimize overall lifecycle cost
Innovation	Performance as opposed to prescriptive specifications and competition encourage innovation
Asset utilization	Private party may establish additional revenue streams
Focus on service delivery	The private party in delivering the specified services is not distracted by other objectives and concerns that a government agency is likely to have
Predictability and transparency of costs and funding	An agreement, which includes anticipated growth and upgrade requirements, minimizes uncertainties of long-term costs for the government
Mobilization of additional funding	Private sector may be more efficient in charging users for the use of facility and it may have access to additional sources of financing
Accountability	Satisfying expected performance level of facility is a condition for service payments

Table 2-13 – PPP screening criteria for transit projects, (Ghavamifar, 2008)

	Screening criterion	**Explanation**
1	Project size	Capital cost
2	Investment environment	Readiness of financial institutions to invest in a project, government subsidies, grants and guarantees as appropriate for the project business profile
3	Project viability	More complex evaluation due to length and complexity of PPP contracts
4	Private sector capacity	Are there competitors technically and financially capable of delivering the project?
5	Risk allocation	Reasonable transfer of risks to the private sector without imposing a huge cost on the owner

6	Competency of public agency	High and diverse management skills required due to integration of functions and complexity, could be in-house or by consultants
7	Potentials for improving Value for Money (VfM)	Preliminary evaluation of expected efficiencies, such as lower lifecycle cost and shorter schedule
8	Development of performance specifications	Owner must be able to develop performance specifications to guarantee performance of completed facility as this is the main contract document

All these sources agree that project size, as well as the ability to define the project requirements through performance specifications, are of utmost importance. All of these sets of criteria represent guidelines, but do not provide a clear path i.e. a method to determine whether a project is suitable or not suitable for PPP. They require interpretation by the user, research of project conditions and its context, and judgement in evaluating what might be critical, and what represents a strong potential for value for money or a reasonable risk transfer.

Ontario Ministry of Infrastructure (2004) states that PPP applies to Major Redevelopment and to New Construction and it does not apply to Minor Investments (Deferred Maintenance, Rehabilitation and Refurbishment and Small Scale Redevelopment and new Construction). Other sources mentioned in this section agree that sufficient project size, which may be regarded as capital cost or as lifecycle cost, is critical, as certain costs are higher for PPP, and can only be offset by other benefits of PPP if project is large enough.

The costs that are higher in PPP than in traditional delivery are the cost of private financing, which is higher than the public rate of borrowing, transaction costs, and the risk premiums for the responsibilities transferred (HM Treasury, 2006, PPP Canada 2013). If the PPP model is chosen correctly, then it could be expected that the risk premiums are justified by the transfer of risks. However, the cost of private financing and the transaction costs may or may not be justified, depending on the project size. Transaction costs include management and consultant expenses of defining the project, soliciting, evaluating and selecting proposals, stipends to bidders to enhance competition and to acquire intellectual property, and legal, financial and technical consulting fees in drafting contracts (CCPPP, 2011c).

The cost of private financing is significant for long-term repayment of all or portion of capital cost. PPP Canada (2013), in a discussion of water and wastewater sector suggests that, for small projects with long term-private financing (DBFMO model, <\$30 million capital cost), the cost of private financing is highest, although there is interest in the market for such projects. For medium DBFMO projects (\$30-\$200 million) it is medium, and for large DBFMO projects (>\$200 million) it is least. HM Treasury (2006) states that PFI (UK term for DBFM or DBFMO) “is not considered to be appropriate for individually procured projects with capital expenditure under £20 million or for IT/ICT procurements.”

For models that include only short-term financing (construction financing), such as BF, and DBF, \$50 million is the preferred minimum size from the standpoint of the financial market, however, contractors themselves may provide smaller construction financing amounts (PPP Canada 2013). Among the projects in the CCPPP Project Database (2013) for which cost information was available, the project with lowest capital cost was Port Hardy Water and Wastewater Treatment System, with the capital cost of approximately $4 million, delivered as DBMO. With DBMO model, it is possible that neither short-term nor long term financing is included in a PPP agreement, so projects with low capital cost but intense maintenance and operations may be suitable for this model.

Tawiah and Russell (2008), suggest evaluating innovation potential of a PPP along with other drivers to evaluate relative efficiencies and to quantify potential benefits of a PPP versus the non-PPP models (public sector comparator). Russell, Tawiah and De Zoysa (2006) define 22 factors of innovation and suggest influences among those factors as shown in Figure 2-7, where arrows represent direction of influence. Tawiah and Russell (2008), define three states for each factor - lowest, moderate, and highest ability to drive innovation, and suggest relative weighing of the factors.

Projects that are evaluated as suitable, based on the screening criteria including the market sounding require a detailed value for money (VFM) analysis, to obtain approval for PPP procurement. Value for money (VFM) assessment is a method of comparing project delivery alternatives for a project. It has been most often used to compare a PPP delivery alternative (shadow bid) with a traditional delivery (public sector comparator or PSC), and determine which is more beneficial to the public. The World Bank Institute

PPP Reference Guide (2012) suggests that a VFM analysis could also be performed to evaluate various PPP options against one another.

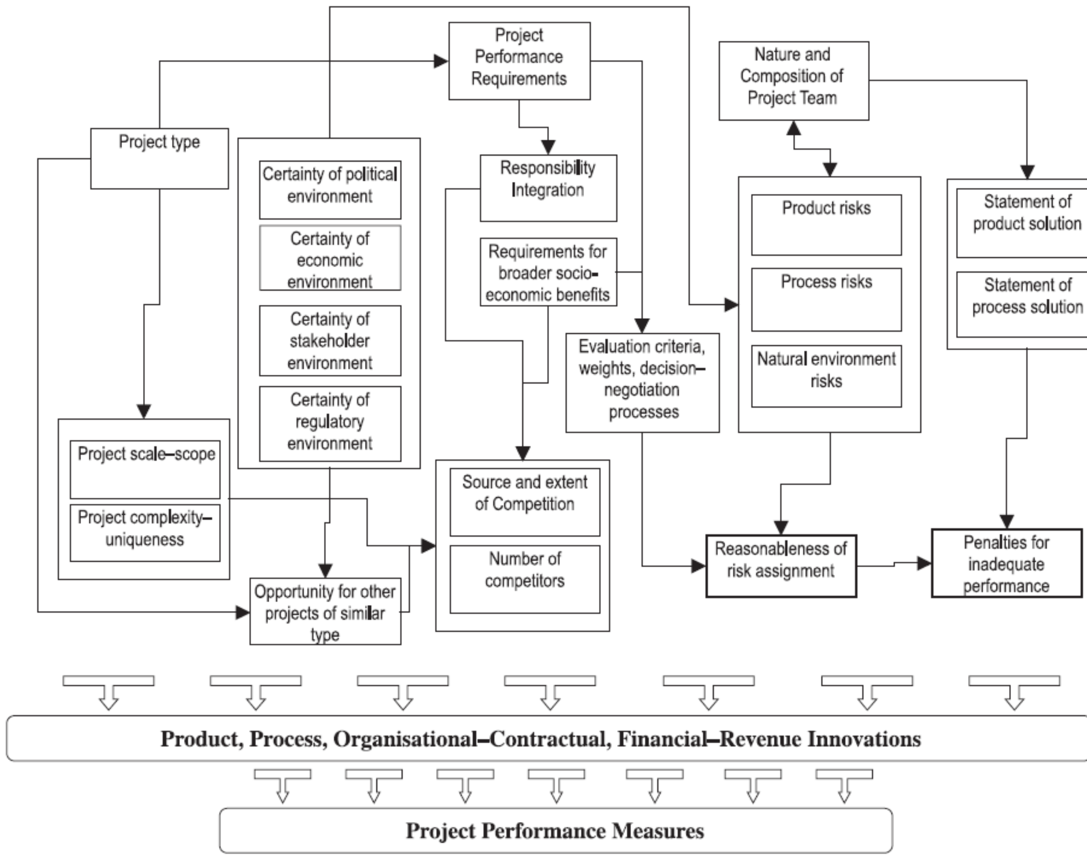

Figure 2-7 - Interaction between factors and conditions to create drivers and inhibitors of innovation (Russell, Tawiah and De Zoysa, 2006)

According to Ontario Ministry of Infrastructure (2004) "the option providing the best value for money is the one that uses the fewest resources to achieve desired service outcomes, . . . considering a broad range of factors including service levels; cost; promotion of growth and employment; environmental considerations; and other health, safety and economic issues." HM Treasury (2006) defines VFM as"the optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user's requirement."

A widely adopted approach to VFM analysis is comparison of the risk-adjusted net present values (NPV), over a specific term, of at least one PPP model, called shadow bid and at least one non-PPP delivery system, called public sector comparator (PSC), (PPP Canada, 2011, World Bank Institute, 2012). A less common approach is a cost-benefit analysis, which may involve economic, social and environmental costs and benefits, of the two project delivery options considered, (World Bank Institute, 2012). Differences in favor of PPP are expected to come from transfer of risk to private partner, particularly during operations phase, and the efficiencies of private sector. Transaction costs and higher financing cost must be more than offset by such savings.

British Columbia Ministry of Finance (2002) states that quantitative assessment considers factors that can be expressed in monetary terms, "such as initial capital costs, operating and maintenance costs over the life of a project (adjusted for risks), and ongoing operating costs related to service delivery," and also those factors that can be quantified but not easily translated into monetary terms, such as "number of indirect jobs created by a project, the potential for broader economic stimulus, the level of measurable environmental benefits or the number of people served within a given timeframe." Detailed guidelines for quantitative VFM assessment were published by Infrastructure Ontario (2007) and Partnerships British Columbia (2011). VFM analysis includes uncertain information and requires assumptions regarding discount rates, financing costs, and risk. At a later stage, VFM analysis of received bids may validate some of the assumptions. (World Bank Institute, 2012)

Literature is less clear regarding the methods of qualitative assessment and how the results of the qualitative and qualitative assessments can be aggregated. British Columbia Ministry of Finance (2002) mentions as qualitative factors “the nature (e.g. flexibility) and duration of a potential business relationship, the potential for innovation in service delivery, environmental considerations, community impacts, labor relations issues, or the potential for alternative use of an asset,” and suggests that they “should be assessed using an objective and disciplined approach, such as a multiple criteria or accounts methodology.” Partnerships BC (2011) similarly suggests that qualitative and quantitative assessment should be combined through multi-criteria analysis (MCA), where qualitative criteria should be those that are critical for project success (project goals and objectives) such as “ability to address stakeholder interests, meet environmental obligations and ensure a fair and transparent procurement process.” Competition, innovation, service delivery outcomes and user satisfaction are given as examples of qualitative criteria. Delivery options receive an ‘order of magnitude’ score with respect to each qualitative criterion (limited, good or best) and each criterion is assigned a relative importance weight (Partnerships BC, 2011).

PPP Canada (2011) suggests that, if there is a discrepancy regarding the highest ranked delivery model between the qualitative and quantitative assessments, the models should be reassessed with respect to qualitative criteria. PPP Canada further suggests that multi-criteria analysis may be applied such that there is no double counting between qualitative and quantitative factors, and that relative importance of qualitative and quantitative results should be clearly stated (PPP Canada, 2011). Ghavamifar (2009) suggests that in considering multiple criteria, quantitative VFM would have the greatest weight but qualitative factors, such as sustainability or participation of small or medium size enterprises should also be considered. HM Treasury (2006) points that if the quantitative analysis results in marginal difference between delivery models, qualitative analysis should govern. None of the guidelines provide a specific method for qualitative VFM analysis - a set of criteria, a method for MCA, or a method for combining qualitative and quantitative results.

In practice, qualitative assessment is often applied as a high-level screening for suitability, but rarely through multi-criteria analysis. All the VFM reports from the CCPPP Project Database (2013) include quantitative assessments, but few mention qualitative analysis. The reports that do mention qualitative aspects of delivery models list the qualitative advantages of the model chosen, but they don't mention whether any other qualitative criteria may have been considered or what evaluation methods were used.

2.4.6 Summary

In this chapter review of literature was presented. This includes the definitions of project delivery system and historical development of various projects delivery systems. Specific PDSs are defined and described, their advantages and disadvantages discussed and situations when they are suitable are presented. Recent developments in project delivery – Integrated Project Delivery and various models of Public-private Partnership are discussed in greater detail. The chapter provides a review of existing methods for selecting project delivery systems, some of which were developed through academic research, and some are practice guides for government agencies who are construction owners. CII Implementation Resource 165-2 (2003), which served as a basis for developing the multi-criteria analysis model of the proposed DSS, was described in detail. Existing government guidelines for selecting PPP, which provided the bases for the related part of the proposed DSS, are also described in detail.

3 CHAPTER THREE: PROPOSED METHOD FOR PROJECT DELIVERY SELECTION

3.1 Overall 5-tier structure of the decision process

The proposed DSS combines the advantages of previous methods. The multi-tier structure was developed with efficiency in mind, to avoid detailed evaluation of non-practical and non-applicable PDSs. This enables a wide range of alternatives to be considered. The use of AHP/ANP for multi criteria analysis provides a high level of objectivity in determining relative importance of factors, and allows a wide range of factors to be considered. Incorporation of relative effectiveness values of PDSs with respect to selection factors, which expands on the CII research by proposing preliminary values for additional factors and alternatives, has the following advantages. It represents a resource of knowledge about PDSs, and saves the user the effort of researching and evaluating PDSs for every decision. It provides consistency from one project decision to another. Also, it does not limit the number of alternatives to be considered, as do AHP and ANP models which use pairwise comparisons of alternatives, as it is recommended that not more than 7 elements should be in one set of comparisons. All the tiers apply to public projects, whereas only tiers 1, 3 and 4 apply to private projects, as shown in Figure 3-1 and Figure 3-2. Tier 1 involves deciding whether the contemplated scope should be regarded as one project, or if it is more suitable to divide it into components (projects), so that each may be delivered under a different PDS (Popic and Moselhi, 2014b). This is a critical decision because a particular project scope determines the inputs for subsequent stages of the decision process, and affects the suitability of various PDSs. Tier 2 determines whether PPP should be considered for public projects and it also identifies viable PPP alternatives, based on a series of screening criteria (Popic and Moselhi, 2014a). Tier 3 represents a screening process of the PDS alternatives other than PPP. Based on the ten key inputs of the Tier 3, certain PDS alternatives as well as certain Tier 4 selection factors may be removed from further consideration, as not applicable (Moselhi and Popic, 2013). Tier 2 and Tier 3 don't depend on each other's results, so the relative order of the Tier 2 and Tier 3 is not important and they can be applied in parallel. Tier 4 may include one or two parallel processes of multi criteria analysis. Process 1 pertains to non-PPP alternatives. It considers up to 67 selection factors, and ranks the available PDS alternatives in order of suitability (Moselhi and Popic, 2013). Process 1 gives the final decision for private projects and, if based on the Tier 2, PPP does not need to be considered, it also gives the final decision for public projects. If based on the Tier 2, PPP needs to be considered, Tier 4 also includes Process 2, which evaluates PPP alternatives and ranks them (Popic and Moselhi, 2014a). In such a case, the final step is Tier 5, value for money (VFM) analysis, to select between the highest ranking PPP and non-PPP alternatives. Tier 1 decision-making has not been part of any previously described decision framework, although it has been applied in practice. Tier 2, Tier 4, Process 2 and Tier 5 represent a development of the concept described in the PPP Canada, P3 Business Case Development Guide (2011). The concept of elimination first, followed by evaluation of fewer alternatives has been incorporated in several previously developed multi-tiered systems. Tier 4, Process 1, expands upon CII IR 165-2. Tiers 1 through 5 are described in detail in the following sections.

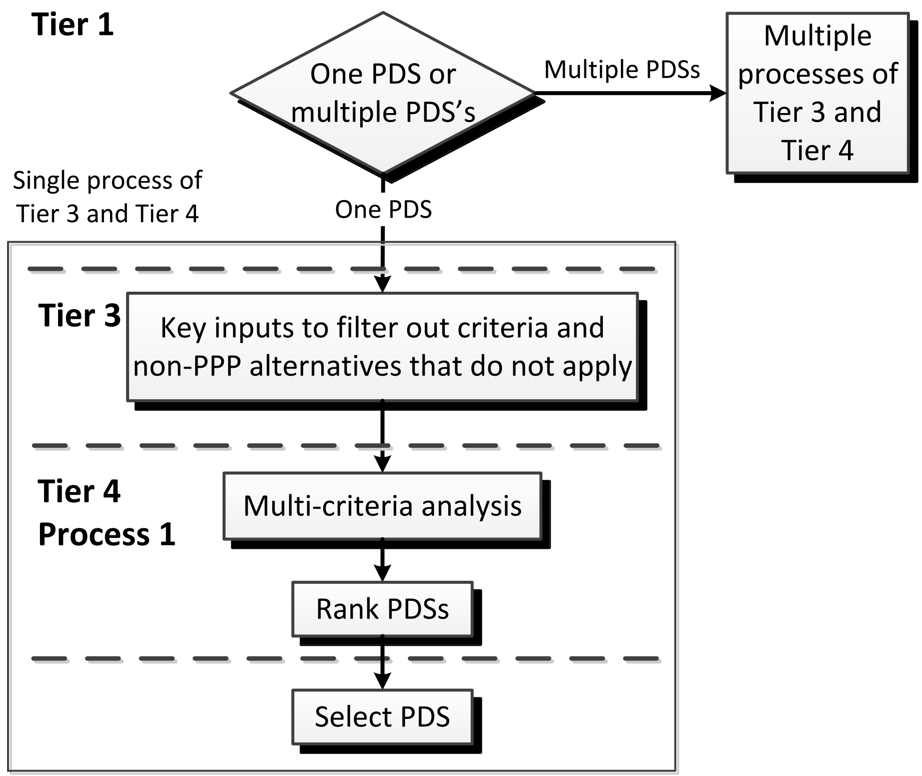

Figure 3-1 PDS selection framework for private projects

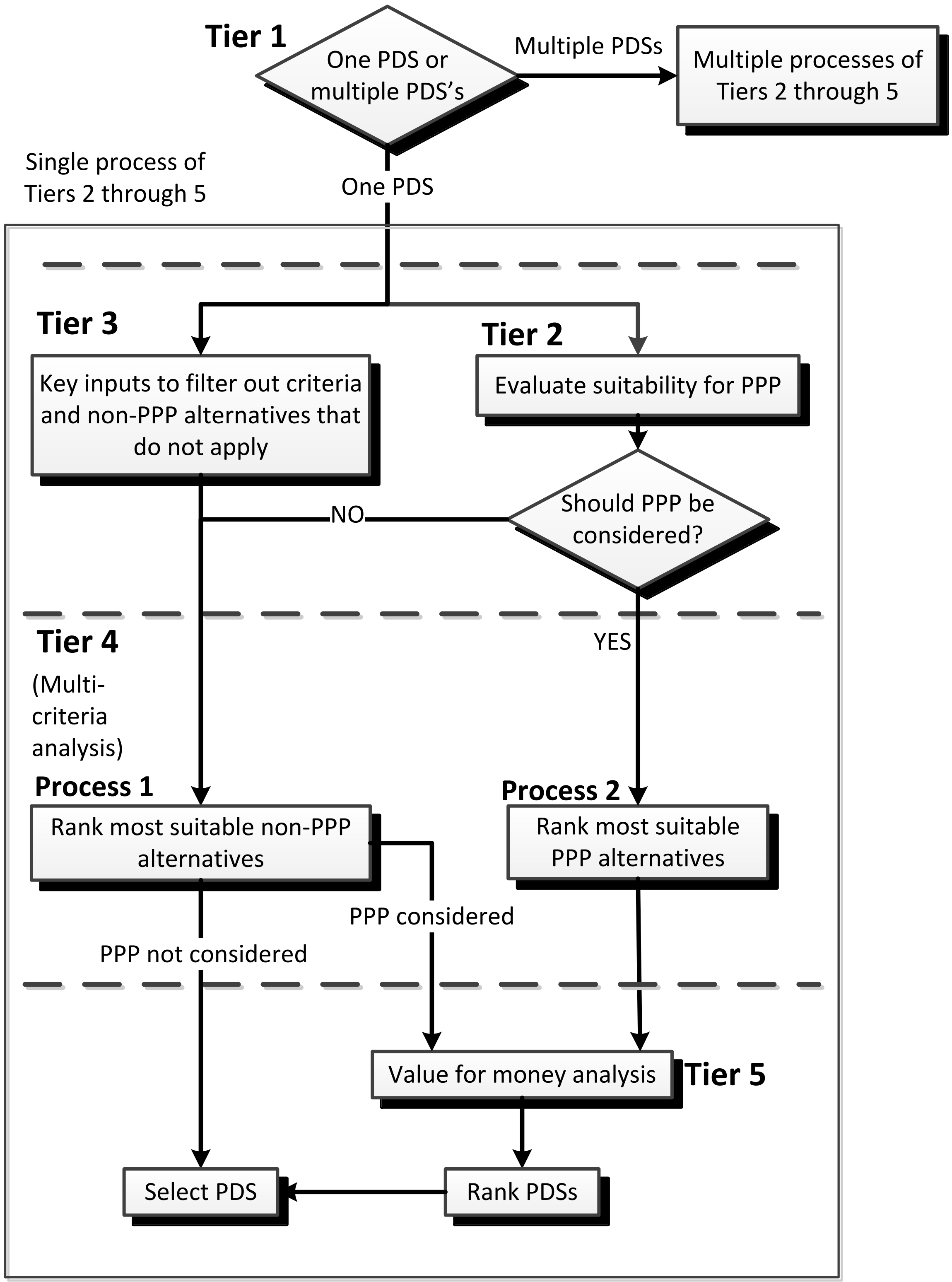

Figure 3-2 PDS selection framework for public projects

3.2 Project delivery systems as alternatives

In addition to the twelve PDS alternatives included in the CII IR 165-2 (2003), listed in Table 2-4, the proposed DSS considers four additional non-PPP alternatives: PDS 13, Design-Negotiate-Build (DNB); PDS 14, Owner-Build (OB); PDS 15, Integrated Project Delivery (IPD) and PDS 16, Engineering-Procurement-Construction Management (EPCM), to account for the current state of practice. The first eight PPP models listed in Table 2-1 is the range of PPP models to be considered as alternatives in the proposed decision support system, whereas the last two models listed in Table 2-1 are subcategories of DBFMOOT, and if this model is selected, one of the subcategories would be selected based on project circumstances. Other combinations may also be possible.

3.3 Tier 1 – One PDS or multiple PDSs

Some projects are complex from the standpoint of PDS suitability, as they may include components for which different PDSs are most suitable. In such cases, it may be suitable to divide the project into distinct components, so that they can be delivered under different delivery systems. The proposed decision process is shown in Figure 3-3. It is important to note that there may be other reasons for dividing the scope into multiple projects, and such projects may or may not be delivered under the same delivery method.

What constitutes a complex versus a simple project? This is relative to each project type and to what the stakeholders are accustomed to.

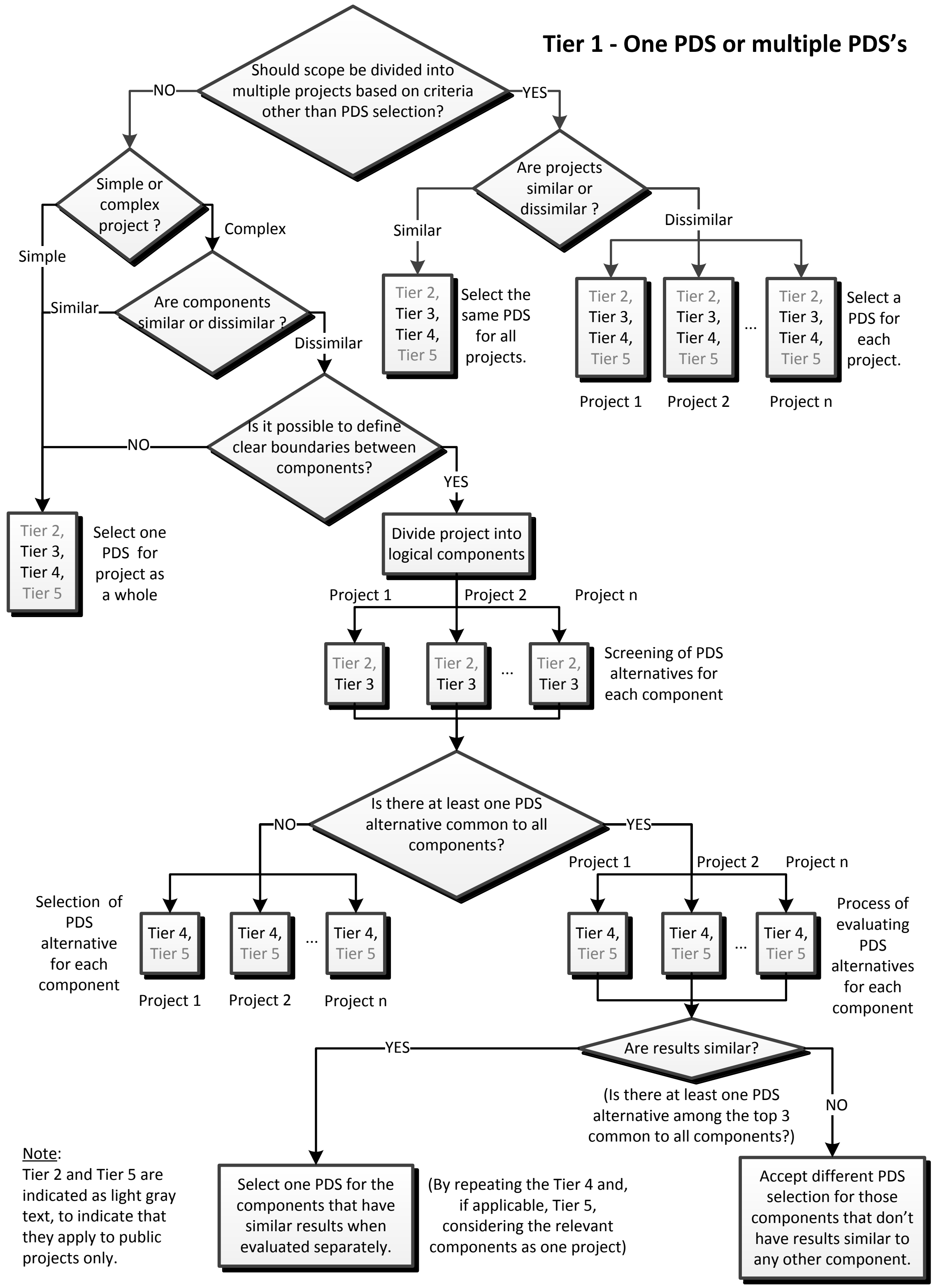

Figure 3-3 Tier 1 decision flowchart

Components may be dissimilar in terms of function, visibility to the public, in general, or to certain groups of users, type of construction, type of expertise and experience required for design and construction, or their urgency of delivery. Components of the project may have different main drivers or priorities, such as space efficiency, energy efficiency, performance of an industrial process, durability, craftsmanship, schedule, aesthetic quality and visual impact, cost etc. Components of the project may also have different needs and opportunities, when it comes to project delivery process, and therefore warrant different PDSs. If the components of the project are to be delivered under different delivery systems, it is necessary to define clear boundaries between the components, and ensure that they can be properly joined. The boundaries are not only physical, as they should ensure the flow of information and the collaboration needed to design and construct the whole complex.

Subsequent steps of the decision process, Tier 2 through Tier 5, described in the following sections, should be applied to different project components. If after the screening processes of Tier 2 and Tier 3 for each component, the components have no remaining PDS alternatives in common, then PDSs should be selected separately by applying the Tier 4 and, if applicable, Tier 5 processes. For those components that have at least one available PDS alternative in common, Tier 4 and Tier 5 processes should also be applied separately and their results compared. If, resulting from Tier 4 and Tier 5, the components don't have, at least one PDS alternative in common among their three highest ranking alternatives, the results should be accepted as different PDSs for those components. If any set of two or more components, have at least one PDS in common among their top three alternatives, then those components may be regarded as one project and a PDS should be selected for that project, by applying the Tier 4 and Tier 5 selection processes and considering those components as one project.

3.4 Tier 2 – PPP or not?

Tier 2 applies only to public projects and evaluates whether any of the PPP models should be considered in the subsequent stages. The criteria are; public agency's resources to carry out a PPP procurement process, project size in relation to suitable PPP models and the capabilities and interest in the market, as shown in Figure 3-4 (Popic and Moselhi, 2014a). As discussed in Section 2.4.5, project size is critical. However, there is no minimum project size for PPP in general, but it is relative to particular PPP models. It is necessary to first examine which PPP models are suitable, based on the high level suitability screening criteria, and then determine if the project size is compatible with those PPP models. If the project size is not compatible with any of the short-listed PPP models, the project is not a good candidate for PPP. Project size suitability may be examined based on guidelines and research, but it should be verified through market sounding. Finally, if there is not enough interest in the market for the project under any of the suitable PPP models, non-PPP delivery should be considered.

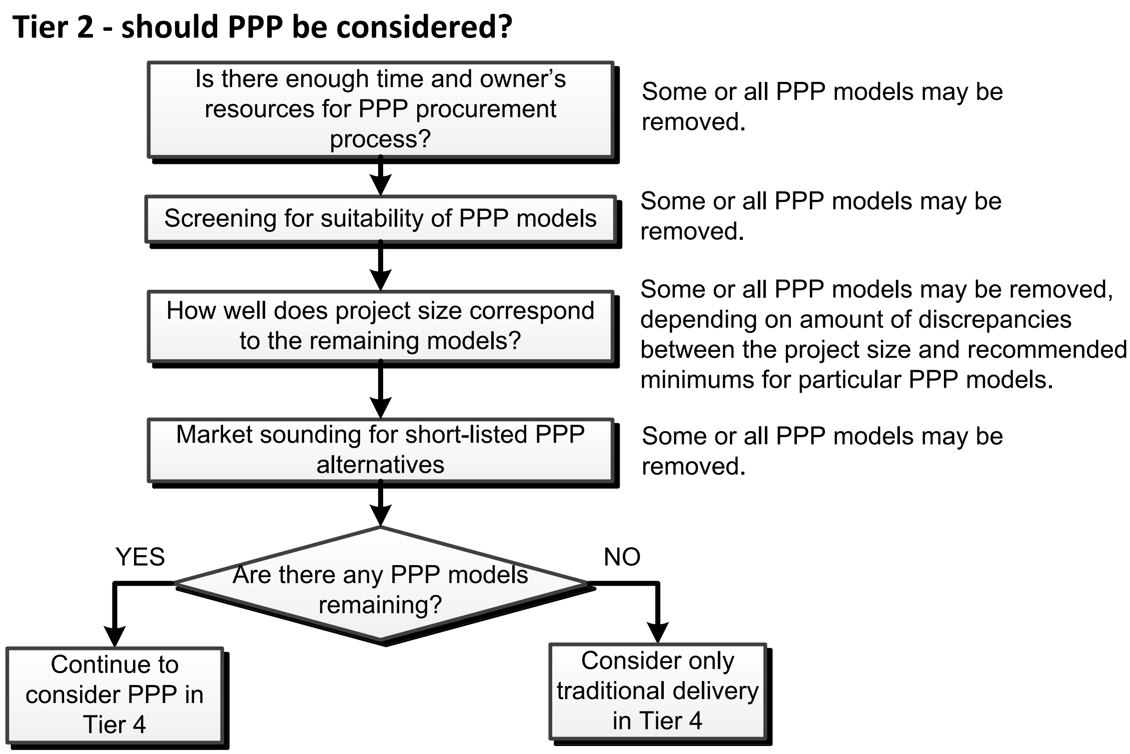

Figure 3-4 Flowchart for decision whether to consider PPP (Popic and Moselhi, 2014a)

3.4.1 Resources for PPP procurement process

Adequate resources for the PPP procurement process, as discussed in section 2.4.5 must exist for any of the PPP models. The greater the scope of responsibilities being transferred to the private partner, the greater the demand on the owner's resources in the procurement process.

3.4.2 High level suitability screening criteria

The set of P3 screening criteria in Table 3-1 was developed based on the set of criteria by P3 Canada (2011), shown in Table 2-10 and expanded through further research and analysis of CCPPP Project Database (2013). A decision maker should evaluate whether to treat all these criteria as eliminatory. For example, criterion 95 (Public agency's experience with operations) may not be considered as eliminatory in every situation. These criteria should be considered in a logical sequence, so that if a criterion at a higher level leads to a decision, criteria at lower levels need not be considered. A suggested hierarchy is shown in Table 3-2. Criteria pertaining to regulatory and public acceptance restrictions take precedence, whereas the sequences of the remaining criteria may be rearranged. In case of a contradiction, i.e. if two criteria at the same level of hierarchy point to opposite decisions, than the decision maker should determine which one of them is more critical and consider that criterion. If both are critical, then no PPP model is suitable. The non-critical criteria should be considered subsequently, in multi-criteria analysis.

Table 3-1 P3 high level suitability screening criteria (Popic and Moselhi, 2014a).

#	Criterion	Source	Meaning	Eliminatory
122	Are there regulatory and public acceptance restrictions to transferring maintenance?	1,3	If yes, maintenance should not be transferred.	Yes
123	Are there regulatory and public acceptance restrictions to transferring operations?	1,3	There may be restrictions on some or all aspects of operations, which would determine which aspects of operations, may be transferred.	Yes
124	Are there regulatory and public acceptance restrictions to transferring ownership of the facility?		If yes, ownership should not be transferred.	Yes
7	Is the completion date critical? If yes, which PPP models can deliver on time and which cannot?		If completion date is critical, than any alternatives that cannot be expected to deliver on time should be eliminated. This could be the case for PPP models that don't transfer design.	Yes
8	Enable the public owner to control detail design.		If this is necessary, design should not be transferred.	Yes

9	Is it possible to clearly define scope and performance requirements, so that detail design can be developed without significant owner participation?		If not, design should not be transferred.	Yes
133	Is it possible to separate operations from maintenance?	4	If not, the models that transfer only one of the two should not be considered.	Yes
132	Does project have significant maintenance requirements?	3	If not, transferring maintenance may not offer significant benefit, and this would be a factor against transferring maintenance.	No
50	Is the project separated of integrated with existing assets or networks?	3	If integrated, this is a factor against transferring maintenance and operations.	No
51	Will the performance requirements and use of the project be relatively stable over time? Can operational flexibility be maintained over the life of the contract at reasonable cost?	2, 3	If answer to second questions is 'no,' then operations should not be transferred.	May be
44	Is the refurbishment cycle for the project relatively predictable and stable?	3	If not, this is a factor against transferring maintenance.	No
125	Is it possible to set clear standards and performance requirements, monitor performance and hold the provider accountable for maintenance?	1,3	If not, maintenance should not be transferred.	Yes
53	Does the asset have an expected useful life greater than 20 years?	3	If not, then a contract that includes long-term financing may not be possible.	May be
101	Ability of public owner to control operations and respond to potential changes of policy.		If this is necessary, transferring some or all aspects of operations may not be possible.	May be
130	What is the size of operations? Are they too small for public agency to carry them out efficiently?		This refers only to the operations that are not a core mission of the public agency. If operations are too small, they should be transferred.	No
131	Is the risk associated with operating the facility acceptable to the public agency?		If not, operations should be transferred.	Yes
126	Is it possible to set clear standards and performance requirements, monitor performance and have the	1,3	If not, operations should not be transferred.	Yes

	provider accountable for operations?			
95	What is the level of the public agency's experience and knowledge with the service or operations that the project will support? Does the project involve technologies that a private party may be more familiar with? Does it seek new solutions that private party may be better able to provide?	1	If public agency does not have enough experience and knowledge with operations, this is a factor towards transferring them.	May be
128	Is there need for long-term private financing?		If yes, then there should be a long-term contract which implies transferring at least maintenance, and may include operations, or operations and ownership.	Yes
153	Is the risk of owning the facility acceptable to the public agency?		If not, ownership should be transferred.	Yes

1 Ontario Ministry of Infrastructure (2004), 2 HM Treasury (2006), 3 PPP Canada (2011), 4 PPP Canada (2013)

Table 3-2 Suggested hierarchy of screening criteria

Hierarchy of PPP screening criteria					
	Responsibility primarily affected				
Order	Design	Financing	Maintenance	Operations	Ownership
1	7,8,9	53	**122**	**123**	**124**
2			**133**	**133**	**153**
3			132	101	
4			51	130	
5			44	131	
6			125	51	
7			53	126	
8				95	
9				128	
10				53	

Bold numbers indicate criteria whose order should not be modified.

Based on the screening process described, it is possible to determine if any of the responsibilities cannot be transferred within a PPP agreement, if any of the responsibilities must be transferred, and if there are combinations of responsibilities that must be maintained. Based on this, PPP models can be short-listed for further consideration.

3.4.3 Project size

Having short-listed applicable PPP models based on screening criteria, it should be determined whether a project is of suitable size for all, some or none of the models available. However, if a project is too small for a certain PPP model, the possibility of bundling several projects into the same PPP agreement, should be evaluated (PPP Canada, 2011, PPP Canada 2013). Also, Combining maintenance and/or operations in one contract with construction, can result in a contract size sufficient for PPP, even if the capital cost is low (PPP Canada, 2013).

For PPP models that don't include private financing or only a short-term private financing, any project size may be suitable for PPP. For projects that include long-term financing various guidelines and recommendations exist, regarding minimum capital cost, which range around $30 million (HM Treasury, 2006, PPP Canada, 2013), as discussed in section 2.4.5. This stage of the proposed method, evaluating PPP models available with respect to project size, is presented conceptually. The evaluation should be informed by the precedent - what PPP models, if any, were used for projects of similar type and size, and with what level of success? The evaluation of suitability of PPP models, with respect to project size, must also take into account the findings of the following stage of the process – the market sounding.

3.4.4 Market Sounding

This stage of the process evaluates whether enough competitors, suitable in terms of experience, and technical and financial capacity can be expected, to ensure an optimal level of competition throughout the procurement process, and how the level of competition may vary for the PPP models considered. The market players may include potential lenders, equity providers, construction contractors, or other relevant entities. Publications such as HM Treasury (2006) and PPP Canada (2011) suggest methods for market shrouding and advice for appropriate government personnel to keep abreast of the market for their projects. Based on the results of the market sounding, the range of available PPP models may be further reduced.

3.5 Tier 3 - Key Inputs

Tier 3 represents a screening process. It solicits key inputs, answers ten questions, and, depending on each answer there may be follow-up questions. Most questions do not require a great amount of judgement or research. Based on the key inputs, certain PDS alternatives, as well as certain selection factors may be removed from further consideration, as not applicable. The ten questions may be answered in any order. They are as follows (Moselhi and Popic, 2013):

Q1: "Is this a public or a private project?" If the answer is 'public, the follow-up question is Q1a: "Are there restrictions regarding the use of certain PDSs?" These may be regulatory or policy restrictions such as those that mandate the open competitive bidding for construction contracts, or separate contracts for design and construction. If the answer is ‘yes,’ then a decision is asked to indicate which PDSs are permitted and others would be removed. Also, if the answer to Q1 is ‘public,’ none of the selection factors are removed. If the answer to Q1 is ‘private’ than none of the PDS alternatives are removed, and the factors F18 (Small business impact) and F34 (Agency goals and objectives) are removed.

Q2: “Are the scope and requirements defined sufficiently so that the design can be developed without significant owner participation, or could they be developed sufficiently before issuing an RFP?” If the answer is ‘yes,’ all PDSs remain, and the Factor 32 (Efficiently utilize poorly defined scope) is removed. If the answer is ‘no,’ then PDS 7 (Design-build or EPC), PDS 8 (Multiple Design-build) and PDS 11 (Turnkey) are removed, and the factors F9 (Capitalize on well-defined scope), F25 (Minimize owner’s involvement) and F41 (Low likelihood of change are removed).

Q3: “Does the owner need to have significant control of design throughout the design process?” If the answer is ‘yes,’ then, as in Q2, PDS 7, PDS 8 and PDS 11 are removed. Factors F25 (Minimize owner’s involvement) and F43 (Minimize owner’s controlling role) are removed. If the answer is ‘no,’ then no PDSs or factors are removed.

Q4: “Do you estimate the time for project completion to be sufficient for the design to be completed before the construction starts?” If the time for project completion is not important, than this input is not relevant, but this is rarely the case. This question requires preliminary estimates of the time needed for design and construction. If the answer is ‘sufficient time,’ PDS 12 (Fast Track) is removed. If the answer is ‘not sufficient time,’ then PDS 1 (Traditional Design-bid-build), PDS 3 (Traditional with PM agent), PDS 4 (Traditional with CM Agent) and PDS 5 (Traditional with early procurement) and CM are removed. No factors are removed.

Q5: “Is owner able to dedicate significant staff resources for the design and construction process? Select yes or no for default values, or select for each PDS, whether owner is able to dedicate adequate staff resources.” If the answer is ’yes,’ by default, none of the PDSs are removed, and factor F10 (Owner’s staff resources are limited) is removed. If answer is ‘no,’ the following PDSs are removed by default; PDS 1 (DBB), PDS 2 (DBB with Early Procurement), PDS 9 (Parallel Primes), PDS 12 (Fast track), PDS 13 (DNB), PDS 14 (OB) and PDS 15 (IPD).

Question 6: “Is the owner comfortable with exploring an unfamiliar method of project delivery on this project?” If the answer is ‘yes,’ then no alternatives and no factors should be removed. If the answer is ’no,’ then the decision maker should indicate the PDSs that the owner is comfortable using while the others are removed. Also, factor F79 (Market position) is removed.

Question 7: “Please select an estimated project size category.” Five size ranges are bounded by $10 million, $50 million, and $1 billion. 10 million was indicated as a threshold for DB by USDoT (2006), 50 million indicates a range defined by CII (2002) and 1 billion is a definition of a mega project (Merrow, 2011). If size is less than $10 million, PDS 3 (Traditional with PM agent), PDS 4 (Traditional with CM agent), PDS 5 (Traditional with early procurement and CM agent) PDS 6 (CMR), PDS 7 (DB), PDS 8 (Multiple DB), PDS 10 (Traditional with staged development) PDS 11 (Turnkey), and PDS 12 (Fast-Track) are removed. If size is greater than $50 million, than PDS 15 (OB) is removed, but the decision maker may override this by indicating the size range that he may be capable in performing with his own forces.

Q8: “Please select the level of project complexity?” Three levels are suggested: high, medium and low. If complexity is low then PDS 6 (CMR) and PDS 15 (IPD) are removed and factor F2 (Project complexity) is removed. However, if the project is being considered for a pilot IPD project, then PDS 15 should be kept in consideration. If complexity is medium PDS 14 (Owner-build) is removed, and the decision maker can override this. If complexity is high, then PDS 9 (Parallel primes) and PDS 14 (Owner-build) are removed

Q 9: “Does the owner prefer to transfer risk to contractors, as much as possible, or accept some risk?” If the answer is ‘transfer’ than the following PDSs are removed: 1 DBB, 2 DBB with early procurement, 3 PMA, 4 CMA, 5 DBB with early procurement and CMA 9 Parallel Primes, 10 DBB with staged development, 12 Fast track, 13 Design-negotiate-build, 14 Owner-build, PDS 15 (IPD), and PDS 16 (EPCM). Factor 68 (Apportion risk equitably and share rewards) is removed. If the answer is ‘accept some risk,’ than no PDSs are removed and the factor 3 (Reduce risk or transfer risk to contractor(s)) is removed.

Q10: "Are there contractors available and qualified to deliver the project under the PDS considered? Indicate for each PDS. For IPD, do you expect to be able to assemble a suitable team for successful application of Integrated Project Delivery?" This input requires the decision maker to have an insight in the market.

It is possible that the key inputs result in no available alternatives. This is the case when the owner wishes to have control of design and to also transfer risk to the greatest degree possible. In such a case, the decision maker should prioritize one of the objectives on account of the other. If only one alternative is available, then the process of selecting a non-PPP alternative is complete.

3.6 Tier 4, Process 1 - Select the most suitable traditional (non-PPP) alternative

Process 1 of the Tier 4 is a multi-criteria analysis, which expands upon the process described in CII IR-165-2, by introducing AHP and ANP to determine weights (preference scores) of selection factors, and by considering additional ranges of selection factors and PDSs. The output of the Tier 4 represents ratings and ranking of the PDS alternatives. In Process 1 of Tier 4, the alternatives are not included in the AHP/ANP models, but rather, the AHP and ANP are used to determine the relative weights (priorities) of all the factors. Then, similar to the weighted sum approach and to MAUT, the rating of any PDS represents a sum of the relative effectiveness values (REVs) of that PDS with respect to relevant selection factors, weighted by the respective relative priorities of factors. Therefore, the PDSs are not compared to one another through pairwise comparisons, but rather their REVs are considered constant for each selection factor, i.e. not changing from project to project. This enables the use of REVs established in the CII-IR 162-5 (2003).

In selecting a PDS, interdependencies among factors of different categories exist. Therefore, as part of the development of the proposed DSS, ANP is considered for its expected suitability. Relative suitability of AHP and ANP was considered, by comparing the results of one specific hierarchy structure and one specific network structure for a case study. No previous work was identified that compared AHP and ANP in a PDS selection decision.

3.6.1 Criteria development

Selection factors were identified from more than twenty literature sources. In evaluating the relevance of factors, the question was: can this factor lead towards selecting a particular PDS; do different PDSs satisfy this factor to different degrees? Some of the factors were discarded for not satisfying this criterion. Some of the factors were combined as multiple formulations of the same meaning. One of the factors was discarded because its only relevance to PDS selection was already accounted for by another factor. Ten factors were identified as key inputs, which can eliminate some of the PDS alternatives, and they were included in the previously described Tier 3. Out of those, seven were also included as factors in the multi-criteria analysis (Q2, Q3, Q5, Q6, Q8, Q9, and Q10). Three of those six factors have two states, which are considered as separate factors in MCA. There are 67 selection factors, with respect to which project delivery system alternatives are evaluated. They are shown in Figure 3-5 (Moselhi and Popic, 2013) and explained in APPENDIX A – Factors for PDS selection

3.6.2 Structuring Hierarchy of Criteria

The hierarchy structure was developed by clustering the factors into categories and subcategories. The factors at a lower level of hierarchy influence a criterion at the level above, to which they are connected. Factors that have the greatest influence on a certain objective or condition were grouped together in a cluster. Some factors were identified as representing general ideas and others as representing specific aspects of such general ideas. For example, factor 'Legal and regulatory constraints' represents a general idea or a category, whereas specific types of constrains represent factors in that category. Furthermore, categories were clustered together. For example, two categories 'Legal and regulatory constraints' and 'Political considerations' were grouped into a higher level category 'Regulatory and political considerations,' as they are more similar in nature to one another than to the other categories. Seven major categories were identified for the highest level of hierarchy: Cost, Time, Relationships and Process, Project Characteristics, Owner Characteristics and Regulatory and Political Considerations. Per the AHP theory, the alternatives are evaluated only with respect to the factors at the lowest level of their respective branch, i.e. the factors that are sink nodes (not influenced by any other node). The resulting hierarchy, with the 67 factors at its lowest level, is shown in Figure 3-5.

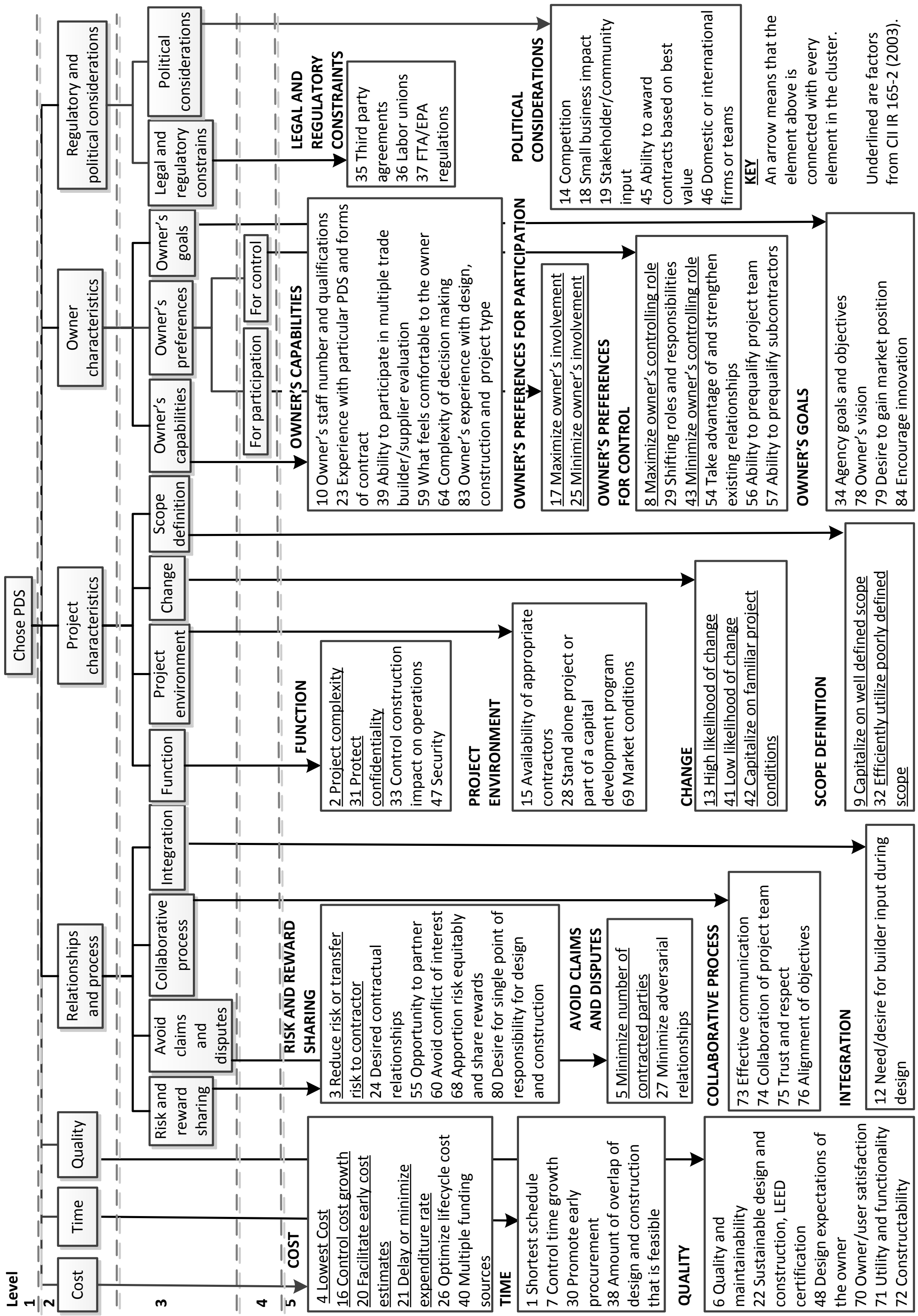

Figure 3-5 Structure of hierarchy model (Moselhi and Popic, 2013)

3.6.3 Structuring the network

Network structure was developed from the hierarchy structure, by adding dependency connections between nodes of the hierarchy (Popic and Moselhi, 2014b). Those additional connections will be referred to as 'network connections.' The principle in identifying such connections was in asking: "Does this factor influence or is it influenced by any other element, aside from those to which it is already connected in the hierarchy." For example factors F20 'Facilitate early cost estimates' and F21 'Delay or minimize expenditure rate' affect cost but also time. To identify network connections, all the factors were considered and sets of two or more factors that may affect an objective were identified, as their relative importance could be meaningfully compared. For example F4 'Lowest cost' and F26 'Optimize lifecycle cost' have opposite effects on F6 'Quality and maintainability.' In developing this network model, the clusters were kept unchanged, from those in the hierarchy model. This means that any new connections that could not be used for pairwise comparisons (i.e. if there were not at least two nodes from the same cluster influencing the same node) were not added to the network. The resulting structure is a network, as there are instances that nodes of one cluster influence, or are influenced by nodes of multiple other clusters, and nodes within a cluster may influence one another. These additional connections enable further pairwise comparisons, which will be referred to as 'network comparisons.' They affect the priorities of all elements in the decision network. This forms a simple network as defined in the AHP/ANP theory without sub networks. The network connections are shown in Figure 3-6. The arrows point from a node that is being influenced to a node that is influencing that node.

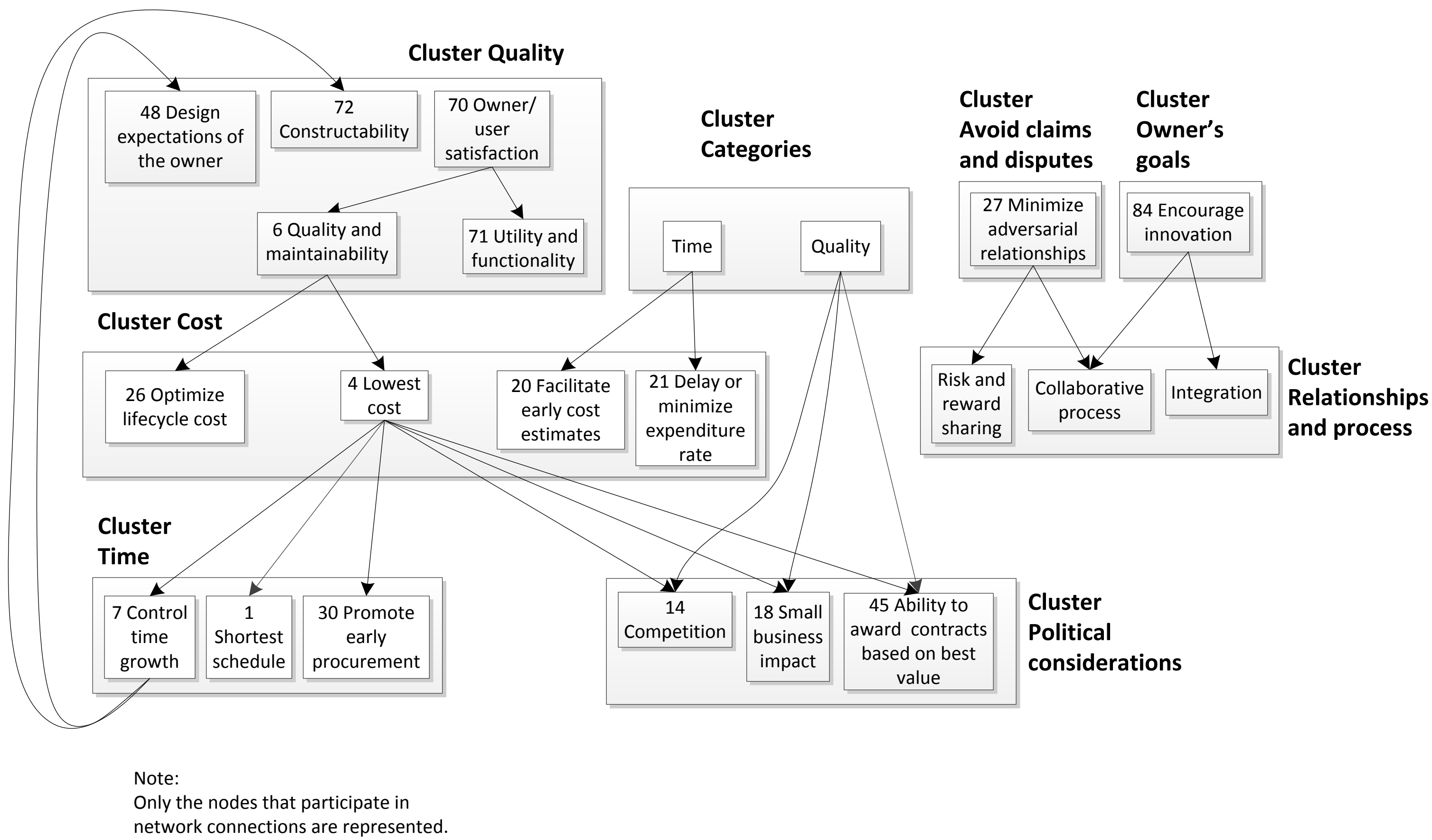

Figure 3-6 Network connections (Popic and Moselhi, 2014b)

3.6.4 Applying the AHP/ANP models

The proposed hierarchy structure, represented in Figure 3-5, is intended for any PDS selection problem. Pairwise comparisons of elements on all levels of the hierarchy that follow from its structure are specific to each decision problem, and they represent user input for Process 1 of Tier 4. Described AHP model has been implemented in the PDS AutoSelect spreadsheet, to facilitate the use of the proposed DSS. The approximate method of calculating priorities described in section 2.4.3 has been applied. In applying the Process 1, before making pairwise comparisons, the non-applicable selection factors are removed from the decision model. Those are the factors eliminated through the key inputs of the previous Tier 3 and also any factors that are otherwise not applicable to the project, based on user's knowledge. In the PDS AutoSelect, factors eliminated though Tier 3 are automatically removed from the pairwise comparisons of Tier 4, and the user is asked to review the remaining factors and to indicate which factors don't apply, before starting with pairwise comparisons.

3.6.5 Relative effectiveness values (REV) of project delivery systems

The 240 relative effectiveness values from the CII IR 165-2 are incorporated in the proposed DSS, and preliminary values for the four additional PDSs and 47 additional selection factors (832 REVs) are proposed. These values were developed based on literature discussing the characteristics of PDSs, and studies of how well they respond to project conditions. Some of the REVs are proposed based on the values established by the CII and the similarities or differences of PDSs with respect to the factors in question. The values were first established as linguistic: low, medium-low, medium, medium-high and high, and then mapped to numerical values of 20, 35, 50, 65 and 80 to enable the use of REV of the CII-IR 165-2, which uses a scale of 0 of 100. It is intended that the user may adjust any of the REVs as warranted.

Some of the REVs are based on other research. Brennan (2011) identified 13 factors as the most critical success factors for overall value creation on large complex projects, and examined relative effectiveness of three PDSs with respect to those factors: DBB, DB and IPD. The following eight factors and their REVs were adopted from Brennan: F70 (Owner/user satisfaction), F71 (Utility and functionality), F72 (Constructability), F73 (Effective communication), F74 (Collaboration of project team), F75 (Trust and respect), F76 (Alignment of objectives), and F78 (Owner's vision).

Brenan's survey results for all stakeholder groups combined from project perspective, were converted from the scale of 1 to 5 to the scale of 0-100. The REVs for the remaining PDSs, with respect to the factors in question, were assigned by interpolation or similarity. One of the 13 factors 'Clear and realistic objectives,' (the ability of a PDS to "maintain clear and realistic project objectives throughout the entire project delivery process," (Brennan, 2011) was not included in the proposed system, because there was not enough basis to assign REVs for the PDSs not included in the survey. The remaining factors identified by Brennan were also identified through other sources. REVs for factor F26 'Optimize lifecycle cost' (referred to as 'Long-term building success and lifecycle value' by Brennan) were assigned by incorporating results of Brennan's research and the discussion of advantages and disadvantages of three PDSs (DBB, DB, and CMR) with respect to lifecycle costs by Touran et al (2009a, b). Two of Brennan's factors, 'Project time performance' and 'Owner/User participation' were included in the proposed MCA model as higher level criteria, so their REVs were not used.

For factor F6 'Quality and Maintainability,' literature sources provide varying results of PDS relative performance. Konchar and Sanvido (1998) defined quality as "the degree to which facility meets expected facility requirements." They measured quality performance through seven metrics for three PDSs, on a scale of 0 (lowest) to 10 (highest). Results are summarized in Table 3-3.

Table 3-3 Mean Quality Scores by Project Delivery System (Konchar and Sanvido, 1998)

Quality Metric	CMR	DB	DBB	Maximum standard error
Start-up	7.43	**7.5**	5.96	0.19
Call backs	**8.07**	7.94	7.04	0.19
Operation and maintenance	6.69	**7.67**	6.88	0.19
Envelope roof structure and foundation	5.36	**5.71**	4.95	0.19
Interior space and layout	**6.28**	6.15	5.19	0.19
Environment	**5.34**	5.24	4.86	0.19
Process equipment and layout	**5.63**	5.61	5.07	0.19

Brannan (2011), asked his survey respondents to evaluate the effectiveness of PDSs to "successfully achieve production of specified quality," and his results are summarized in Table 3-4.

Table 3-4 Relative effectiveness of PDSs with respect to factor Production of Specified Quality (Brennan, 2011)

	Production of Specified Quality		
	DBB	DB	IPD
Self-Interest	3.78	3.03	**3.83**
Project-Interest	3.73	3.03	**3.85**

Merrow (2011) compared four contracting approaches most frequently used on industrial megaprojects: EPC Lump Sum (essentially DB), EPC/EPCM reimbursable (essentially EPCM), Alliances (essentially IPD) and Mixed (essentially DBB). Merrow's findings are summarized in Figure 3-7. Production failures can be considered as a measure of quality.

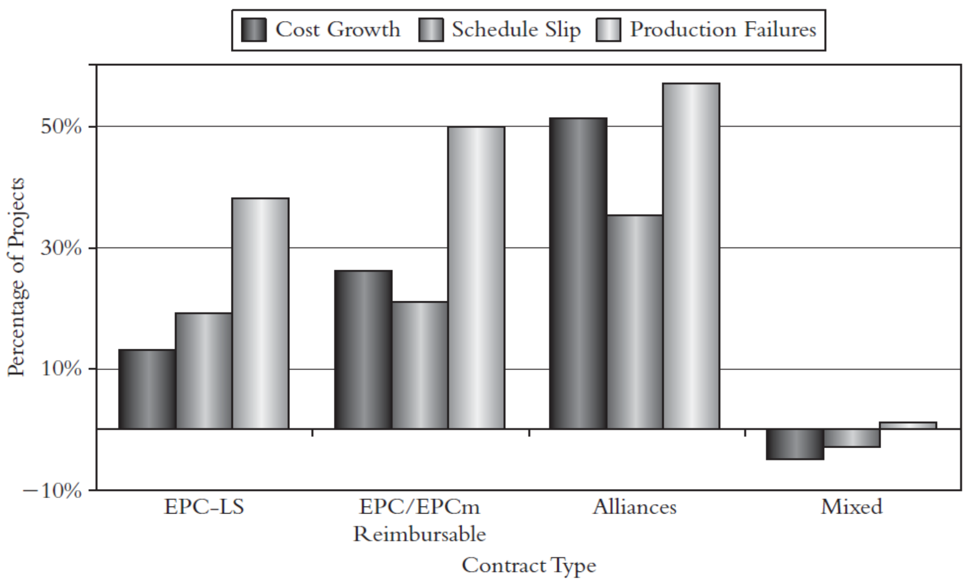

Figure 3-7 Patterns of Outcomes Vary by Type of Contract (Merrow, 2011)

Touran et al (2009a, b) considering airport and transit projects, discuss the advantages and disadvantages of DBB, DB, and CMR with respect to maintainability, which refers to quality and ease of maintenance. They suggest that DB requires greater care on part of the owner in defining the performance criteria and in selecting contractors, to ensure quality and maintainability. The results of all four sources are summarized in Table 3-5. PDS performance with respect to quality cannot be summarized in simple terms and further research is required. Quality performance of PDSs may be related to project type i.e. industry sector. Since quality is paramount to many projects, in the proposed DSS, default REVs are assigned and the user is asked to adjust these values based on the specific project type and best information available.

Table 3-5 Performance of PDSs with respect to quality, by various sources

Source	Konchar and Sanvido (1988)		Touran et al (2009) a, b	Brennan (2011)		Merrow (2011)	
Project types	U.S. building projects		Airports and transit projects	Large complex military medical projects		Industrial megaprojects	
	Criterion	Scale	Criterion	Criterion	Scale	Criterion	Scale
Rank	Quality	0 to 10 (average for 7 metrics)	Maintainability	Production of specified quality	1 to 5	Production failures	% of projects
1	DB	6.55	CMR	IPD	3.85	DBB	~1%
2	CMR	6.4	DBB	DBB	3.73	DB	~38%
3	DBB	5.7	DB	DB	3.03	EPCM	~50%
4						IPD	~58%

The REVs for the factor 84 ‘Encourage innovation’ were determined based on the research of Russell, Tawiah and De Zoysa (2006). These researchers identified 22 factors that can be either drivers or inhibitors of innovation for infrastructure projects, as a function of procurement mode (project delivery system) and project context. Out of those 22 factors, the following seven factors were identified as dependant on the project delivery system: 1) Responsibility integration, 2) Nature and composition of project team, 3) Source and extent of competition, 4) Number of competitors, 5) Proposal evaluation criteria and relative weights decision-making and negotiation, 6) Statement of product solution, and 7) Reasonableness of assigning risk between owner and contractors and attitudes toward risk. To find REVs with respect to factors F84 ‘Encourage Innovation,’ each PDS was evaluated with respect to each of these factors using the previously described linguistic scale, values were converted to numerical ones and, for each PDS, the average value of seven factors was assigned as its potential for innovation, i.e. its REV with respect to factor 84 ‘Encourage Innovation.’

The values for factor F60 ‘Avoid conflict of interest’ were established based on the technical paper “Qualification and Selection of Construction Managers with Suggested Guidelines for Selection Process” by The Committee on Construction Management (1987). That article discusses the relative potential for conflict of interest of various PDSs including the forms and variations of construction management and other delivery systems.

For three factors, the user needs to enter the REV specifically for the owner-project situation. Those are the factors F23 ‘Experience with particular PDS and forms of contract,’ F59 ‘What feels comfortable to the owner’ and F79 ‘Market position (desire to gain experience with a new PDS).’

3.7 Tier 4 – Process 2 –Select the most suitable PPP alternatives

This stage of the decision process represents a multi-criteria analysis of the PPP models that are being considered after the screening process of the Tier 2. The selection criteria, or factors proposed for this analysis have been identified from the literature, primarily from government guidelines on PPP. Moreover, the CCPPP Project Database (2013), and specific project information including PPP project websites and VFM reports, was analysed in order to identify reasons that particular PPP models were selected for specific projects, and to find the relationships between PPP models and project characteristics. ANP was chosen as a method for multi criteria analysis, because of interdependences among some of the selection factors, which are described in the following section.

3.7.1 Development of the multi-criteria analysis model

The decision problem is to find the most suitable PPP model for the project by ranking the available PPP alternatives in the order of suitability. PPP models are distinguished by specific combinations of responsibilities for major project aspects (design, construction, financing, maintenance, operations and ownership), that are transferred to one single private partner. One approach to analyzing the problem is to consider each project aspect independently and determine whether the responsibility for that aspect should be transferred through a PPP. Within the scope of this research, construction is included in all the PPP models considered. The criteria for transfer of each responsibility, i.e. the reasons or factors contributing to the decision that it should or should not be transferred were identified from the literature and the analysis of case studies.

However, the transfers of specific project responsibilities are not independent of one another. Transfer of a combination of responsibility, and not one single responsibility, determines how well a delivery model can respond to some of the project objectives and circumstances. Evaluating PPP models as alternatives allows such combinations of responsibilities to be considered. These alternatives may be evaluated with respect to a wide range of selection factors, and the MCA process must meaningfully combine all the evaluations into one set of results. AHP and ANP are suitable methods for such analysis. One way to cluster selection factors is by project aspects, i.e. the transfer of responsibility for which project aspect does the factor primarily affect. Factors can be meaningfully compared to one another within such groups, as shown in Figure 3-8.

However, factors may be grouped in more than one way, not only according to project aspects, but also according to the major concepts relevant to the project delivery and operation. Such major concepts have been identified as: Competition, Control and flexibility, Innovation, Integration and optimization, Resources and efficiency, Risk transfer and performance guarantees, and Save on risk premiums, profits and consultant fees. Example of a cluster based on this principle is shown in Figure 3-9. Factor F80 belongs to two sets of comparisons. This suggests that the selection problem can be regarded from two standpoints. One is optimizing the whole project delivery by balancing the major concepts, the other one – by finding the best option for each aspect of the project. This is the major organizing principle of the model. Because of the condition that one factor may be influencing multiple other factors, the model represents a network.

After factors were grouped into sets, some of the factors were further grouped into subsets based on similarity or connectedness, and for each subset, an overall idea was identified.

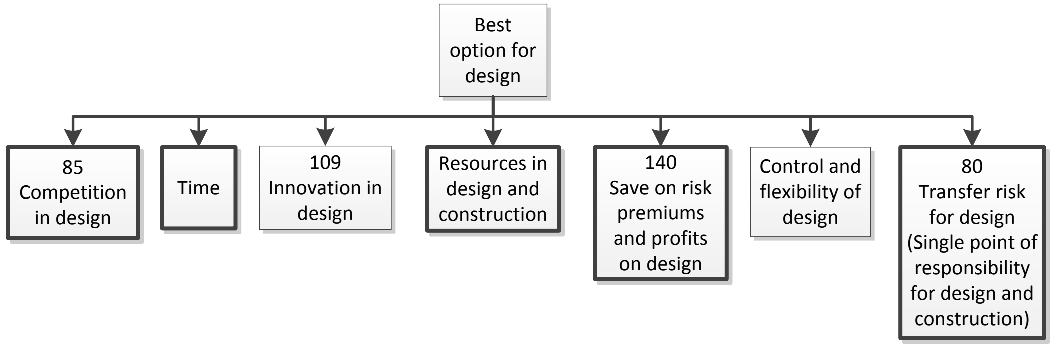

Figure 3-8 Tier 4 Process 2 partial network diagram

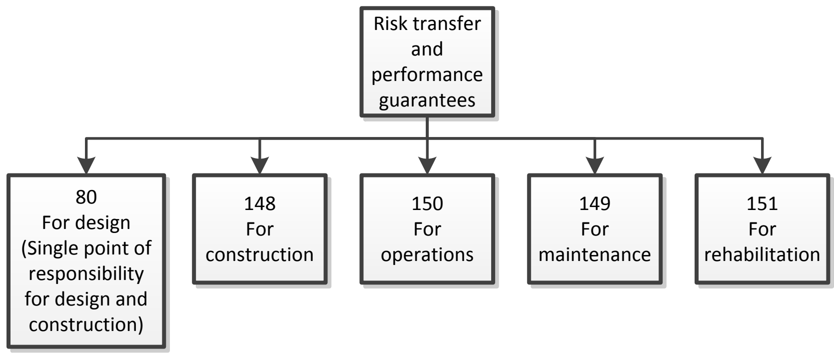

Figure 3-9 Tier 4 Process 2 partial network diagram

For example the factors 8 'Control detail design' and 13 'Scope flexibility for design and construction,' were grouped into a subset 'Control and flexibility of design.' Similar to Process 1 of the Tier 4, some factors may not be relevant to the project and should be removed. Some of the factors have two opposite states, for example 'Certainty of long-term need for facility by the public' has the states 104 'High certainty' and 105 'Low certainty.' When considering such sets of two states, a decision maker may select the state that applies and discard the other if that best corresponds to the project situation, or he may determine a state between the two extreme values, though a pairwise comparison.

The decision network for the Tier 4, Process 2 is represented in Figure 3-10. Rectangles containing multiple elements represent clusters, and rectangles containing only one element represent criteria. According to the AHP/ANP theory, networks are generally not characterized by levels. However, since this network is similar to a hierarchy and it is possible to identify its levels, the term 'level' will be used for this model. The arrows represent dependence, such that the element from which the arrow originates depends on (is being influenced by) the element to which the arrow points. Connections are always between nodes, which may be the overall goal, objectives, factors, or alternatives. Figure 3-10 is a summary representation, as not all the node-to-node connections are shown. The arrows pointing from a node to a cluster or from cluster to cluster represent multiple connections between the nodes inside clusters. Such node-to-node connections are shown in Figure 3-11, Figure 3-12 and Figure 7-1 to Figure 7-10.

Alternatives, which are PPP models, are included in this multi-criteria analysis model, and compared to one another with respect to selection factors. Default REVs for PPP models with respect to factors relevant in PPP selection have not been established. For some factors, the relative effectiveness of PPP models may depend on the project circumstances. For example, for the factor 98 'Private sector efficiency in operations,' the REVs would vary, depending on whether those particular aspects of operations would be transferred to a private contractor regardless of PPP. If yes, then, there may be little difference between a PPP model that includes those operations and the one that doesn't, and if not, than there may be a great difference between such two models.

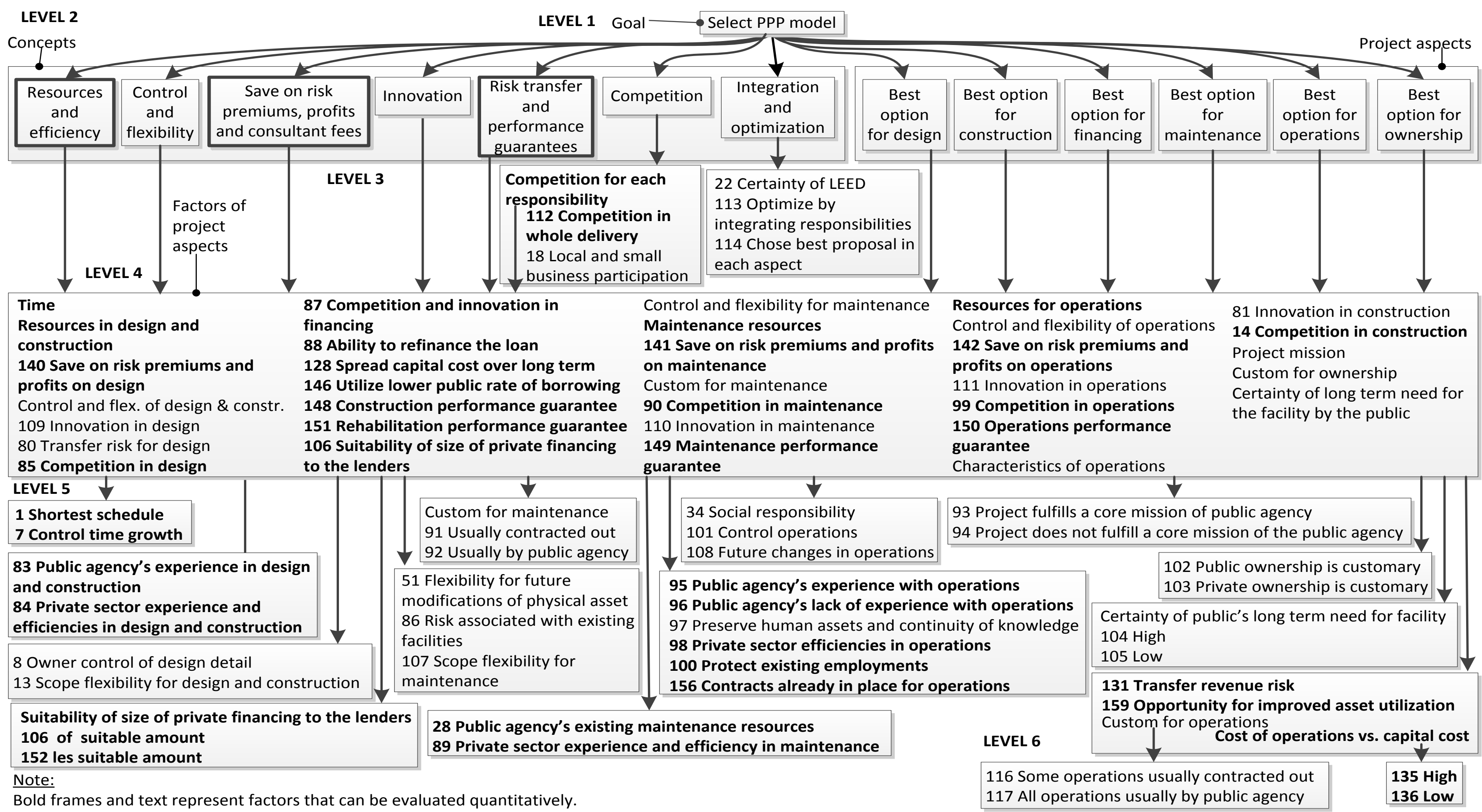

Figure 3-10 Tier 4 Process 2 overall network diagram (Popic and Moselhi, 2014a)

Alternatives are not shown in Figure 3-10. In this network, alternatives are compared to each other only with respect to those factors that are not dependant on other factors in the network. Those factors are assigned numbers in front of their names. There are 61 such factors.

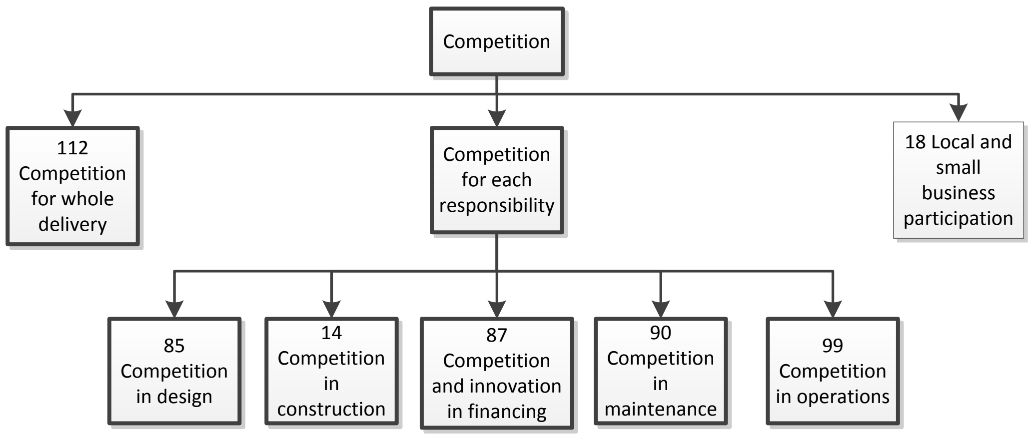

Figure 3-11 Tier 4 Process 2 partial network diagram

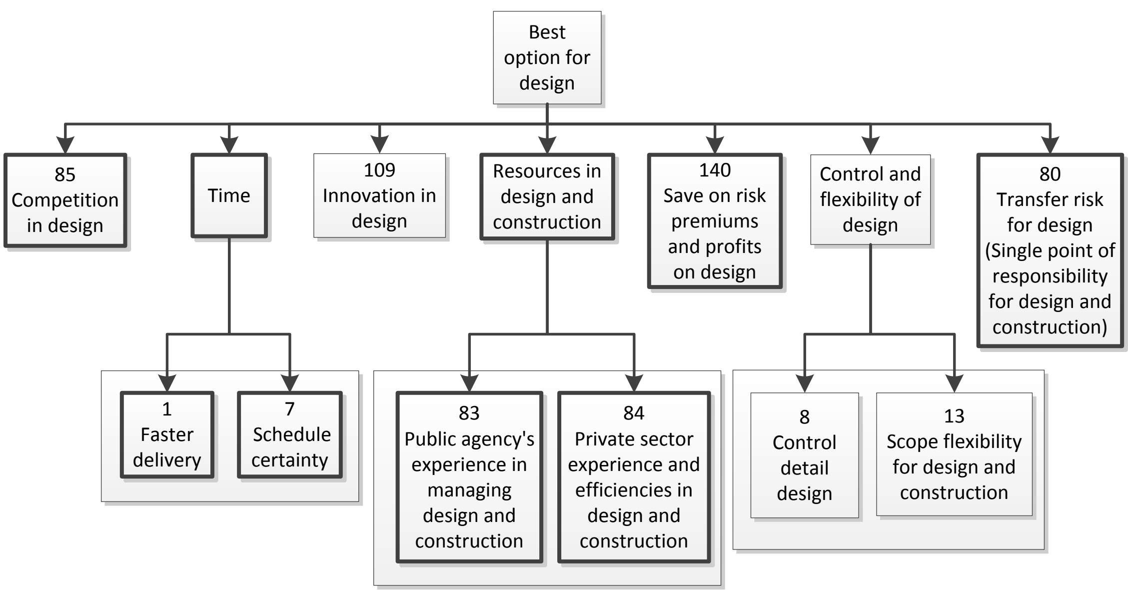

Figure 3-12 Tier 4 Process 2 partial network diagram

3.7.2 Applying the Tier 4 Process 2 model

Before doing pairwise comparisons, factors that don't apply to the project should be removed. Also, some of the selection factors may be removed based on the results of Tier 2, as some of the alternatives may be removed, and because of that, some of the selection factor may not be relevant to distinguish the remaining alternatives. In determining which factors should be removed, it should be established for each factor whether it affects the selection among the remaining alternatives or not.

3.8 Tier 5 – Value for Money Analysis

3.8.1 The proposed method of VFM analysis

The proposed DSS is a development based on the principle outlined in PPP Canada Business Case Development Guide (2011), which recommends that project delivery models, including PPP and traditional (other than PPP) should be short-listed, and that at least two models, one from each category should be evaluated through both qualitative and quantitative detailed VFM analysis, to arrive at an integrated recommendation. Tier 5 of the proposed DSS represents a detailed assessment of the delivery models short-listed, which includes the analysis of both qualitative and quantitative values. Quantitative analysis should be done fist, using the established methods, such as those mentioned in section 2.4.5. Results of qualitative VFM are usually expressed as monetary values.

The qualitative and quantitative assessments are combined through multi criteria analysis, by Analytical Network Process (ANP). In Tier 5, all the delivery models short-listed are evaluated by the same criteria. Those criteria include selection factors relevant in selecting among the PPP alternatives and factors relevant in selecting among non-PPP alternatives. The Tier 5 ANP model integrates the models of Tier 4, Process 1 and Tier 4, Process 2. To limit the effort in making judgements, only the factors that account for 80% of all the factor priorities in each of their respective Tier 4 models are used in Tier 5. Some factors may be common to both sets, as the two models of Tier 4 have some factors in common. Tier 5 multi criteria analysis consists of three principal stages.

3.8.2 Tier 5 Stage 1

The first stage of the Tier 5 MCA consists of structuring an integrated model, (Tier 5 Stage 1 model). An overall conceptual structure is shown in Figure 3-13. It integrates the structures of both Process 1 and Process 2 models of Tier 4. The factors indicated or prefixed by a number are the selection factors, with respect to which, the alternatives are evaluated. Vertical dashed lines define groups of criteria principally related to the same project aspect, whereas horizontal dashed lines indicate a structure that corresponds to the structures of the Tier 4, Process 1 and Tier 2, Process 2. Nodes above the dashed lines are influenced by the nodes below the dashed lines. Since most of the criteria are in one cluster, greater number of comparisons is possible. Dependency connections between the nodes of the clusters Goal, Project aspects and concepts are shown in Figure 3-14, and other connections are shown in Figure 7-11 through Figure 7-20 in APPENDIX B.

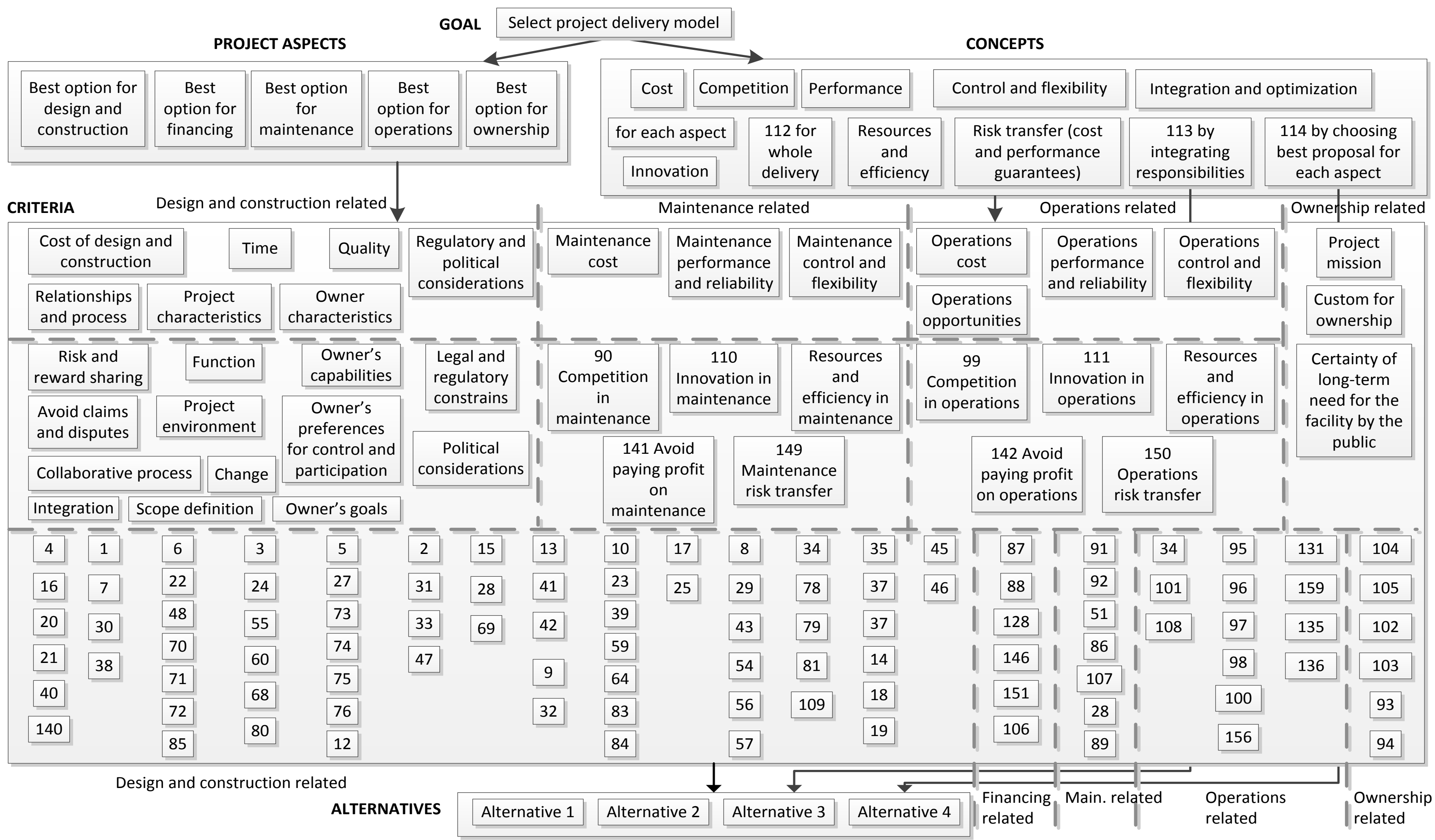

Figure 3-13 – Tier 5 Stage 1 Conceptual network structure

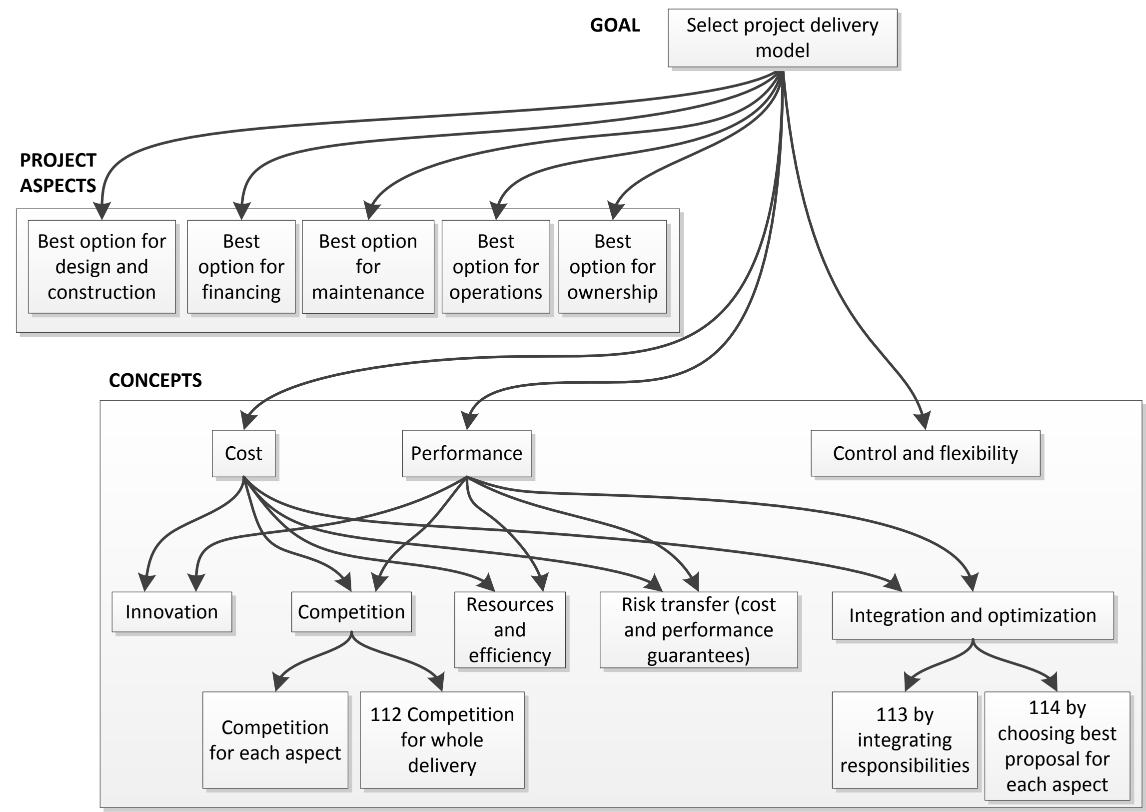

Figure 3-14 Tier 5 dependency connections

The relationships that are not shown in these diagrams are the same as they are in Tier 4, Process 1 and Process 2 for the same nodes. To create a network model for a specific case from this master model, factors are removed, so that only the short-listed factors remain. Also, any other nodes that become disconnected from the alternatives, as a result of removing factors, are removed. Additional dependency connections among the remaining nodes should be considered, and added as warranted. The pairwise comparisons that were already done in the Tier 4 may be kept unchanged. However, at this stage more detailed information may be available, particularly the information that was gathered or obtained through the quantitative VFM assessment, and pairwise comparisons should be based on such information. For example more detailed information would be available regarding the costs of construction, maintenance and operations. The inputs for Tier 5, Stage 1 consist in making all the required pairwise comparisons. The user may also make additional connections between nodes and the associated pairwise comparisons. The outputs are relative priorities of all the factors, which will be used in the Stage 3.

3.8.3 Tier 5 Stage 2

The second stage of the Tier 5 uses a transformed decision network (Tier 5, Stage 2 model). First, quantitative factors are identified. These are the factors that can be accounted for in the quantitative VFM of each alternative. Qualitative factors are those that cannot be accounted for in quantitative VFM. All the quantitative factors are removed from the network, as well as any nodes that become disconnected from the alternatives as a result of removing factors. The schematic overall structure is shown in Figure 3-15, whereas the model is similar to that in Figure 3-13, but has fewer factors. The source node and cluster of this network are called 'Qualitative value.'

At Stage 2, pairwise comparisons of the alternatives are also made. Comparisons of the PPP alternatives with respect to the PPP factors (factors from Tier 4, Process 2) that were already done in Tier 4, Process 2 can be kept, or modified if there is more accurate information. Comparison among non-PPP alternatives with respect to non-PPP factors (factors from Tier 4, Process 1) are based on the relative effectiveness values of PDSs with respect to those factors, or on user knowledge. The rest of the comparisons among the alternatives need to be made.

The priorities and ranking of the alternatives based on this network should be noted. The ranking of the alternatives based on only qualitative analysis (when only qualitative criteria are considered) and only quantitative analysis (risk adjusted net present cost) should be compared and any differences noted.

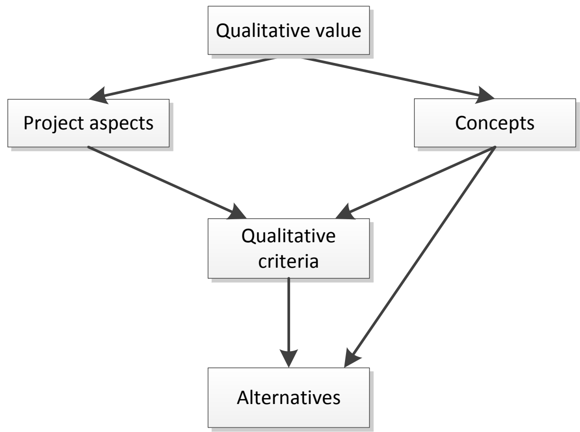

Figure 3-15 Tier 5 stage 2 network diagram

3.8.4 Tier 5 Stage 3

To combine the results of these two types of analysis, the ANP model is further transformed. A factor 'Quantitative value' is added to the network as a new node, and a new goal node is added (Select the most suitable project delivery system). The two major nodes, 'Qualitative value' and 'Quantitative value' are connected to the newly added goal node, so that their relative importance can be compared. Tier 5, Stage 3 model is shown in Figure 3-16.

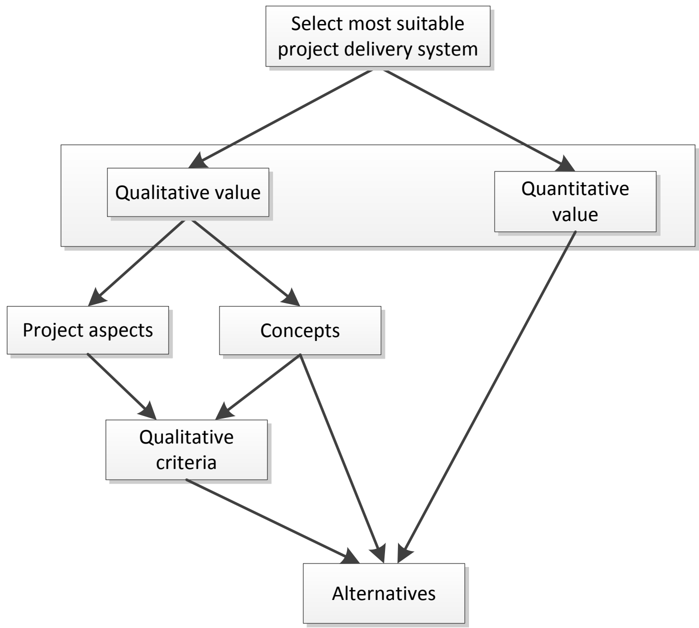

Figure 3-16 Tier 5 Stage 3 network diagram

If the highest ranking alternative is the same for both qualitative VFM assessment and the quantitative only analysis (Tier 5, Stage 2), this is likely to be the highest ranking alternative overall. However, if there are differences between the two, than the relative importance (relative weights) of the qualitative value and quantitative value in the Tier 5, Stage 3 model may determine the overall result. Such number could be manipulated. As part of the proposed DSS, method is suggested for determining the relative importance of qualitative and quantitative values, with a higher level of objectivity. It consists of adding up the priorities of all the qualitative factors from Tier 5, Stage 1 (removed in Tier 5, Stage 2 model) and of all the qualitative factors (remaining in Tier 5, Stage 2 model) as two separate sums. The ratio of these two numbers represents the relative weights of the qualitative and quantitative values.

Pairwise comparisons among the alternatives, with respect to qualitative factors, were already done at Stage 2. Quantitative values of alternatives are a result of the detailed quantitative VFM assessment, but they cannot be directly input into an ANP model. If percentage savings compared to the most expensive alternative were used, this would heavily punish the most expensive alternative, even if differences are marginal. A method should be established to translate the monetary values of the quantitative assessment into the ratings to be entered in the ANP model. This could be done by developing a utility function. The priorities and ranking of the alternatives that result from Tier 5, Stage 3 would be based on the qualitative and quantitative assessments combined. The three sets of Tier 5 results should be compared: quantitative VFM, Tier 5 Stage 2 (qualitative analysis) and Tier 5 Stage 3 (quantitative and qualitative analysis combined). The results of quantitative VFM and Tier 5, Stage 2 may not be similar, because one considers only quantitative factors while the other one considers only qualitative factors.

PPP Canada (2011) suggests that at least one PPP and at least one traditional model, each the most suitable within its category be included in the VFM analysis. Quantitative analysis of each alternative requires significantly more effort than qualitative comparisons of alternatives, and it makes sense to use qualitative analysis to shortlist the candidates for the quantitative analysis. On the other hand, when quantitative assessment for two alternatives is performed, the additional effort to assess additional alternatives may not be proportionally large. In the proposed DSS, it is recommended that at least two most suitable PDS alternatives of each category be evaluated in the Tier 5. This allows that not only the highest ranked PPP model be compared to the highest ranked non-PPP model, but also that the two highest ranked models for each category be compared to one another through a detailed assessment. In this way, the results of the Tier 4 may be validated and possible errors or inconsistencies from the Tier 4 may be corrected, which represents for a more reliable decision model.

3.9 Description of the software tool PDS AutoSelect

To implement the proposed decision support system, an automated tool named PDS AutoSelect has been developed in MS Excel 2010 in which Tier 1, Tier 3 and Tier 4, Process 1 have been automated. Tier 4, Process 1 when AHP is used as a method of MCA has been fully automated. For the other portions, which use ANP as a method of multi-criteria analysis, Super Decisions software is used in combination with automated worksheets in Excel. This includes a manual step of exporting results from Super Decisions and importing into MS Excel. In Tier 4, Process 1 when using ANP, Super Decisions software is used for calculating factor priorities, which are imported into PDS AutoSelect, and used along with the relative effectiveness values of PDS alternatives to calculate ratings of alternatives and rank them. For Tier 4, Process 2 and for Tier 5, the ANP additionally includes comparisons of alternatives, and the ratings and ranking of alternatives are obtained by Super Decisions Software. For all the parts of the proposed DSS that include MCA, PDS AutoSelect is used to automatically generate reports in a uniform format, to enable comparison of AHP and ANP results when such comparison applies, and to compare multiple scenarios for a particular decision problem.

The automation of Tier 1, Tier 3 and Tier 4, Process 1 is described next. For Tier 1, decision process is guided by a series of questions and answers. Each subsequent question depends on the preceding answers. The user selects answers from drop-down menus, and a logical flow is achieved by IF functions in Excel, as shown in Figure 3-17, Figure 3-18 and Figure 3-19. Tier 3 is organized as a series of filters, corresponding to each key input. Each PDS alternative gets a point if it passes the filter and a zero otherwise. Only the alternatives that pass all the ten filters pass this screening. The interface is shown in Figure 3-20 and Figure 7-21. Answers are selected from pull-down menus, including those that require user input regarding specific PDSs. The ten key inputs can be entered in any order. The user observes how each key input affects the range of available alternatives. The alternatives that pass the screening are highlighted in yellow. Specific selection factors are similarly removed by the some of the key inputs. The results of Tier 3 are linked with the subsequent stage - Tier 4, Process 1.

In Tier 4, Process 1, user enters pairwise comparison judgements among elements on various levels of the hierarchy, according to the structure shown in Figure 3-5. The example of interface is shown in Figure 3-21 and Figure 7-22. There are 22 comparison matrices, which have between two and seven comparison items. A user enters judgements only in the yellow highlighted cells, as values of the Saaty scale. The factors that are determined to be non-applicable in Tier 3 are automatically disabled in these matrices. The user can choose to disable any of the other factors, by selecting ‘no’ (for not applicable) from a pull-down menu for specific factors. As judgements are entered, if a consistency ratio is greater than 0.1 it gets highlighted.

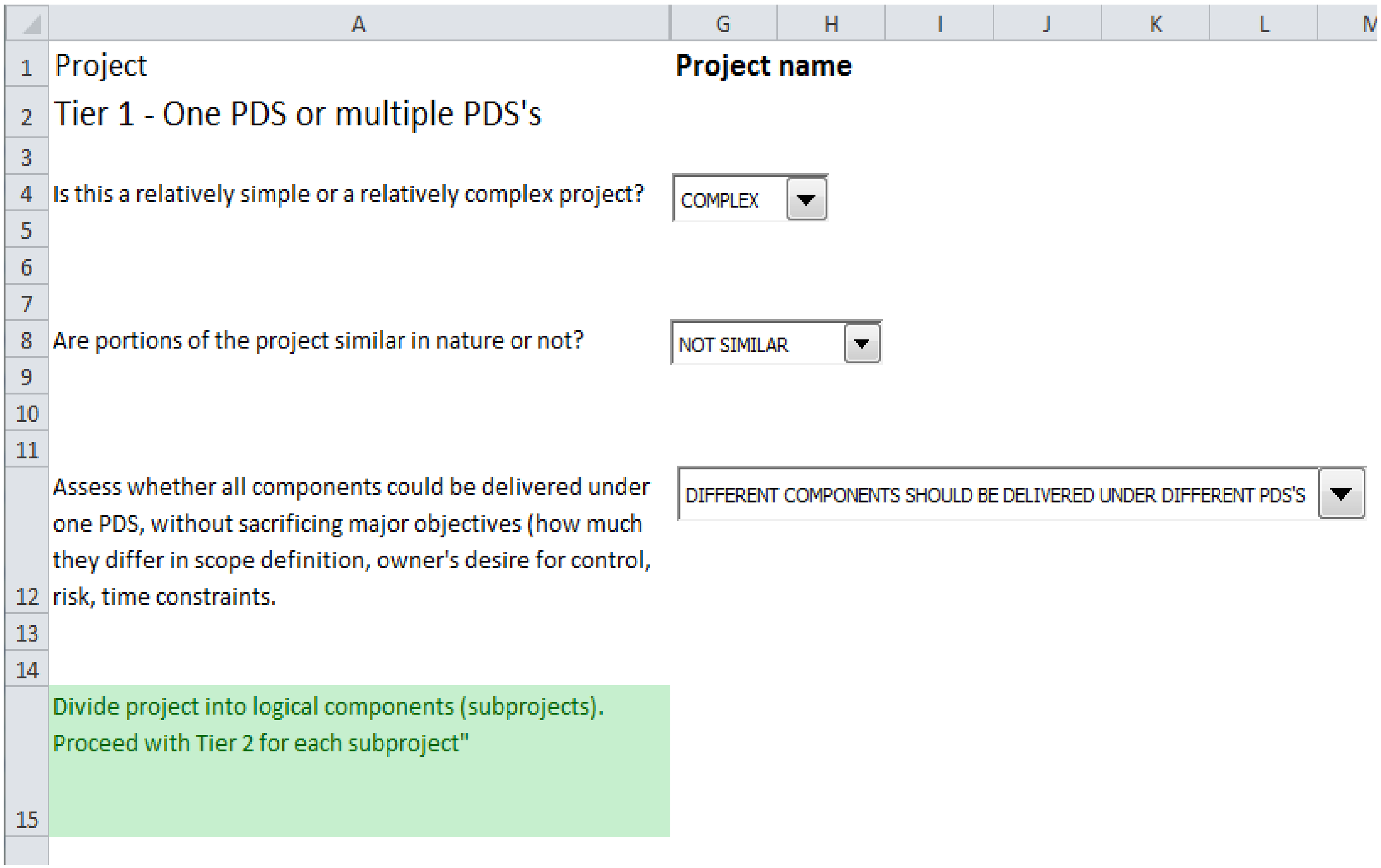

Figure 3-17 PDS AutoSelect Tier 1 interface in MS Excel

	A	B	C	D
1	Project			
2	Tier 1 - One PDS or multiple PDS's			
3				
4	Is this a relatively simple or a relatively complex project?			
5				
6				
7				
8	=IF(F6=1,"",IF(F6=3,"Are portions of the project similar in nature or not?",F16))			
9				
10				
11				
12	=IF(F6=3, B12, "")	=IF(F10=2, F16, C12)	=IF(F10=3,E12, "")	
13				
14				
15	=IF(F6=3, B15, "")	=IF(F10=3,C15, "")	=IF(F14=2, F16, D15)	=IF(F14=3, E15, "")

Figure 3-18 – PDS AutoSelect Tier 1 formulae

E	F	G	H
		=Start!F7	
	SIMPLE	COMPLEX	
	COMPLEX		
	3		
	SIMILAR	NOT SIMILAR	
	NOT SIMILAR		
	3		
Assess whether all components could be delivered under one PDS, without sacrificing major objectives (how much they differ in scope	ALL COMPONENTS COULD BE DELIVERED UNDER ONE PDS	DIFFERENT COMPONENTS SHOULI	
	DIFFERENT COMPONENTS SHOULD BE DELIVERED UNDER DIFFERENT PDS'S		
	3		
Divide project into logical components (subprojects). Proceed with Tier 2 for each subproject"			
	Proceed with Tier 2		

Figure 3-19 PDS AutoSelect Tier 1 formulae (cont.)

Question	Project	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Tier 3 - Key Inputs	**Project name**															
Question		Traditional Design-Bid-Build	Traditional with early procurement	Traditional with PM (agent)	Traditional with CM (agent)	Traditional with early procurement and CM (agent)	CM @ Risk	Design-Build (or EPC)	Multiple Design Build	Parallel Primes	Traditional with staged development	Turnkey	Fast Track	Design-Negotiate-Build	Owner-Build	Integrated Project Delivery (Relational Contracting,	Engineer Procure Construction Manage (EPCM)
1	Is this a public or private project? PUBLIC																
	Are there restrictions to using any PDS? NO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Are the scope and requirements defined sufficiently that design can be developed without significant owner participation? (Or could they be developed before issuing RFP?) YES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	Does the owner need to have significant control of design throughout the design process? NO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	Do you estimate the time for completion of the project to be sufficient for design to be completed before construction starts? SUFFICIENT TIME	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
5	Is owner able to dedicate significant staff resources for design and construction process? Select yes or no for default values, or select for each PDS, whether owner is able to dedicate adequate staff re[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	YES RESET TO DEFAULT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 3-20 PDS AutoSelect Tier 3 Interface Key inputs 1 through 5

All the local priorities and consistency ratios are calculated using the approximate method described in section 2.4.3. Local priorities on various levels are used to calculate the overall priorities of factors. The outputs of factor priorities is on another worksheet, where they can be ranked, and the factors that account for 80% of priorities are automatically highlighted, as shown in Figure 3-22. The relative effectiveness values of PDSs are on a separate worksheet shown in Figure 3-23. The user is asked to define the REVs, for factors that are highlighted yellow, if those factors are considered. The user may also modify other REVs as warranted. The final output of the Tier 4 Process 1, the rating of PDS alternatives is on a separate worksheet, as shown in Figure 3-24, where values are displayed only for the alternatives that pass the screening of Tier 3. Ratings of all the alternatives are also calculated and displayed as shown in Figure 3-25. Worksheets have been set up to import Unweighted Super Matrix and Limit Matrix from Super Decisions software. The PDS AutoSelect contains formulae and macro buttons to automatically extract priorities of factors from those imported sets of data, and to calculate ratings of alternatives. It also enables comparison of results by different methods: AHP by approximate method, AHP by Super Decisions and ANP by Super Decisions, as shown in the case studies in the next chapter.

Sensitivity analysis, which shows how varying a particular judgement may affect the final output of Tier 4, Process 1 (ranking and priorities of alternatives), is done by running an Excel macro. It also shows how varying a specific judgement affects consistency ratio for the set of judgements in question. The sensitivity analysis is not fully automated, as the macro needs to be adjusted for each judgement examined, but this is fairly simple. This sensitivity analysis is different than the one that can be performed in Super Decisions software. In Super Decisions, when alternatives are included in the model and their pairwise comparisons or ratings are entered, sensitivity analysis shows how priorities and ranking of alternatives vary, when a priority of a particular node varies from 0 to 1 and priorities of other nodes are adjusted accordingly. That analysis does not show the effect of varying particular judgements or how consistency is affected. PDS AutoSelect should be used in conjunction with the theoretical knowledge included as part of the proposed DSS, which explains the meaning of each selection factor. Further development of the software tool, should enable access to this theoretical information through a help function.

Instructions for Tier 4 Process 1

1. In column C selection boxes, indicate for each factors whether it applies or not.
2. In yellow highlighted cells enter pairwise comparison judgments expressed as 1, 3 , 5, 7, 9 , 1/3, 1/5, 1/7 or 1/9. If consistency ratio is greater than 0.1, adjust the judgment values until the C.R .is less than 0.1.
3. Go to tab "Comp of Factor Rank-Approx. vs SD "and click on box **RANK FACTORS BY PREFERENCE SCORES BY APPROXIMATE METHOD** to review factor ranking.
4. Go to tab "PDS ranking" and click on box **RANK PDS'S IN ORDER BY APPROXIMATE METHOD** to review PDS ranking and priorities

Project **Miami Intermodal Center**

Comparison of Clusters

Matrix I — Reset matrix I

		Cluster	Cost	Time	Quality	Relationships and process	Project characteristics	Owner characteristics	Regulatory and political consideratio ns	Priorities	C.R.
Cluster 1	Cost	1	**1**	1	1	3	1	3	3	0.2014	
Cluster 2	Time	1	1	**1**	1	3	1	3	3	0.2014	
Cluster 3	Quality	1	1	1	**1**	3	1	1	5	0.1852	
Cluster 4	Relationships and process	1	1/3	1/3	1/3	**1**	1/3	1	3	0.0786	
Cluster 5	Project characteristics	1	1	1	1	3	**1**	3	3	0.2014	
Cluster 6	Owner characteristics	1	1/3	1/3	1	1	1/3	**1**	1	0.0786	
Cluster 7	Regulatory and political considerations	1	1/3	1/3	1/5	1/3	1/3	1	**1**	0.0534	
		7	0.20	0.20	0.19	0.08	0.20	0.08	0.05	1.0000	0.0358
									1		

Comparisons of Subclusters

Matrix II — Reset matrix II

Cluster 4	**Relationships and process**	Subcluster	Risk and reward sharing	Avoid claims and disputes	Collaborative Process	Integration	Priorities	C.R.
Subcluster 1	Risk and reward sharing	1	**1**	1/2	3	1/2	0.1991	
Subcluster 2	Avoid claims and disputes	1	2	**1**	5	1/2	0.3200	
Subcluster 3	Collaborative Process	1	1/3	1/5	**1**	1/3	0.0826	
Subcluster 4	Integration	1	2	2	3	**1**	0.3983	
		4	0.20	0.32	0.08	0.40	1.0000	0.0574

Matrix III — Reset matrix III

Cluster 5	**Project characteristics**	Subcluster	Function	Project environment	Change	Scope definition		Priorities	C.R.
Subcluster 1	Function	1	**1**	3	1	7		0.4292	
Subcluster 2	Project environment	1	1/3	**1**	1/3	3		0.1523	
Subcluster 3	Change	1	1	3	**1**	3		0.3473	
Subcluster 4	Scope definition	1	1/7	1/3	1/3	**1**	KI	0.0712	
		4	0.43	0.15	0.35	0.07		1.0000	0.0373

Figure 3-21 PDS auto Select Tier 4 Process 1 interface

	B	C	D	E
1	**Miami Intermodal Center**			
2	Comparison of factor priorities and ranking			
3		SORT FACTORS BY NUMBER / RANK FACTORS BY PREFERENCE SCORES BY APPROXIMATE METHOD	Hierarchy	
4	Factor #	Factor name	Approx. method	
5			Factor rank	Priority
6	7	Control time growth	1	0.1074
7	48	Design expectations of the owner	2	0.0770
8	16	Control cost growth	3	0.0664
9	13	High likelihood of change	4	0.0583
10	40	Multiple funding sources	5	0.0527
11	2	Project complexity	6	0.0450
12	1	Shortest schedule	7	0.0415
13	6	Quality and maintainability	8	0.0339
14	38	Amount of overlap of design and construction that is feasible	9	0.0315
15	70	Owner/user satisfaction	10	0.0313
16	71	Utility and functionality	10	0.0313
17	12	Desire for builder's input during design	12	0.0313
18	20	Facilitate early cost estimates	13	0.0285
19	35	Third party agreements	14	0.0238
20	4	Lowest cost	15	0.0237
21	28	Stand alone project or part of a capital development program	16	0.0230
22	30	Promote early procurement	17	0.0211
23	27	Minimize adversarial relationships	18	0.0189
24	33	Control construction impact on operations	19	0.0174
25	47	Security	19	0.0174
26	26	Optimize lifecycle cost	21	0.0164
27	32	Efficiently utilize poorly defined scope	22	0.0143
28	21	Delay or minimize expenditure rate	23	0.0137
29	72	Constructability	24	0.0117
30	42	Capitalize on familiar project conditions	25	0.0117
31	78	Owner's vision	26	0.0107
32	37	Environmental regulations	27	0.0100
33	83	Owner's experience with design, construction and project type	28	0.0095
34	64	Complexity of decision making	29	0.0088
35	84	Encourage innovation	30	0.0082
36	15	Availability of appropriate contractors	31	0.0077
37	31	Protect confidentiality	32	0.0067
38	17	Maximize owner's involvement	33	0.0065
39	36	Labor unions	34	0.0063

Figure 3-22 PDS Auto Select output of factor ranking

	B	D	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
2			Relative Effectiveness Values															
3			Project Delivery Systems															
4																		
5	Selection Factors		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	Number	Short name	Traditional Design-Bid-Build	Traditional with early procurement	Traditional with PM (agent)	Traditional with CM (agent)	Traditional with early procurement and CM (agent)	CM @ Risk	Design-Build (or EPC)	Multiple Design Build	Parallel Primes	Traditional with staged development	Turnkey	Fast Track	Design-Negotiate-Build	Owner-Build	Integrated Project Delivery (Relational Contracting, Lean Design and Construction)	Engineer Procure Construction Manage (EPCM)
30	12	Desire for builder's input during design	0	0	20	30	30	50	80	80	20	35	80	50	80	80	80	65
31	14	Competition	80	80	80	80	80	50	20	20	80	80	20	80	20	20	20	50
32	15	Availability of appropriate contractors	**80**	**80**	**80**	**80**	**80**	**50**	**20**	**20**	**80**	**80**	**20**	**50**	**65**	**80**	**20**	**20**
33	18	Small business impact	**80**	**80**	**80**	**80**	**80**	**80**	**50**	**50**	**80**	**80**	**50**	**80**	**80**	**80**	**50**	**65**
34	19	Stakeholder/community input	**50**	**50**	**65**	**65**	**65**	**80**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**80**	**65**
35	22	Sustainable design and construction, LEED certification	**50**	**50**	**50**	**50**	**50**	**80**	**80**	**65**	**35**	**50**	**80**	**50**	**80**	**65**	**80**	**65**
36	23	Experience with particular PDS and forms of contract	**50**	**50**	**50**	**80**	**65**	**50**	**35**	**20**	**50**	**65**	**50**	**50**	**35**	**20**	**20**	**20**
37	24	Desired contractual relationship and ability to recoup savings	**20**	**20**	**20**	**20**	**20**	**80**	**20**	**20**	**65**	**20**	**50**	**20**	**50**	**80**	**80**	**80**
38	26	Optimize lifecycle cost	56.25	56.25	56.25	56.25	56.25	50	48.75	48.75	56.25	50	48.75	56.25	56.25	80	69.5	50
39	27	Minimize adversarial relationships	20	20	20	20	20	50	80	80	20	20	80	20	50	80	80	35

Figure 3-23 PDS AutoSelect standard and user-defined relative effectiveness values of PDSs

RANK PDS'S IN ORDER BY APPROXIMATE METHOD

Comparison of approximate method and Super Decision

PDS #	PDS	Ranking Approx. method	Rating Approx. method
15	Integrated Project Delivery (Relational Contracting, Lean Design and Construction)	1	72.9342
6	CM @ Risk	2	64.1485
12	Fast Track	3	60.7167
13	Design-Negotiate-Build	4	50.4490
10	Traditional with staged development	5	43.2685
1	Traditional Design-Bid-Build	6	0.0000
2	Traditional with early procurement	6	0.0000
3	Traditional with PM (agent)	6	0.0000
4	Traditional with CM (agent)	6	0.0000
5	Traditional with early procurement and CM (agent)	6	0.0000
7	Design-Build (or EPC)	6	0.0000
8	Multiple Design Build	6	0.0000
9	Parallel Primes	6	0.0000
11	Turnkey	6	0.0000
14	Owner-Build	6	0.0000
16	Engineer Procure Construction Manage (EPCM)	6	0.0000

Figure 3-24 PDS AutoSelect, ranking of alternatives output

	A	B	C	D	E	F
1						
2				Approximate method		
3	PDS #	PDS	Abbreviation	Rating with filter	Rating w/o filter	Rank
4	1	Traditional Design-Bid-Build	DBB	0.0	51.6	6
5	2	Traditional with early procurement	DBBw/EP	0.0	59.1	6
6	3	Traditional with PM (agent)	PMA	0.0	54.2	6
7	4	Traditional with CM (agent)	CMA	0.0	53.8	6
8	5	Traditional with early procurement and CM (agent)	CMA/wEP	0.0	57.3	6
9	6	CM @ Risk	CMR	64.1	64.1	2
10	7	Design-Build (or EPC)	DB	0.0	60.4	6
11	8	Multiple Design Build	MDB	0.0	56.8	6
12	9	Parallel Primes	PP	0.0	43.4	6
13	10	Traditional with staged development	DBB w/SD	43.3	43.3	5
14	11	Turnkey	TK	0.0	63.2	6
15	12	Fast Track	FT	60.7	60.7	3
16	13	Design-Negotiate-Build	DNB	50.4	50.4	4
17	14	Owner-Build	OB	0.0	54.3	6
18	15	Integrated Project Delivery (Relational Contracting, Lean Design and Construction)	IPD	72.9	72.9	1
19	16	Engineer Procure Construction Manage (EPCM)	EPCM	0.0	61.2	6

Figure 3-25 PDS AutoSelect, ratings of all alternatives

3.10 Summary

In this chapter, the proposed decision super system for selecting the most suitable project delivery system was described, and the development of its particular aspects explained. PDSs considered as alternatives are listed. The proposed DSS consists of five tiers. Tiers 1, 3 and 4 apply to all projects, and Tiers 2 and 5 apply to public projects only. Tier 1 assists in evaluating whether it would be most suitable to deliver the project under a single PDS or whether different components should be delivered under different PDSs. Tier 2 assists in evaluating whether PPP should be further considered for a public project, and which PPP models are be applicable. Tier 3 assists in determining which PDSs outside of PPP are applicable and should be further considered. Tier 4 represents multi-criteria analysis with two parallel processes of AHP and ANP. Process 1 applies to all projects. It evaluates PDS alternatives other than PPP, and ranks them in order of suitability. Process 2 applies to public projects, if PPP is considered. It evaluates PPP alternatives and ranks them in order of suitability. If PPP is considered, Tier 5 also applies. In Tier 5, the most suitable non-PPP alternatives and the most suitable PPP alternatives are evaluated through qualitative and quantitative analysis, to provide an integrated recommendation. Automated spreadsheet, developed in MS Excel is described, including its principles of working and interface.

4 CHAPTER FOUR: IMPLEMENTATION

The use of the proposed DSS is illustrated through three case study examples. The first two examples, Gulf Coast Cogeneration Plant and Federal Courthouse are the same two examples that were presented in CII-IR 165-2 (2003) to illustrate that decision support system. The third example, Miami Intermodal Center core, Phase I was described as a case study of a project delivery system selection by Minchin, Thakkar and Ellis (2007).

4.1 Case study 1 – Gulf Coast Cogeneration Plant

4.1.1 Description of case

The proposed DSS is applied and, for the MCA (Process 1 of Tier 4) the results of the approximate method of AHP calculations were compared with those of the Super Decisions software. The project, Gulf Coast Co-Generation Plant (CII 2003), is an industrial facility to generate electric power, steam and high-pressure boiler feedwater within the complex of an existing refinery. The site has been selected at a central location within the complex. The major elements have been identified, which include a Heat Recovery Steam Generator (HRSG), Gas Turbine Generator (GTG), water treatment plant, transformer, substation, a building for switchgear and motor controls and an extensive piping system and pipe racks. HRSG and GTG are long lead items. The major piping, electrical lines and controls are to be integrated with the existing lines and equipment. There is a time pressure to complete the design, starting form conceptual engineering and reach mechanical completion within 18 months because the emissions from the existing steam generation facilities are of environmental concern. Cost is estimated to $32 million. The construction of the new plant should cause minimal disruptions to the operation of the existing plant. This is the first co-generation project for this owner. In the CII analysis of this case study, it is pointed out that, because of the confined location, the proximity of existing installations with underground piping, and tie-ins with exiting systems, an above normal level of changes is anticipated. Also because of the need to keep disruptions of existing operations to a minimum, owner's high degree of control of the construction process is desired.

4.1.2 Applying the proposed DSS

The developed method described in Chapter 3 and its related software application is applied to this case. Since this is a private project, Tier 1, Tier 3 and Tier 4 Process 1 were triggered. In Tier 1, it was determined that the entire project should be developed under one PDS. In Tier 3, the key inputs are provided as described in Chapter 3. The inputs that triggered elimination of alternatives or factors are: Q1 - private ownership, Q2 - scope not well defined due to potential for changes, Q4 - time pressure, Q7 project size ($10-50 million), and Q8 project complexity (medium). For Question 9, it is assumed that owner accepts some risk, as he needs a high degree control of construction process. For Question 10, since this is the first project of this type for the owner, assembling an IPD team may take significant time, so this PDS is removed. The remaining PDS alternatives are PDSs 6 through 13 and PDS 16. Factors 3, 10, 18, 32 and 34 are removed.

In Process 1 of Tier 4, factors that are not applicable to the project are removed and then pair wise comparisons among elements of the hierarchy described in Chapter 3 are performed. The following twelve factors were removed as non-applicable: F21 'Delay or minimize expenditure rate,' F22 Sustainable design and construction, LEED certification, F23 'Experience with particular PDS and forms of contract,' F24 Desired Contractual relationship,' F28 'Stand-alone project or part of a capital development program,' F35 'Third party agreements,' F40 'Multiple funding sources,' F46 'Domestic or international firms or teams,' F54 'Take advantage of and strengthen existing relationships,' F55 'Opportunity to partner,' F64 'Complexity of decision making,' F69 'Market conditions, F78 'Owner's vision,' F79 'Market position (desire to gain experience with a new PDS),' and F80 'Desire for single point of responsibility for design and construction.' Next, pairwise comparisons are made on all levels of hierarchy. Figure 4-1 shows the pairwise comparisons at the highest level of hierarchy, with local priorities and consistency ratio obtained by approximate method and by Super Decisions Software.

Table 4-1 shows the overall priorities and rankings of factors by approximate method and by Super Decisions software, and Figure 4-2 is a plot of factor priorities versus ranking. Differences in results by these two methods are not significant. The same highest ranked 18 factors account for 80% of all priorities by both methods. This is approximately 27% of the 67 factors available in the model. In the overall ranking of factors, the relative ranking of factor within their respective clusters (local ranking) is preserved.

	Cost	Time	Quality	Relationships and process	Project characteristics	Owner characteristics	Regulatory and political considerations	Priorities	Priorities from Super Decisions software	Difference	Rank in cluster
Cost	**1**	1	1	3	1	1	3	0.1808	0.1806	-0.0003	1
Time	1	**1**	1	3	1	1	3	0.1808	0.1806	-0.0003	1
Quality	1	1	**1**	3	1	1	3	0.1808	0.1806	-0.0003	1
Relationships and process	1/3	1/3	1/3	**1**	1/2	1/2	1	0.0677	0.0678	0.0001	6
Project characteristics	1	1	1	2	**1**	1	2	0.1611	0.1613	0.0002	4
Owner characteristics	1	1	1	2	1	**1**	2	0.1611	0.1613	0.0002	4
Regulatory and political considerations	1/3	1/3	1/3	1	1/2	1/2	**1**	0.0677	0.0678	0.0001	6

Consistency ratio 0.00509

Inconsistency from Super Decisions 0.01122

Figure 4-1 Case study 1 - Pairwise comparisons at Level 2

Table 4-1 Case study 1 - Priorities and rankings of factors by approximate method and by Super Decisions Software

Factor #	Factor name	Approx. method		Super Decisions software		Difference	
		Factor rank	Priority	Factor rank	Priority	In rank	In priority
16	Control cost growth	1	0.0923	1	0.0910	0	-1.43%
30	Promote early procurement	2	0.0698	2	0.0712	0	1.99%
13	High likelihood of change	3	0.0688	3	0.0683	0	-0.70%
7	Control time growth	4	0.0530	6	0.0518	2	-2.39%
6	Quality and maintainability	5	0.0526	4	0.0523	-1	-0.73%
71	Utility and functionality	5	0.0526	4	0.0523	-1	-0.73%
17	Maximize owner's involvement	7	0.0513	7	0.0514	0	0.15%
72	Constructability	8	0.0443	8	0.0445	0	0.47%
26	Optimize lifecycle cost	9	0.0424	9	0.0425	0	0.18%
37	Environmental regulations	10	0.0423	10	0.0424	0	0.21%
1	Shortest schedule	11	0.0403	11	0.0403	0	0.11%
4	Lowest cost	12	0.0340	12	0.0349	0	2.60%
70	Owner/user satisfaction	13	0.0313	13	0.0316	0	0.97%
83	Owner's experience with design, construction and project type	14	0.0312	14	0.0312	0	0.15%
27	Minimize adversarial relationships	15	0.0273	15	0.0276	0	1.11%
8	Maximize owner's controlling role	16	0.0265	16	0.0265	0	0.03%
9	Capitalize on well-defined scope	17	0.0242	17	0.0244	0	0.67%
33	Control construction impact on operations	18	0.0233	18	0.0238	0	1.89%
38	Amount of overlap of design and construction that is feasible	19	0.0177	19	0.0173	0	-2.39%
84	Encourage innovation	20	0.0169	20	0.0169	0	0.15%
42	Capitalize on familiar project conditions	21	0.0138	21	0.0137	0	-0.70%
15	Availability of appropriate contractors	22	0.0123	24	0.0121	2	-1.44%
56	Ability to prequalify project team	23	0.0122	22	0.0122	-1	0.42%
20	Facilitate early cost estimates	24	0.0121	23	0.0122	-1	0.79%
60	Avoid conflict of interest	25	0.0108	26	0.0106	1	-1.43%
47	Security	26	0.0104	25	0.0106	-1	2.00%
39	Ability to participate in multiple trade builder/supplier evaluation	27	0.0104	27	0.0104	0	0.15%

14	Competition	28	0.0095	28	0.0095	0	0.22%
57	Ability to prequalify subcontractors	29	0.0086	29	0.0086	0	0.29%
36	Labor unions	30	0.0085	30	0.0085	0	0.23%
73	Effective communication	31	0.0066	31	0.0066	0	-0.35%
12	Desire for builder's input during design	32	0.0063	32	0.0065	0	3.00%
45	Ability to award contracts based on best value	33	0.0060	33	0.0060	0	0.22%
5	Minimize number of contracted parties	34	0.0055	34	0.0055	0	1.13%
2	Project complexity	35	0.0048	35	0.0049	0	2.45%
29	Shifting roles and responsibilities, clarity of defined roles	36	0.0040	36	0.0040	0	-0.11%
68	Apportion risk equitably and share rewards	37	0.0036	37	0.0035	0	-1.45%
74	Collaboration of project team	38	0.0034	39	0.0034	1	-1.59%
31	Protect confidentiality	39	0.0034	38	0.0035	-1	2.26%
76	Alignment of objectives	40	0.0023	40	0.0022	0	-1.70%
75	Trust and respect	41	0.0020	41	0.0020	0	-4.23%
19	Stakeholder/community input	42	0.0015	42	0.0015	0	0.28%
3	Reduce or transfer risk to contractor	43	0	43	0.0000	0	N/A

Figure 4-2 is a plot of factor priorities versus factor ranking by the two methods. One point may represent multiple factors if their priorities are equal.

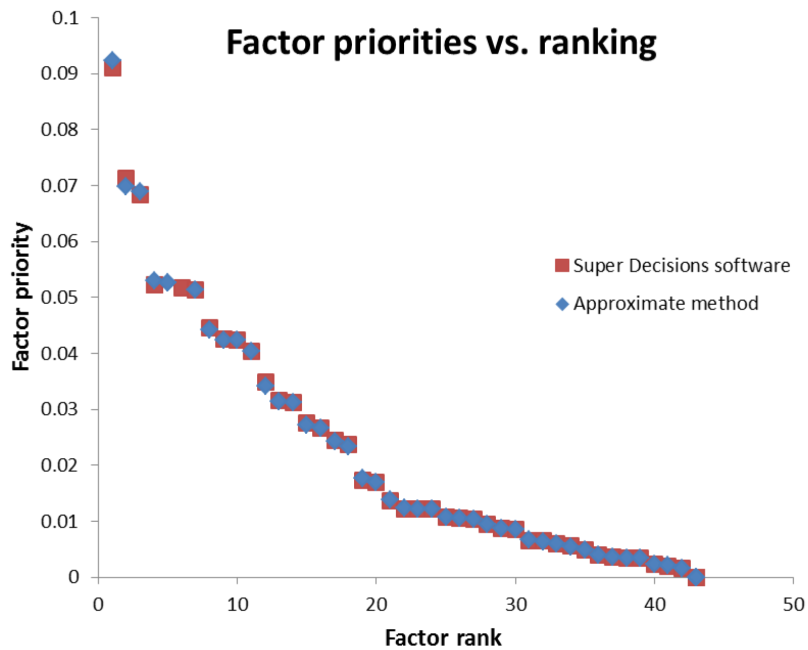

Figure 4-2 Case study 1 – Graph of factor priorities vs. ranking

From these factor priorities result the ratings of PDSs, as shown in Table 4-2 and Figure 4-3. Rankings are similar by the two methods. The differences in ratings among PDSs are relatively small. This could be expected as the differences among the factors are also relatively small.

Table 4-2 Case study 1 - PDS ranking and ratings

PDS #	PDS	Ranking		Rating	
		Approx. method	Super Decisions	Approx. method	Super Decisions
6	CM @ Risk	1	1	65.5586	65.5775
12	Fast Track	2	2	64.3539	64.3819
11	Turnkey	3	4	61.8430	61.8625
16	Engineer Procure Construction Manage (EPCM)	4	3	61.8159	61.8929
7	Design-Build (or EPC)	5	5	61.7283	61.7694
8	Multiple Design Build	6	6	58.9469	59.0313
13	Design-Negotiate-Build	7	7	52.1650	52.2763
9	Parallel Primes	8	8	50.3116	50.4172
10	Traditional with staged development	9	9	41.6497	41.7088

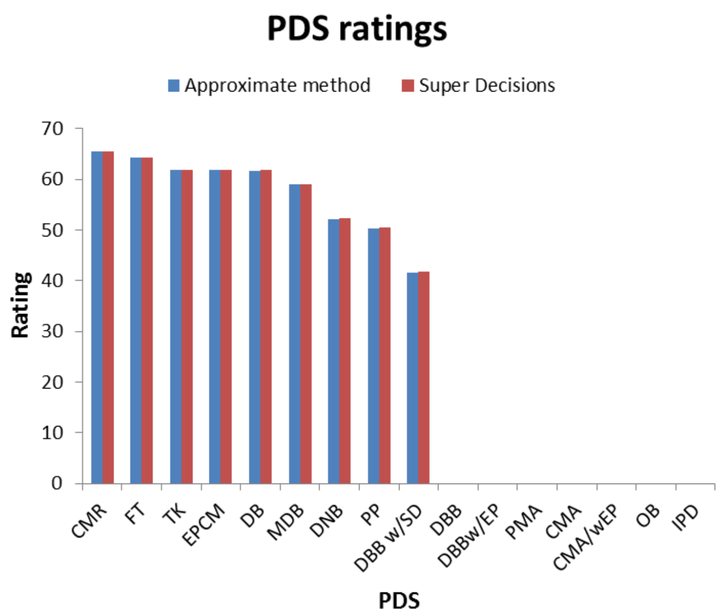

Figure 4-3 Chart of PDS ratings

Comparison with result of CII IR 165-2 (2003)

The CII method requires that only four to six most important factors be selected. In the original case (CII, 2003) the factors were selected and their preference scores assigned as shown Table 4-3. The differences between the factors are much more pronounced by the CII method than by the AHP method of the proposed DSS because, in the former, a small number of factors is considered and the preference scores are assigned based on ranking.

Table 4-3 Case study 1 - Factors from CII IR 165-2 (2003)

Factor rank	Selection factors	Preference scores	Relative weighing
1	Ensure shortest schedule	100	32.26%
2	Control cost growth	85	27.42%
3	Ease change incorporation	75	24.19%
4	Maximize Owner's controlling role	50	16.13%

The ranking and ratings of PDSs in the original case study are shown in Table 4-4. As can be expected, the differences among the PDSs are much more pronounced. The same two PDSs ranked highest by the two methods, but in reversed order. Factors 6, 71, 72, and 70, which pertain to quality ranked high by the proposed method, whereas they are not available through the CII method. CMR has somewhat higher relative effectiveness values with respect to these factors. According to CII (2003) Fast Track has somewhat better ability to accommodate change than CMR (REV of 70 vs. 60), and this factors is ranked third by both CII method and the proposed method. CMR is better able to control cost (REV of 60 vs. 40), and this factor ranked second by the CII method and first by the proposed method.

Table 4-4 Case study 1 - PDCS rankings and ratings by CII IR-165-2 (2003)

Rank	PDCS #	Rating	PDCS
1	12	76.3	Fast Track
2	6	66.5	CM @ Risk
3	2	65.3	Traditional with early procurement
4	7	61.0	Design-Build (or EPC)
5	3	60.6	Traditional with PM (agent)
6	1	60.6	Traditional Design-Bid-Build
7	11	59.7	Turnkey
8	4	59.0	Traditional with CM (agent)
9	5	56.5	Traditional with early procurement and CM (agent)
10	8	51.5	Multiple Design Build
11	9	48.4	Parallel Primes
12	10	37.1	Traditional with staged development

4.2 Case study 2 – Federal Courthouse

4.2.1 Description of case

The second case study is a Federal Courthouse (CII, 2003), a new 205,000 sf facility for the GSA (General Services Administration, the division of the U.S. Federal Government responsible for providing building facilities to all the civilian government agencies). This owner usually awards a contract to the lowest bidder, and typically retains the services of a construction manager (agent) to supplement in-house project management resources and to review constructability. As stated in the original case study analysis by the CII, the major project objectives, in the order of priority are 1) adherence to the budget, 2) conform to space allocation, 3) appearance of the building must project appropriate image, 4) accommodate special security requirements and 5) provide capability for future facility expansion (CII, 2003). In the original case study it is also noted that since projects funded by the U.S. Federal Government receive funds through Congressional appropriation, which occurs in phases related to design and construction, this suggests that owner's cash flow for the project is constrained and it is desired to delay or minimize expenditure rate. This owner also has limited staff and prefers to deal with minimal number of contracted parties. Project complexity arises from special security requirements, the goal to project a desired image, and the need for flexibility for future expansion (CII, 2003). Regarding the operations phase, GSA through its Public Building Service (PBS), offers facility management services for the properties that it owns and leases including courthouses. GSA facility operations services include building maintenance, maintenance of certain equipment and custodial operations, and they may be delegated to private contractors (U.S. GSA, 2014). The Department of Homeland Security's (DHS) Federal Protective Service (FPS) provides law enforcement and security services to federally owned and leased facilities nationwide (U.S. GSA, 2014).

4.2.2 Applying the proposed DSS

For this case study, all five tiers are triggered. Since only limited information is available through the original case study, several assumptions are made in applying the proposed DSS. In Tier 1, similar to the first case study, it was determined that one PDS should be selected for the whole project. Tier 2 is applied as follows. It is assumed that the owner can dedicate resources for the procurement process for any of the PPP models, in spite of limited staff resources, as this is a relatively short-term effort. Next, the high level suitability screening criteria for PPP models are considered. Regarding public acceptance of transfer of responsibilities for project aspects, maintenance and non-core operations can be transferred (Factors 122 and 123), whereas core operations and ownership cannot be transferred (Factor 123 and 124). Table 4-5 shows the application of the other screening criteria.

Table 4-5 Case study 2 – High-level screening criteria

#	High level P3 screening criteria	Answer	Explanation of answer	Result
7	Is the completion date critical? If yes, which PPP models can deliver on time and which cannot?	No	Completion date is not critical.	No restriction on PPP model selection.
8	Enable the public owner to control detail design.	Yes	Detailed design requires owner participation because of the goal to project appropriate image and particularly special security requirements	Design is not transferred.
9	Is it possible to clearly define	No	Same as for criterion #	Design is not

	scope and performance requirements, so that detail design can be developed without significant owner participation?		8	transferred.
133	Is it possible to separate operations from maintenance?	Yes		No restriction on PPP model selection.
132	Does project have significant maintenance requirements?	No	Maintenance requirements are relatively little, but it may still be suitable to transfer maintenance.	Suitability should be further evaluated though market sounding.
51	Will the performance requirements and use of the project be relatively stable over time? Can operational flexibility be maintained over the life of the contract at reasonable cost?	No	Future expansion is anticipated. This could interfere with a long term maintenance and/or operations contract. Also, need for integration of new technologies in the future may interfere with such a contract.	Suitability should be further evaluated though market sounding.
44	Is the refurbishment cycle for the project relatively predictable and stable?	Yes		Maintenance can be transferred
125	Is it possible to set clear standards and performance requirements, monitor performance and hold the provider accountable for maintenance?	Yes		Maintenance can be transferred.
53	Does the asset have an expected useful life greater than 20 years?	Yes		Long term contract can be considered.
101	Enable the public owner to control operations and respond to potential changes of policy.	Yes	Public owner needs to control the core operations.	Core operations cannot be transferred.
130	What is the size of operations? Are they too small for public agency to carry them out efficiently?	Yes	Does not apply to core operations. It may be more efficient for a private entity to be responsible for non-core operations.	Non-core operations may be transferred.
131	Is the risk associated with operating the facility acceptable to the public agency?	Yes	The risks are acceptable to the public agency.	No restriction on PPP model selection.

126	Is it possible to set clear standards and performance requirements, monitor performance and have the provider accountable for operations?	Yes	This refers to non-core operations.	Non-core operations may be transferred.
95	What is the level of the public agency's experience and knowledge with the service or operations that the project will support? Does the project involve technologies that a private party may be more familiar with? Does it seek new solutions that private party may be better able to provide?	Government has enough experience with core operations.	The service to be provided is strictly a government service, therefore the public party is the only one experienced with core operations. The owner may be interested in new technologies, and it may be beneficial to transfer the associated operation to a private party. However, this would likely require special expertise and selection of contractors should be separate from selection of contractors for delivery of the building.	It may be suitable to transfer certain aspects of operations associated with new technologies to take advantage of private sector expertise. However this should not be part of the same PPP as the building.
128	Is there need for long-term private financing?	No		No PPP models are eliminated.

From this screening process, it results that design, ownership and core operations should not be transferred to private partner, whereas maintenance, some of the non-core operations, and some portion financing either short-term or long-term may be transferred. The available PPP alternatives are build-finance (BF) and build-finance-maintain (BFM) with or without retransferring some of the non-core operations. Regarding project size, courthouses that were delivered as PPP included projects of similar size. The information on courthouses from the CCPPP database is summarized in Table 4-6.

Table 4-6 Courthouse projects from CCPPP database (CCPPP, 2013)

Project Name	PPP Type	Level of government	Price of Contract millions of CAD	Capital Cost in millions of CAD	Size
Durham Consolidated Courthouse	DBFM	Provincial/Territorial	334		350,000 sf
Quinte Consolidated Courthouse	DBFM	Provincial/Territorial	247.2		162,000 sf
St Thomas Consolidated Courthouse	DBFM	Provincial/Territorial	249		
Thunder bay Consolidated Courthouse	DBFM	Provincial/Territorial	247.7		
Waterloo Region Consolidated Courthouse	DBFM	Provincial/Territorial	379		420,000 sf
Moncton Law Courts	DBFMO, BOOT	Provincial/Territorial		50 estimated	133,000 sf
Calgary Courts Centre	DBO	Provincial/Territorial			1 million sf

PPP courthouses were most often delivered under the DBFM model, and none under BF, or BFM models. Since the main difference is whether design is included in the PPP agreement, and as cost of design is relatively small compared to costs of construction, maintenance and operation, BFM would also be suitable form the standpoint of project size. The size range of BF projects in the CCPPP database is wide (32.2 to 715.6 million CAD), and this project is within that range. The next step, market sounding is not in the scope if this thesis, and it is assumed that there would be market interest in the project for both BF and BFM models.

Tier 3 solicits key inputs. The inputs that resulted in elimination of alternatives and factors are the following. Q2 - design requires owner participation, Q3 - owner wishes to have control of design, Q4 - time is not critical, Q5 - owner's staff resources are limited, Q7 Project's size is over $50 million, and Q8 project complexity is medium. For Q9, similar to Case 1, it is assumed that owner accepts some risk since he desires significant control of design. For Q10 it is also assumed that there are suitable contractors for any PDS except EPCM, which is not common for building projects. Based on these inputs, there are nine remaining PDS alternatives: PDS 1 DBB, PDS 2 DBB with early procurement, PDS 3 PMA, PDS 4 CMA, PDS 5 Traditional with early procurement and CM agent, PDS 6 CMR, PDS 10 Traditional with staged development, PDS 13 Design Negotiate Bid, and PDS 15 IPD. Factors 3, 9, 25, 41 and 43 are removed.

In Tier 4, the following factors are removed as non-applicable to the project: F30 Promote early procurement, F33 Control construction impact on operations, F35 Third party agreements, F40 multiple funding sources, F54 Take advantage of and strengthen existing relationships, F69 Market conditions, F79 Market position and F80 Desire for single point of responsibility for design and construction. Owner input is needed regarding the REV of the factors F15 'Availability of appropriate contractors,' F23 'Experience with particular PDS and forms of contract,' F24 'Desired contractual relationship and ability to recoup savings,' and F59 'What feels comfortable to the owner.' Pairwise comparisons at the highest level of hierarchy are shown in Figure 4-4. Local ranking of elements is the same by the two methods and the differences in priorities are very small. The rest of the pairwise comparisons were performed. The resulting overall priorities and ranking of factors are shown in Table 4-7 and graph in Figure 8-1 in APPENDIX C.

	Cost	Time	Quality	Relationships and process	Project characteristics	Owner characteristics	Regulatory and political considerations	Priorities	Priorities from Super Decisions software	Difference in priorities	Rank in cluster (approximate method)	Rank in cluster (Super Decisions)
Cost	**1**	3	2	3	3	3	3	0.2896	0.2914	0.0017	1	1
Time	1/3	**1**	1/3	1	1/5	1/3	1	0.0594	0.0577	-0.0017	6	6
Quality	1/2	3	**1**	3	2	2	3	0.2116	0.2034	-0.0082	2	2
Relationships and process	1/3	1	1/3	**1**	1/3	1/3	1/3	0.0546	0.0536	-0.0010	7	7
Project characteristics	1/3	5	1/2	3	**1**	1/3	3	0.1364	0.1410	0.0046	4	4
Owner characteristics	1/3	3	1/2	3	3	**1**	3	0.1736	0.1786	0.0051	3	3
Regulatory and political considerations	1/3	1	1/3	3	1/3	1/3	**1**	0.0747	0.0743	-0.0005	5	5

Consistency ratio 0.07497

Inconsistency from Super Decisions 0.07383

Figure 4-4 Case study 2 – Pairwise comparisons at highest level of hierarchy

Table 4-7 Case study 2 Tier 2 Process 1 Priorities and rankings of factors by approximate method and by Super Decisions Software

Factor #	Factor name	Approx. method		Super Decisions software		Difference between the two methods	
		Factor rank	Priority	Factor rank	Priority	In rank	In priority
16	Control cost growth	1	0.1118	1	0.1117	0	-0.10%
26	Optimize lifecycle cost	2	0.0627	2	0.0626	0	-0.26%
78	Owner's vision	3	0.0555	3	0.0571	0	2.91%
48	Design expectations of the owner	4	0.0522	5	0.0492	1	-5.72%
71	Utility and functionality	4	0.0522	5	0.0492	1	-5.72%
21	Delay or minimize expenditure rate	6	0.0504	4	0.0517	-2	2.65%
4	Lowest cost	7	0.0438	7	0.0443	0	1.08%
6	Quality and maintainability	8	0.0435	9	0.0419	1	-3.54%
47	Security	9	0.0429	8	0.0438	-1	2.05%
7	Control time growth	10	0.0356	10	0.0346	0	-2.88%
15	Availability of appropriate contractors	11	0.0246	11	0.0263	0	6.64%
70	Owner/user satisfaction	12	0.0228	12	0.0230	0	0.68%
72	Constructability	13	0.0224	13	0.0224	0	0.38%
59	What feels comfortable to the owner	14	0.0216	14	0.0222	0	2.96%
20	Facilitate early cost estimates	15	0.0209	15	0.0211	0	1.01%
14	Competition	16	0.0207	17	0.0200	1	-3.26%
27	Minimize adversarial relationships	17	0.0199	18	0.0197	1	-1.01%
84	Encourage innovation	18	0.0197	16	0.0202	-2	2.91%
36	Labor unions	19	0.0187	19	0.0186	0	-0.62%
22	Sustainable design and construction, LEED certification	20	0.0186	22	0.0176	2	-5.28%
2	Project complexity	21	0.0174	21	0.0178	0	2.05%
32	Efficiently utilize poorly defined scope	22	0.0171	20	0.0179	-2	4.67%
17	Maximize owner's involvement	23	0.0170	23	0.0175	0	2.91%
13	High likelihood of change	24	0.0168	24	0.0172	0	2.06%
23	Experience with particular PDS and forms of contract	25	0.0142	25	0.0144	0	2.08%
1	Shortest schedule	26	0.0119	26	0.0115	0	-2.88%
38	Amount of overlap of design and construction that is feasible	26	0.0119	26	0.0115	0	-2.88%
45	Ability to award contracts based on best value	28	0.0107	29	0.0107	1	-0.04%
34	Agency goals and objectives	29	0.0105	28	0.0108	-1	2.91%
18	Small business impact	30	0.0079	31	0.0078	1	-1.04%

10	Owner staff number and qualifications (limited)	31	0.0078	30	0.0082	-1	4.51%
31	Protect confidentiality	32	0.0071	32	0.0072	0	2.05%
8	Maximize owner's controlling role	33	0.0069	33	0.0070	0	2.04%
12	Desire for builder's input during design	34	0.0067	35	0.0066	1	-2.61%
5	Minimize number of contracted parties	35	0.0066	34	0.0066	-1	-0.99%
37	Environmental regulations	36	0.0062	37	0.0062	1	-0.63%
19	Stakeholder/community input	37	0.0060	36	0.0063	-1	5.26%
42	Capitalize on familiar project conditions	38	0.0056	38	0.0057	0	2.07%
83	Owner's experience with design, construction and project type	39	0.0054	40	0.0056	1	2.96%
56	Ability to prequalify project team	40	0.0054	39	0.0056	-1	4.35%
73	Effective communication	41	0.0053	42	0.0052	1	-0.84%
28	Stand-alone project or part of a capital development program	42	0.0049	41	0.0053	-1	6.66%
74	Collaboration of project team	43	0.0048	43	0.0047	0	-2.17%
60	Avoid conflict of interest	44	0.0047	45	0.0045	1	-4.55%
46	Domestic or international firms or teams	45	0.0045	44	0.0046	-1	2.93%
57	Ability to prequalify subcontractors	46	0.0031	46	0.0032	0	3.18%
64	Complexity of decision making	47	0.0030	47	0.0031	0	2.71%
75	Trust and respect	48	0.0023	48	0.0023	0	-0.74%
39	Ability to participate in multiple trade builder/supplier evaluation	49	0.0020	49	0.0020	0	2.01%
68	Apportion risk equitably and share rewards	50	0.0019	50	0.0018	0	-4.62%
29	Shifting roles and responsibilities, clarity of defined roles	51	0.0016	51	0.0016	0	1.34%
76	Alignment of objectives	52	0.0015	52	0.0015	0	-1.30%

Gray shading indicates the factors that account for 80% of priorities
Yellow shading indicates the ranking that is different by Super Decisions software than by the approximate method.

In this case, the 22 highest ranked factors, which is 33% of the 67 factors available in the model account for 80% of the overall priorities. The overall ranking of factors was consistent with their local rankings by both methods. To calculate the priorities of PDSs, some of the relative effectiveness values are defined by the user, and they are show in

Table 8-1 in APPENDIX C. The resulting ratings and ranking of PDS alternatives by the two methods are shown in

Table 4-8 and in Figure 4-5. The rankings of PDSs are equal by both methods and ratings are very similar. The ratings for the highest seven alternatives are quite close to one another.

Table 4-8 Case study 2 Tier 4 Process 1 PDS ranking and priorities

PDS #	PDS	Ranking		Rating	
		Approx. method	Super Decisions	Approx. method	Super Decisions
15	Integrated Project Delivery (Relational Contracting, Lean Design and Construction)	1	1	66.0344	65.9007
4	Traditional with CM (agent)	2	2	63.8201	63.9663
1	Traditional Design-Bid-Build	3	3	63.8106	63.9405
3	Traditional with PM (agent)	4	4	62.9710	63.0890
2	Traditional with early procurement	5	5	61.9074	61.9628
6	CM @ Risk	6	6	59.2709	59.1661
5	Traditional with early procurement and CM (agent)	7	7	58.9739	58.9731
13	Design-Negotiate-Build	8	8	51.4070	51.3255
10	Traditional with staged development	9	9	44.5012	44.3406

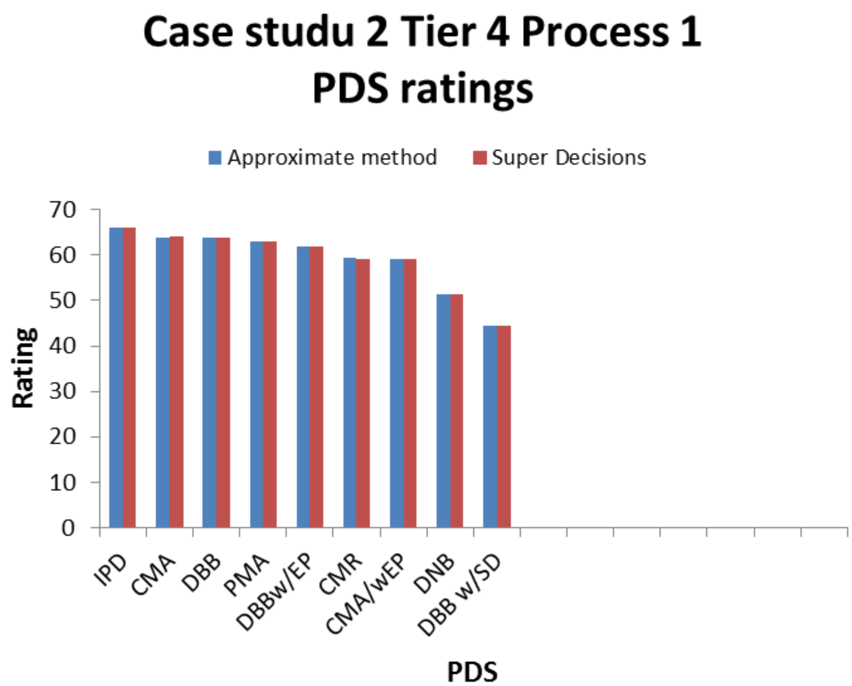

Figure 4-5 Case study 2 Tier 4 Process 1 PDS ratings

For this case study, a sensitivity analysis was performed by varying one of the judgements at the highest level of hierarchy, as those judgements are expected to have greatest impact on the results. The judgement of 'Cost' versus 'Quality' was varied using the Saaty scale values from 1/9 to 9, while all the other judgments were kept constant. The results are shown in Table 4-9 and Figure 4-6. The consistency ratio is at the recommended value below 0.1 only for judgements between 1/3 and 4. The highest ranked alternative IPD was not affected by this judgement, but the rankings of second and third alternatives CMA and DBB become reversed as the importance of cost versus quality becomes greater than 2 (between equally important and moderately more important). The ranking of the other alternatives is also not affected by this judgement.

Table 4-9 Case study 2 - Sensitivity analysis varying comparison judgement 'Cost' vs. 'Quality'

	PDS#	1	2	3	4	5	6	10	13	15
Judgment 'Cost' versus 'Quality'	Consistency ratio	DBB	DBB w/EP	PMA	CMA	CMA w/ EP	CMR	DBB w/SD	DNB	IPD
1/9	0.1584	62.98	62.44	62.54	63.38	60.29	60.69	48.98	54.91	66.32
1/8	0.1486	63.00	62.41	62.55	63.39	60.24	60.63	48.81	54.76	66.31
1/7	0.1385	63.03	62.39	62.56	63.40	60.18	60.57	48.61	54.61	66.29
1/6	0.1280	63.06	62.36	62.57	63.42	60.11	60.49	48.38	54.42	66.27
1/5	0.1169	63.10	62.32	62.59	63.44	60.03	60.41	48.10	54.20	66.25
1/4	0.1054	63.16	62.28	62.62	63.47	59.93	60.30	47.76	53.93	66.22
1/3	0.0934	63.23	62.23	62.65	63.51	59.80	60.16	47.32	53.59	66.19
1/2	0.0812	63.34	62.15	62.71	63.57	59.61	59.96	46.69	53.09	66.15
1	0.0717	63.56	62.03	62.83	63.68	59.29	59.62	45.60	52.25	66.08
2	0.0750	63.81	61.91	62.97	63.82	58.97	59.27	44.50	51.41	66.03
3	0.0830	63.97	61.84	63.06	63.91	58.79	59.07	43.86	50.92	66.01
4	0.0918	64.09	61.79	63.14	63.98	58.65	58.92	43.40	50.57	66.00
5	0.1005	64.18	61.75	63.19	64.03	58.55	58.81	43.04	50.30	65.99
6	0.1090	64.26	61.72	63.24	64.07	58.47	58.72	42.75	50.08	65.98
7	0.1172	64.33	61.70	63.28	64.11	58.40	58.64	42.50	49.90	65.97
8	0.1251	64.39	61.68	63.32	64.15	58.33	58.58	42.29	49.74	65.97
9	0.1328	64.44	61.66	63.35	64.18	58.28	58.52	42.10	49.60	65.97

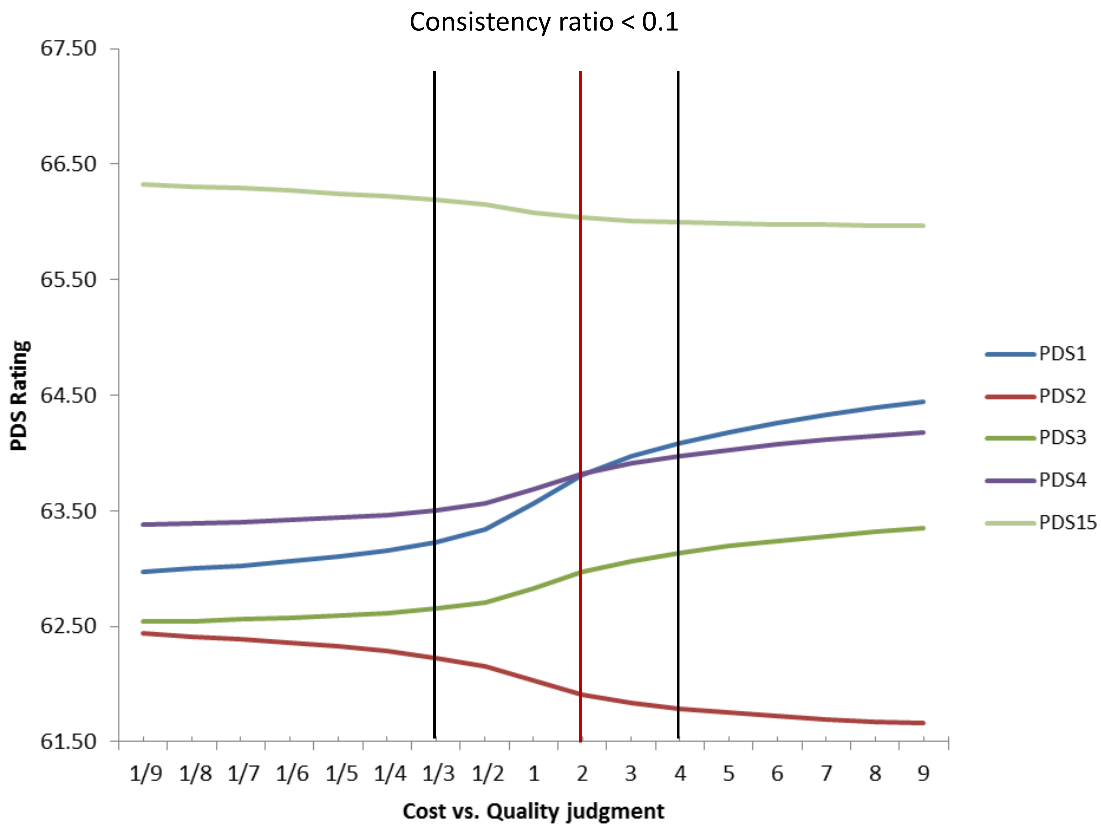

Figure 4-6 Case study 2 - Sensitivity analysis graph varying the comparison judgement 'Cost' vs. 'Quality'

The Process 2 of the Tier 4 represents a multi-criteria analysis of the short-listed PPP models through analytical network process. Only two models were shortlisted, but model BFM may or may not include some non-core operations. For the purpose of analysis, these two possibilities are considered as different PPP models, so a third alternative BFMo is also considered. First, the factors that don't apply to the project and the factors that don't distinguish between the three PPP models being considered are removed. They are listed in Table 4-10. The associated higher level criteria are also removed.

Table 4-10 Factors removed from multi-criteria analysis

#	Factor
	Factors that don't apply to the project
86	Risk associated with existing facilities
96	Public agency's lack of experience with operations
131	Transfer revenue risk
159	Opportunity for improved asset utilization
100	Protect existing employments in operations (new facility)
105	Low certainty of public agency's long-term need for facility
	Factors that don't affect selection among short listed alternatives
1	Schedule certainty
8	Owner control of design detail
34	Social responsibility
80	Transfer risk for design
85	Competition in design
83	Public agency's experience in design and construction
84	Private sector experience and efficiencies in design and construction
93	Project fulfills the core mission of public agency
94	Project does not fulfill the core mission of the public agency
102	Public ownership is customary
103	Private ownership is customary
104	High certainty of public agency's long term need for facility
109	Innovation in design
140	Save on risk premiums and profits on design

Next, pairwise comparisons are made. Analytical Network Process is applied through Super Decisions Software. Comparisons at highest two levels are shown in Figure 4-7, Figure 4-8 and Figure 4-9. Any judgments that refer to operations refer only the non-core operations.

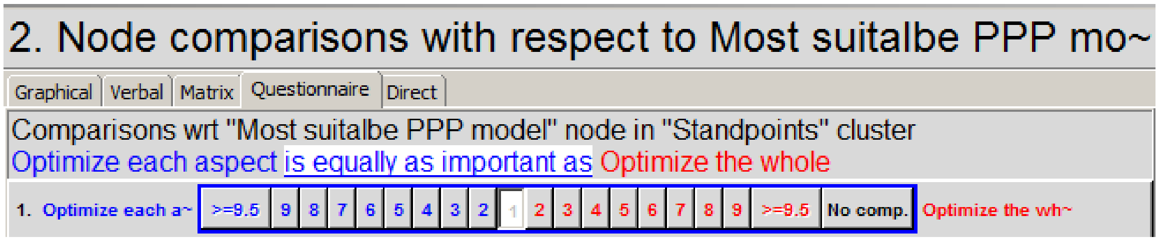

Figure 4-7 Case study 2 Comparison at Level 2

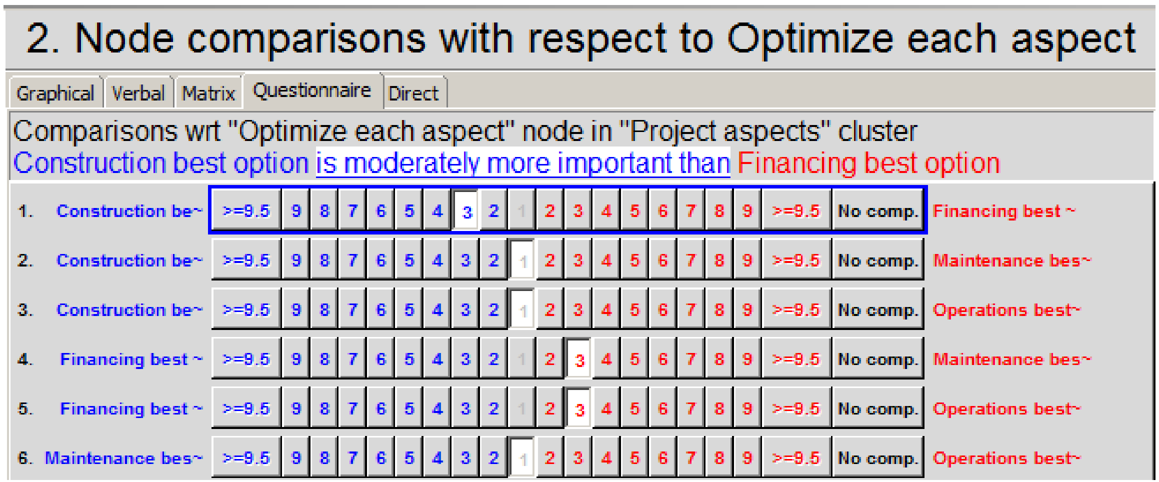

Figure 4-8 Case study 2 – Comparisons at Level 3

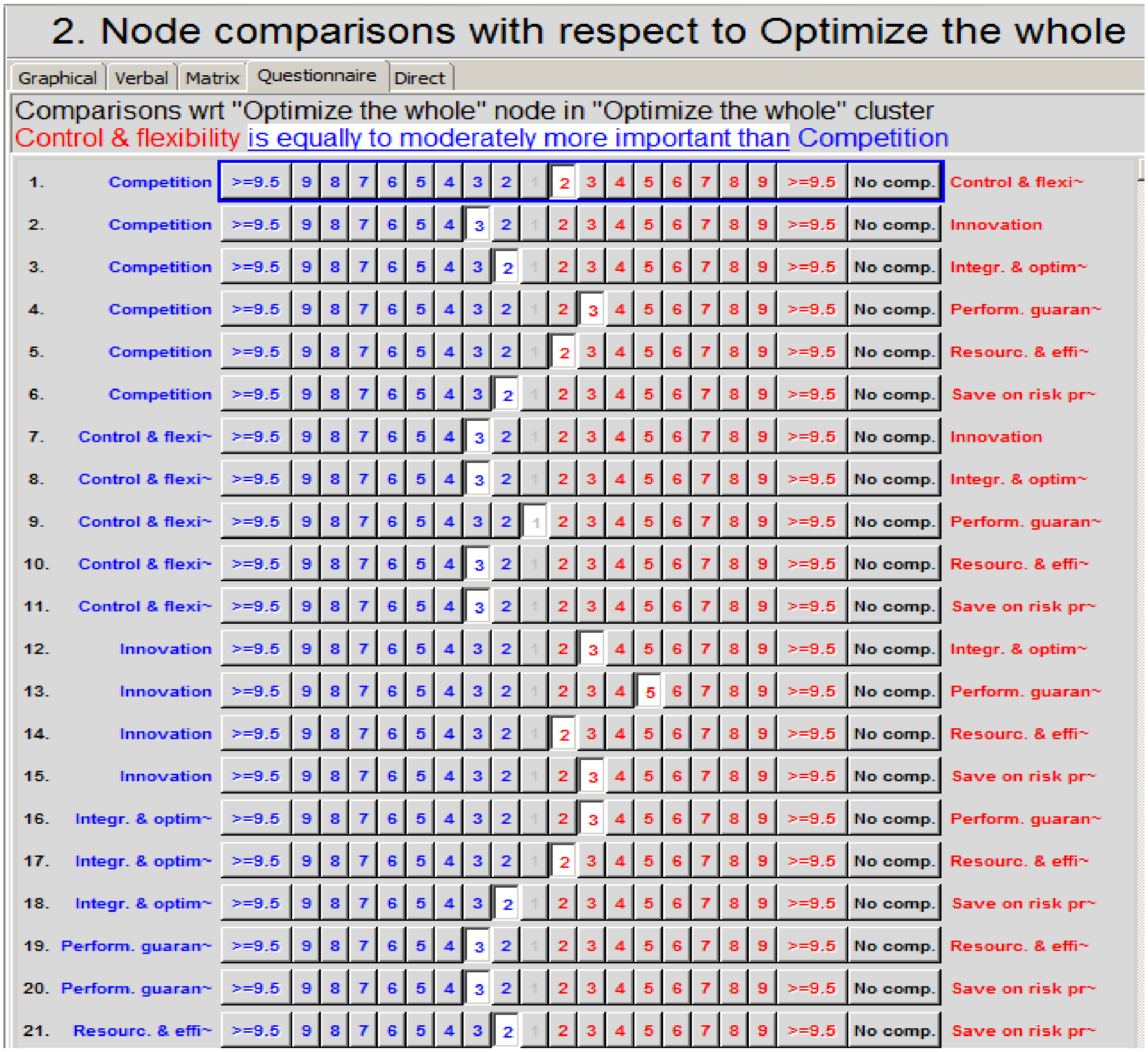

Figure 4-9 Case study 2 – Comparisons at Level 3

The resulting overall priorities and ranking of factors are shown in Table 4-11, and the graph of priorities versus ranking in Figure 8-2 in APPENDIX B. The highest ranked 20 factors, which is 33% of the 61 factors available in the model account for 80% of factor priorities. In this network model, the local ranking of factors represents the raking within a set of factors that are all being compared to the same element. After all the pairwise comparisons in the network were made, there were four sets of factors for which the local ranking and overall ranking didn't agree. Two of those sets involved the factors that were ranked in the first 20. Factor 90 (Competition in Maintenance) ranked lower than Factor 141 (Avoid paying profit, risk premium and consultant fees for maintenance) in the overall ranking but higher locally (compared to node Maintenance best option) and Factor 99 (Competition in operations) ranked lower than Factor 142 (Avoid paying profit, risk premium and consultant fees for operations) in the overall ranking but higher locally (compared to node Operations best option).

Table 4-11 Case study 2 Tier 2 Process 2 Ranking and priorities of factors for PPP model selection

Factor #	Factor name	Factor rank	Factor priorities	
			From Limit Matrix	Normalized
148	Construction performance guarantee	1	0.0273	0.0926
150	Operations performance guarantee	2	0.0235	0.0799
51	Flexibility for future modifications of physical asset	3	0.0222	0.0753
149	Maintenance performance guarantee	4	0.0218	0.0739
13	Scope flexibility for design and construction	5	0.0163	0.0555
108	Future changes in operations	6	0.0158	0.0537
14	Competition in construction	7	0.0138	0.0467
141	Avoid paying profit, risk premium and consultant fees for maintenance	8	0.0115	0.0391
151	Rehabilitation guarantee	9	0.0102	0.0347
142	Avoid paying profit, risk premium and consultant fees for operations	10	0.0095	0.0323
90	Competition in maintenance	11	0.0081	0.0275
107	Flexibility for change in maintenance	12	0.0074	0.0251
95	Public agency's experience with operations	13	0.0069	0.0236
99	Competition in operations	14	0.0069	0.0235
146	Lower public rate of borrowing	15	0.0065	0.0220
28	Public existing maintenance resources	16	0.0064	0.0218
98	Private sector efficiencies for operations through PPP	17	0.0061	0.0206
156	Contracts in place or existing relationships for operations	17	0.0061	0.0206
18	Local and small business participation	19	0.0058	0.0198

114	Optimization by choosing best option for each responsibility	20	0.0057	0.0194
88	Options to refinance	21	0.0057	0.0194
101	Control operations	22	0.0053	0.0179
110	Innovation in maintenance	23	0.0051	0.0174
112	Competition for whole integrated delivery	24	0.0046	0.0157
22	LEED certainty	25	0.0045	0.0154
7	Schedule certainty	26	0.0041	0.0140
81	Encourage innovation (in design)	27	0.0041	0.0140
87	Competition and innovation in financing	28	0.0036	0.0123
113	Optimization by integrating responsibilities -	29	0.0036	0.0123
128	Spread capital cost over long-term	30	0.0033	0.0112
111	Innovation in operations	31	0.0028	0.0095
89	Private sector experience and efficiency in maintenance	32	0.0021	0.0073
97	Preserve knowledge and human assets	33	0.0018	0.0061
91	Maintenance usually contracted out	34	0.0014	0.0046
135	High cost of operations vs. capital cost	35	0.0011	0.0036
136	Relatively low cost of operations vs. capital cost	35	0.0011	0.0036
106	Financing size suitability	37	0.0010	0.0033
116	Some operations are usually contracted out	38	0.0009	0.0030
92	Maintenance usually by public agency	39	0.0005	0.0015
117	All operations are usually by public agency	40	0.0002	0.0006

Gray shading indicates the factors that account for 80% of priorities

For the multi criteria analysis of the PPP models, the alternatives were also included in the network model, and pairwise compared to each other. The resulting ranking and priorities of the PPP alternatives is shown in Table 4-12 and Figure 4-10.

Table 4-12 Case study 2 Tier 4 Process 2, ranking of PPP models through multi-criteria analysis

PDS	Ranking	Rating (priorities normalized by cluster)
BF	1	0.3918
BFMo	2	0.3162
BFM	3	0.2920

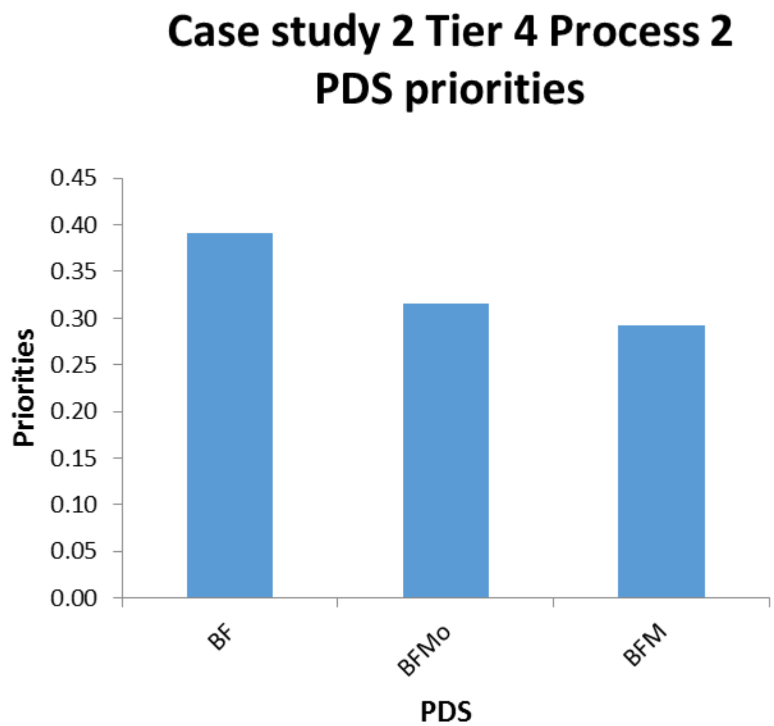

Figure 4-10 Case study 2 Tier 4 Process 2 PDS priorities

Three Stages of Tier 5 are demonstrated, but without performing a qualitative value for money analysis, which is not in the scope of this thesis. For the Tier 5 Stage 1 model, the factors that account for 80% of priorities in Tier 4 Process 1 and in Tier 4 Process 2 are considered. Factor 14 Competition in construction is common to the two sets and factor 26 Optimize lifecycle cost from Process 1 is considered in the Tier 5 as a higher level criterion 'Cost.' The combined set has 40 factors. Those factors are included in a network structure based on that described in Chapter 3 (Figure 3-13, Figure 3-14 and Figure 7-11 though Figure 7-19). Additional connections made in this network are shown in Figure 4-11. The pairwise comparisons that were previously done in Tier 4 Processes 1 and 2 were kept unchanged, and additional comparisons were made for the connections specific to this model. The resulting ranking and priorities of factors are shown in Table 4-13 and in Figure 4-12. Sixteen factors were identified as quantitative and their combined priorities are 0.437, or 43.7%. It is expected that quantitative VFM could account for the possible differences among alternatives with respect to the 16 quantitative factors.

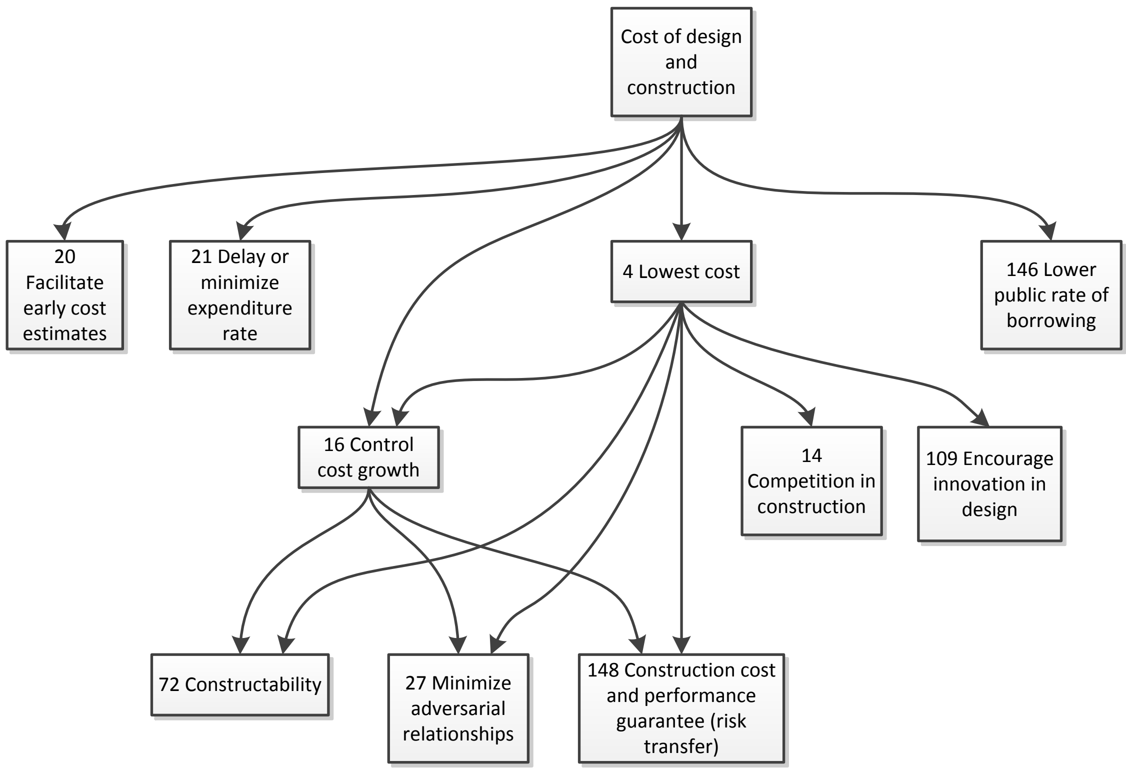

Figure 4-11 – Case study 2, Tier 5 Stage 1 additional connections in cluster 'Criteria'

Table 4-13 Tier 5 Stage 1 Factor priorities and ranking

Factor #	Factor name	Factor rank	Factor priorities normalized	Factor from Tier 4, process 1 or 2?
51	Flexibility for future modifications of physical asset	1	0.0874	2
71	Utility and functionality	2	0.0844	1
6	Durability and maintainability	3	0.0794	1
108	Future changes in operations	4	0.0723	1,2
150	**Operations performance guarantee**	**5**	**0.0709**	2
149	**Maintenance performance guarantee**	**6**	**0.0676**	2
146	**Lower public rate of borrowing**	**7**	**0.0516**	2
151	**Rehabilitation guarantee**	**8**	**0.0389**	2
148	**Construction performance guarantee**	**9**	**0.0388**	2
107	Flexibility for change in maintenance	10	0.0291	2
90	**Competition in maintenance**	**11**	**0.0289**	2
114	Optimization by choosing best option for each responsibility	12	0.0253	2
13	Scope flexibility for design and construction	13	0.0248	1,2
28	**Public existing maintenance resources**	**14**	**0.0247**	1
14	**Competition in construction**	**15**	**0.0235**	1,2
16	Control cost growth	16	0.0226	1
99	**Competition in operations**	**17**	**0.0214**	2
27	Minimize adversarial relationships	18	0.0204	2
81	Encourage innovation (in design)	19	0.0190	1,2
48	Design expectations of the owner	20	0.0158	1
72	Constructability	21	0.0140	1
95	**Public agency's experience with operations**	**22**	**0.0128**	2
98	**Private sector efficiencies for operations through PPP**	**22**	**0.0128**	2
156	**Contracts in place or existing relationships for operations**	**22**	**0.0128**	2
78	Owner's vision	25	0.0118	1
15	Availability of appropriate contractors	26	0.0113	1
21	**Delay or minimize expenditure rate**	**27**	**0.0111**	1,2
4	**Lowest cost**	**28**	**0.0100**	1
7	Schedule certainty	29	0.0086	1

59	What feels comfortable to the owner	30	0.0078	1
70	Owner/user satisfaction	31	0.0074	1
142	**Avoid paying profit, risk premium and consultant fees for maintenance**	**32**	**0.0060**	2
22	LEED certainty	33	0.0057	1
141	**Avoid paying profit, risk premium and consultant fees for design**	**34**	**0.0049**	2
20	Facilitate early cost estimates	35	0.0045	1
36	Labor unions	36	0.0044	1
47	Security	37	0.0029	1
18	Local and small business participation	38	0.0022	1,2
32	Efficiently utilize poorly defined scope	39	0.0010	1
2	Project complexity	40	0.0010	1

Bold numbers and text indicate factors for which the alternatives could be evaluated quantitatively

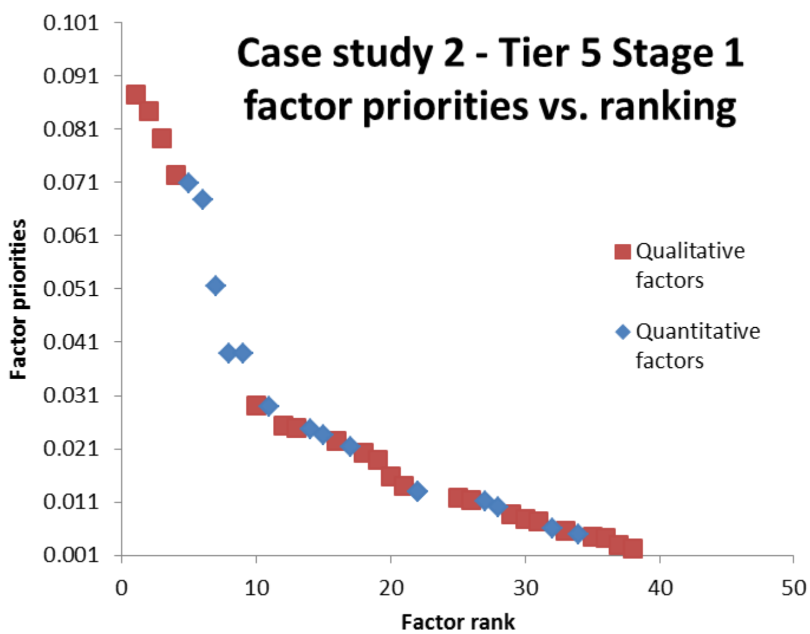

Figure 4-12 Case study 2 Tier 5 Stage 1 Factor priorities vs. ranking

Even though the comparisons for those pairs of factors that existed in both Tier 4 and in Tier 5 were not changed, the relative ranking of the factors did change, as shown in Table 4-14. Relative ranking is the ranking within the same group of factors (from Process 1 or from Process 2). The differences can be attributed to different structure of the Tier 5 model compared to the Tier 4 models, and to the additional comparisons required in the Tier 5 model.

Table 4-14 Case study 2 Change in relative ranking of factors from Tier 4 to Tier 5

Factor #	Factor name	Factor rank in Tier 5 Stage 1	Difference in relative rank	
			Compared to Tier 4 Process 1	Compared to Tier 4 Process 2
51	Flexibility for future modifications of physical asset	1		2
71	Utility and functionality	2	4	
6	Durability and maintainability	3	7	
108	Future changes in operations	4		4
150	**Operations performance guarantee**	**5**		-1
149	**Maintenance performance guarantee**	**6**		0
146	**Lower public rate of borrowing**	**7**		10
151	**Rehabilitation guarantee**	**8**		3
148	**Construction performance guarantee**	**9**		-6
107	Flexibility for change in maintenance	10		4
90	**Competition in maintenance**	**11**		2
114	Optimization by choosing best option for each responsibility	12		10
13	Scope flexibility for design and construction	13		-6
28	**Public existing maintenance resources**	**14**		4
14	**Competition in construction**	**15**	14	-6
16	Control cost growth	16	-3	
99	**Competition in operations**	**17**		0
27	Minimize adversarial relationships	18	13	
81	Encourage innovation (in design)	19	10	
48	Design expectations of the owner	20	-2	
72	Constructability	21	5	
95	**Public agency's experience with operations**	**22**		-2
98	**Private sector efficiencies for operations through PPP**	**22**		2
156	**Contracts in place or existing relationships for operations**	**22**		2

78	Owner's vision	25	-6	
15	Availability of appropriate contractors	26	1	
21	**Delay or minimize expenditure rate**	**27**	-7	
4	**Lowest cost**	**28**	-5	
7	Schedule certainty	29	-3	4
59	What feels comfortable to the owner	30	0	
70	Owner/user satisfaction	31	-3	
142	**Avoid paying profit, risk premium and consultant fees for maintenance**	**32**		-9
22	LEED certainty	33	6	1
141	**Avoid paying profit, risk premium and consultant fees for design**	**34**		-13
20	Facilitate early cost estimates	35	-2	
36	Labor unions	36	1	
47	Security	37	-11	
18	Local and small business participation	38		-3
32	Efficiently utilize poorly defined scope	39	0	
2	Project complexity	40	0	

Bold numbers and text indicate factors for which the alternatives could be evaluated quantitatively

Positive numbers mean that factor ranked higher in Tier 5 relative to other factors from the same set than in Tier 4.

Stage 2 of the Tier 5 is an intermediate stage. At this stage factors that allow only qualitative evaluation of alternatives are isolated. No new pairwise comparisons are made. The resulting priorities of factors are shown in Table 4-15 and Figure 4-13.

Table 4-15 Case study 2 tier 5 Stage 2 qualitative factors priorities and ranking

Factor #	Factor name	Factor rank in Tier 5 Stage 2	Factor priorities		Factor from Tier 4, process 1 or 2?
			From Limit Matrix	Normalized	
71	Utility and functionality	1	0.0494	0.1943	1
6	Durability and maintainability	2	0.0458	0.1804	1
51	Flexibility for future modifications of physical asset	3	0.0290	0.1139	2
108	Future changes in operations	4	0.0235	0.0926	1,2

15	Availability of appropriate contractors	5	0.0151	0.0594	1
114	Optimization by choosing best option for each responsibility	6	0.0146	0.0575	2
16	Control cost growth	7	0.0107	0.0421	1
107	Flexibility for change in maintenance	8	0.0097	0.0380	2
13	Scope flexibility for design and construction	9	0.0087	0.0344	1,2
81	Encourage innovation (in design)	10	0.0084	0.0331	1,2
27	Minimize adversarial relationships	11	0.0078	0.0308	2
72	Constructability	12	0.0058	0.0229	1
48	Design expectations of the owner	13	0.0049	0.0194	1
20	Facilitate early cost estimates	14	0.0036	0.0140	1
78	Owner's vision	15	0.0033	0.0130	1
18	Local and small business participation	16	0.0025	0.0097	1,2
7	Schedule certainty	17	0.0024	0.0095	1
70	Owner/user satisfaction	18	0.0023	0.0090	1
59	What feels comfortable to the owner	19	0.0022	0.0087	1
22	LEED certainty	20	0.0018	0.0069	1
36	Labor unions	21	0.0012	0.0048	1
47	Security	22	0.0008	0.0032	1
32	Efficiently utilize poorly defined scope	23	0.0003	0.0011	1
2	Project complexity	24	0.0003	0.0011	1

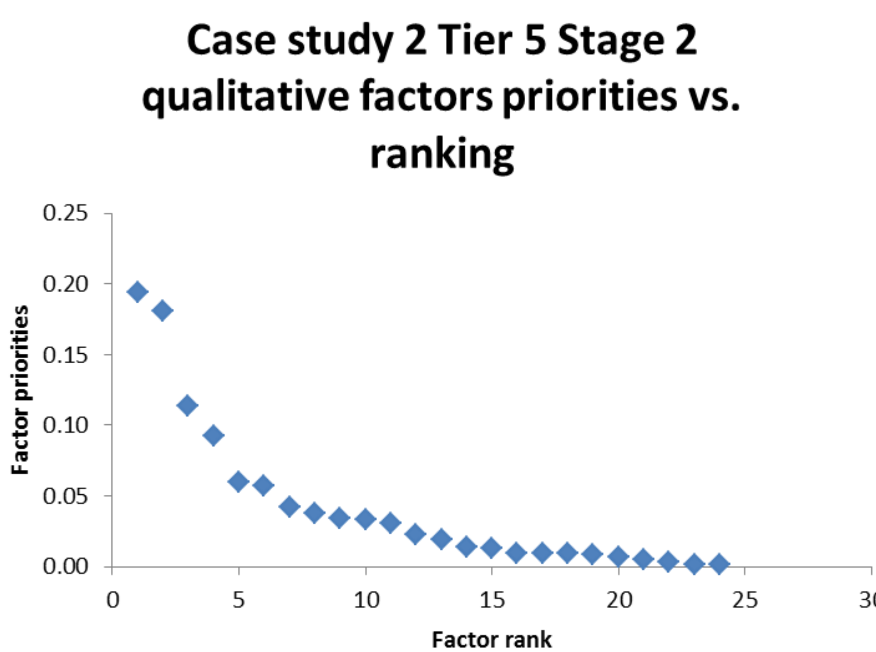

Figure 4-13 Case study 2 qualitative factors

In short-listing the alternatives to be considered in Tier 5, since the results of Tier 4 Process 1 were quite close, the three highest ranked alternatives (IPD, CMA, and DBB) are included. Also, all three of the PPP alternatives that were considered in Tier 4 Process 2 (BF, BFM and BFMo) are included. Pairwise comparisons among the PPP alternatives with respect to the PPP factors (factors from the Tier 4 Process 2) were kept as in Tier 4. Pairwise comparisons among the non-PPP alternatives with respect to the non-PPP factors (factors from Tier 4 Process 1) are based on the relative effectiveness values of PDSs with respect to the factors in question. The remaining pairwise comparisons were made based on the knowledge and understanding of project delivery systems.

The resulting priorities of the PDS alternatives for Tier 5 Stage 2 are shown in Table 4-16 and Figure 4-14. At this stage, the differences between alternatives are more pronounced because fewer factors are being considered. The three non-PPP alternatives ranked higher than the three PPP alternatives. This could be expected, because most of the qualitative factors came from the Tier 4 Process 1, and the three non-PPP alternatives were evaluated highly based on those factors. Most of the factors from Tier 4 Process 2, which evaluated highly the three PPP alternatives, are not included in this model as they are considered to be quantitative. Quantitative VFM analysis, which considers only quantitative factors, would complement this qualitative evaluation.

Table 4-16 Case study 2 Tier 5 Stage 2 PDS ranking and ratings

PDS	Ranking	Rating (priorities normalized by cluster)
Integrated project delivery	1	0.2536
Construction management agency	2	0.1745
Design-bid-build	3	0.1584
Build finance	4	0.1558
Build finance maintain	5	0.1381
Build finance maintain operate	6	0.1196

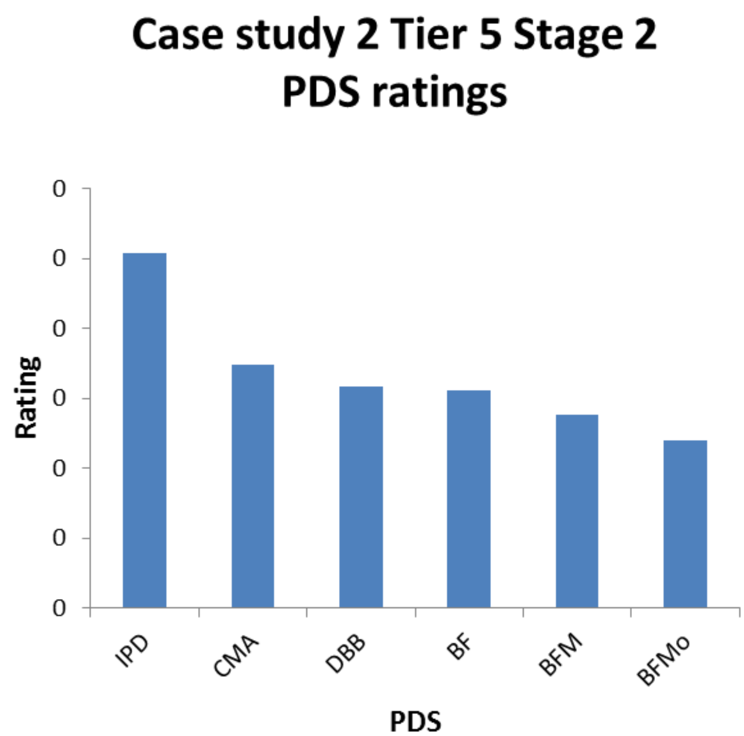

Figure 4-14 Case study 2 tier 5 Stage 2 PDS ranking and ratings

At Stage 3 of the Tier 5 the qualitative results of the Stage 2 would be aggregated with the quantitative results as shown in Table 4-17. The weighted sum method, shown in

Table 4-17 is equivalent to using Super Decisions software. The weights for the qualitative and quantitative values were determined in Tier 5 Stage 1 as a sum of qualitative factors' priorities and a sum of quantitative factors' priorities, when all the factor priorities are normalized (their sum is 1).

Table 4-17 Tier 5 Stage 3, combining the qualitative and quantitative values

(1)	(2)	(3)	(4)	(5)	(6)
PDS Alternatives	Qualitative value	Qualitative value weight	Quantitative value	Quantitative value weight	Overall value (weighted sum) (2)*(3)+(4)*(5)
BF	0.1558	0.5630		0.4370	
BFM	0.13812	0.5630		0.4370	
BFMo	0.11959	0.5630		0.4370	
PDS 1 DBB	0.15843	0.5630		0.4370	
PDS 4 CMA	0.17445	0.5630		0.4370	
PDS 15 IPD	0.25361	0.5630		0.4370	

For the final result, it would be necessary to perform quantitative VFM analysis and to translate the results of that analysis into ratings of quantitative value. If, for example, BFM was to have a greater overall value than IPD, its qunatitative value would need to be greater than the quantitative value of IPD by 0.1488 when the quantitative values of all the alternatives are normalized.

The results of the Tier 4 and Tier 5 are summarized in Table 4-18. Tier 4 Process 1 considers only the factors that distinguish between the non-PPP alternatives. Tier 4 Process 2 considers only the factors that distinguish between the PPP alternatives available, and Tier 5 Stage 2 considers only qualitative factors. None of the assessment made included quantitative analysis. IPD ranked highest among the non-PPP alternatives in Tier 4 Process 1, and highest overall in Tier 5 Stage 1 and Tier 5 Stage 2. Quantitative analysis is not likely to reveal significantly higher cost of IPD then of the other two non-PPP alternatives, so IPD is expected to also be the highest ranked non-PPP alternative in Tier 5 Stage 3. Regarding the PPP alternatives, BF ranked highest in Tier 4 process 2 and in Tier 5 Stage 2. However, BF is not likely to be the highest ranked overall, because it is very similar to the non-PPP alternative DBB. The main difference between BF and DBB is the inclusion of construction financing. DBB consistently ranked lower than IPD and CMA. Based on this, IPD is the likely winner. However, this is primarily based on qualitative analysis, whereas quantitative analysis would enable the final selection. In such analysis, long-term costs and risks for each delivery system play major role.

Table 4-18 Case study 2, summary of stages of multi-criteria analysis

Rank	Tier 4 Process 1	Pier 4 Process 2	Tier 5 Stage 2
1	IPD	BF	IPD
2	CMA	BFMo	CMA
3	DBB	BFM	DBB
4	PMA		BF
5	DBB w/EP		BFM
6	CMR		BFMo

It should be noted that possible combinations of PDSs were not considered in this analysis. By reviewing the short-listed PDSs from the two categories (PPP and non-PPP) it becomes apparent that some of them could be combined, to capture multiple advantages. The three PPP models short-listed were evaluated with the understanding that they include a DBB arrangement for design and construction. However, these models do not preclude the use of construction manager agent, so BF, BFM, and BFMo can be combined with CMA. In further assessment, these combinations could be considered as PDS alternatives, and the Steps 2 and 3 of Tier 5 could be repeated.

Comparison with result of CII IR 165-2 (2003)

The original CII case study considered five factors for this project, with ranking and preference scores as shown in Table 4-19.

Table 4-19 Case study 2 - Factors from CII IR 165-2 (2003)

CII Factor #	Factor rank	Selection factors	Preference scores	Relative weighing
1	1	Control cost growth	100	45.45%
3	2	Delay or minimize expenditure rate	60	27.27%
13	3	Maximize Owner's involvement	30	13.64%
20	4	Efficiently coordinate project complexity and innovation	20	9.09%
19	5	Minimize the number of contracted parties	10	4.55%

The corresponding ranking and rating of PDSs is shown in Table 4-20.

Table 4-20 Case study 2 - PDCS rankings and ratings by CII IR-165-2 (2003)

Rank	PDCS #	Rating	PDCS
1	1	85.5	Traditional Design-Bid-Build
2	3	77.3	Traditional with PM (agent)
2	4	77.3	Traditional with CM (agent)
4	12	69.5	Fast Track
5	2	63.6	Traditional with early procurement
6	7	58.2	Design-Build (or EPC)
7	11	58.2	Turnkey
8	6	55.9	CM @ Risk
9	5	55.5	Traditional with early procurement and CM (agent)
10	8	53.6	Multiple Design Build
11	10	26.8	Traditional with staged development
12	9	25.9	Parallel Primes

The ranking of PDSs by proposed MCA method of Tier 4 Process 1 is not drastically different than that of the CII method. The final step of the CII method is to closely consider the three highest ranking alternatives. CII results for PDCS 3 PMA and PDCS 4 CMA are equal. They share 2nd and 3rd place. In the CII analysis, PDCS 3 PMA was removed from closer consideration. The explanation was that although PMA had the same rating as CMA, PMA increases the number of contracted parties, whereas it was important for the owner to minimize the number of contracted parties (CII Factor 19, which ranked fifth in the original case study). However, the CII REV for the CII Factor 19 is slightly higher for PDCS 3 (REV=50) than for PDCS 3 (REV=40), so the opposite choice between the two (PMA and CMA) would be expected. The second ranked PDCS 4 CMA was selected for the project even though PDCS 1 ranked highest. The reason indicated in the CII study was that the owner was familiar with the CMA approach and had positive experience with it. The proposed DSS accounts for this by considering factors F23 ‘Experience with particular PDS and forms of contract’ and F59 ‘What feels comfortable to the owner.’

The factors that ranked high by the proposed method but were not available in the CII method are factors 26, 78, 48, and 71. IPD, which ranked highest by the proposed method, has greater relative effectiveness values with respect to those factors than CMA. IPD also has greater REV with respect to factors 4 and 7 which were available and ranked high by both methods, but it has a lower REV with respect to factor 21 which was also available and ranked high by both methods. The CII model does not have the ability to evaluate any of the PPP alternatives.

4.3 Case study 3 – Miami Intermodal Center

4.3.1 Description of case

Selection of a PDS for a project encompassing portions of Miami Intermodal Center (MIC) Core, Phase I was studied by Minchin, Thakkar and Ellis (2007). The project is part of development of Miami International Airport (MIA), with the purpose of relieving traffic congestion around the airport. Diagram of the entire scope, planned for two phases is shown in Figure 4-30. DBB and DB were selected for different elements of the Phase 1, but the study by Minchin, Thakkar and Ellis (2007) concentrates on the process of PDS selection for the specific elements, for which CMR delivery system was selected. These elements include a rental car facility (RCF) building, foundations, underground utilities and bridge, terminal access roadways, tunnels and bridge, stations for two transit systems – Tri-rail (a local rapid transit system) and the MIA Mover (Miami International Airport people mover connecting the MIC with the airport), and MIC/MIA Guideway Foundation. The cost of this scope was estimated to $230-$250 million.

The owner, Florida Department of Transportation (FDOT) did not have experience with all PDSs, but was willing to explore a new PDS, even if that meant overcoming certain regulatory constraints. FDOT had experience with construction projects but not with vertical construction that this project incorporated. Aside from FDOT, numerous other public and private parties had interest in the project and the funding came from multiple sources. Elevated fuel distribution centers on every floor of the RCF were to be used for the first time in the U.S. The appearance and the experience of the public spaces were very important as this facility would be part of the first impression of Miami and the U.S. to many visitors.

The criteria important for PDS selection were owner's control of design, ability to meet or exceed schedule requirements, ability to select a highly qualified contractor and a highly qualified designer, budget/cost control, project team formation and constructability input in design (Minchin, Thakkar and Ellis, 2007). In addition, from the explanation of the PDS selection it can be understood that the schedule required overlapped sequence of design and construction. The decision maker sought to reduce the risk to the owner but also to minimize the risk for all parties and to foster non-adversarial relationships. For this public owner, it was important that all the construction work would be bid competitively, but that the trade contractors were pre-qualified. A mechanism to share savings between the owner and the main contractor was instituted. Ability to handle change and the unexpected was important. (Minchin, Thakkar and Ellis, 2007)

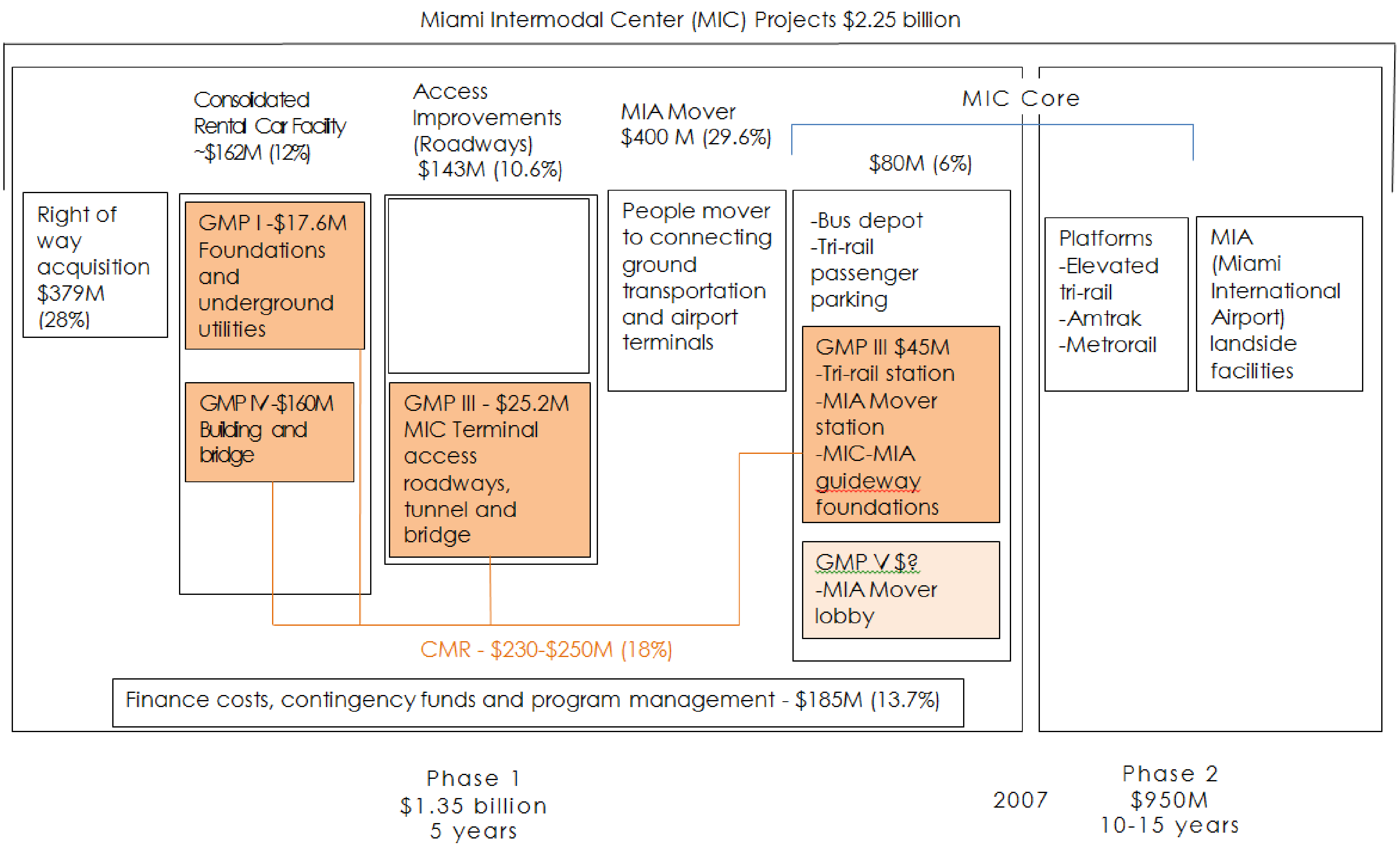

Figure 4-15 Case study 3 scope diagram, based on information from Minchin, Thakkar and Ellis, 2007

4.3.2 Applying the proposed DSS

The Tier 1 decision process, described in Chapter 3, determined that different nature of the elements of the Phase 1 of this mega project warrants that they be delivered under different project delivery systems. Further analysis of the case focuses on the same scope that was the subject of the original case study by Minchin, Thakkar and Ellis (2007). This scope is treated as one for which one PDS should be selected.

This is a public project, so Tier 2 applies. Regarding the resources for the procurement process, similar to Case 2, it is assumed that the owner can provide the resources for the process of PPP procurement. The high level screening criteria were applied as shown in Table 8-2 in APPENDIX C. Criteria 7 and 8, which pertain to transfer of design, lead to contradictory responses. There is no PPP model that can satisfy both criteria, i.e. allow both the owner's control of detail design, and an overlapped sequence of design and construction. Therefore it is determined that PPP is not suitable and it would not be evaluated further. Subsequent steps in the process include Tier 3 and Process 1 of Tier 4, similar to Case 1.

Tier 3 key inputs described in Chapter 3 are applied. Key inputs for questions 1, 2, 3, and 6 through 10 have the same effects as in Case 2. Different than Case 2 are answers to Question 4 (schedule requires overlap of design and construction) and Question 5 (Owner is able to dedicate sufficient staff resources for PDSs other than PDS 14 Owner-build).

There are five remaining PDS alternatives available: PDS 6 CMR, PDS 10 Traditional with staged development, PDS 12 Fast track, PDS 13 Design-Negotiate Build and PDS 15 IPD. The same set of factors as in Case 2 are eliminated, and, in addition, Factor 10 (Owner's staff number and qualifications are limited), is also eliminated.

In the Process 1 of Tier 4, the following factors were also removed as non-applicable based on the information about the project: 22 Sustainable design and construction, LEED certification, 46 Domestic or international firms or teams, 54 Take advantage of and strengthen existing relationships, 69 Market conditions, and 80 Desire for single point of responsibility for design and construction. There were 56 factors remaining. For this case study, both the analytical hierarchy process and the analytical network process were applied in the multi criteria analysis of the non-PPP alternatives, and the results were compared. The hierarchy model is based on that in Figure 3-5, from which the non-applicable factors are removed. The network model has additional dependency connections shown in Figure 3-6. The judgments for the comparisons common to both models were kept identical. The seven major categories that are being compared to one another with respect to the goal, i.e. the nodes connected directly to the goal node are the same for both models. They constitute Level 2 of the hierarchy. Their comparisons are shown in Figure 8-3 in APPENDIX C. Pairwise comparisons specific to the network are shown in Figure 8-4 through Figure 8-12.

The priorities of the factors were obtained from the Limit Matrix (Saaty, 2003) generated by the Super Decisions software, from both the hierarchy and network models. From each model, the priorities of the same 56 factors (factors on the lowest level of any branch of the hierarchy) were extracted and normalized so that they sum to 1. Factor priorities and ranking are shown in Table 4-21 and in Figure 4-16.

Table 4-21 Factors priorities and ranking by Hierarchy and by Network, ranked by results of Hierarchy

Factor #	Factor name	Hierarchy (Super Decisions)		Network (Super Decisions)		Difference between Network and Hierarchy	
		Factor rank	Priority	Factor rank	Priority	In rank	In priority
7	Control time growth	1	0.1037	5	0.0509	4	-50.87%
48	Design expectations of the owner	2	0.0792	9	0.0393	7	-50.38%
16	Control cost growth	3	0.0633	3	0.0526	0	-16.83%
13	High likelihood of change	4	0.0578	7	0.0481	3	-16.83%
40	Multiple funding sources	5	0.0507	8	0.0422	3	-16.83%
2	Project complexity	6	0.0435	10	0.0362	4	-16.83%
1	Shortest schedule	7	0.0414	18	0.0191	11	-53.93%
6	Quality and maintainability	8	0.0345	15	0.0210	7	-39.20%
12	Desire for builder's input during design	9	0.0327	11	0.0325	2	-0.43%
71	Utility and functionality	10	0.0319	17	0.0199	7	-37.62%
70	Owner/user satisfaction	10	0.0319	23	0.0133	13	-58.41%
38	Amount of overlap of design and construction that is feasible	12	0.0311	25	0.0129	13	-58.41%
20	Facilitate early cost estimates	13	0.0299	1	0.0932	-12	211.72%
35	Third party agreements	14	0.0244	16	0.0200	2	-18.16%
4	Lowest cost	15	0.0243	14	0.0237	-1	-2.47%
28	Stand-alone project or part of a capital development program	16	0.0226	19	0.0188	3	-16.83%
30	Promote early procurement	17	0.0211	27	0.0110	10	-47.99%
27	Minimize adversarial relationships	18	0.0193	20	0.0161	2	-16.83%
33	Control construction impact	19	0.0167	21	0.0139	2	-16.82%

	on operations						
47	Security	19	0.0167	21	0.0139	2	-16.82%
26	Optimize lifecycle cost	21	0.0160	12	0.0308	-9	92.15%
32	Efficiently utilize poorly defined scope	22	0.0144	26	0.0120	4	-16.83%
21	Delay or minimize expenditure rate	23	0.0130	13	0.0245	-10	88.40%
72	Constructability	24	0.0120	6	0.0496	-18	312.22%
42	Capitalize on familiar project conditions	25	0.0116	29	0.0096	4	-16.82%
78	Owner's vision	26	0.0114	31	0.0095	5	-16.83%
37	Environmental regulations	27	0.0103	29	0.0096	2	-6.31%
83	Owner's experience with design, construction and project type	28	0.0102	32	0.0085	4	-16.82%
64	Complexity of decision making	29	0.0093	33	0.0078	4	-16.82%
84	Encourage innovation	30	0.0086	34	0.0071	4	-16.82%
15	Availability of appropriate contractors	31	0.0075	36	0.0063	5	-16.82%
17	Maximize owner's involvement	32	0.0069	37	0.0058	5	-16.83%
31	Protect confidentiality	33	0.0065	39	0.0054	6	-16.82%
36	Labor unions	34	0.0065	45	0.0046	11	-28.50%
5	Minimize number of contracted parties	35	0.0064	40	0.0054	5	-16.83%
60	Avoid conflict of interest	36	0.0063	28	0.0100	-8	60.15%
8	Maximize owner's controlling role	37	0.0062	41	0.0052	4	-16.85%
56	Ability to prequalify project team	37	0.0062	41	0.0052	4	-16.85%
57	Ability to prequalify subcontractors	37	0.0062	41	0.0052	4	-16.85%
79	Market position (desire to gain experience with a new PDS)	40	0.0058	44	0.0048	4	-16.81%
45	Ability to award contracts based on best value	41	0.0051	2	0.0703	-39	1291.42%
14	Competition	42	0.0049	4	0.0524	-38	979.43%
68	Apportion risk equitably and share rewards	43	0.0044	35	0.0070	-8	60.14%
73	Effective communication	44	0.0032	38	0.0055	-6	69.31%
59	What feels comfortable to the owner	45	0.0032	49	0.0027	4	-16.87%
39	Ability to participate in multiple trade builder/supplier evaluation	46	0.0030	50	0.0025	4	-16.83%
19	Stakeholder/community input	47	0.0028	51	0.0023	4	-16.81%

24	Desired contractual relationship and ability to recoup savings	48	0.0028	46	0.0045	-2	60.24%
55	Opportunity to partner	49	0.0023	47	0.0036	-2	60.17%
29	Shifting roles and responsibilities, clarity of defined roles	50	0.0021	52	0.0017	2	-16.81%
23	Experience with particular PDS and forms of contract	51	0.0020	53	0.0016	2	-16.85%
75	Trust and respect	52	0.0020	48	0.0033	-4	69.35%
34	Agency goals and objectives	53	0.0019	54	0.0016	1	-16.82%
18	Small business impact	54	0.0010	24	0.0132	-30	1228.51%
76	Alignment of objectives	55	0.0008	55	0.0014	0	69.39%
74	Collaboration of project team	56	0.0007	56	0.0012	0	69.34%

Gray shading indicates the factors that account for 80% of priorities.
Yellow shading indicates the ranking that is different by the two methods.

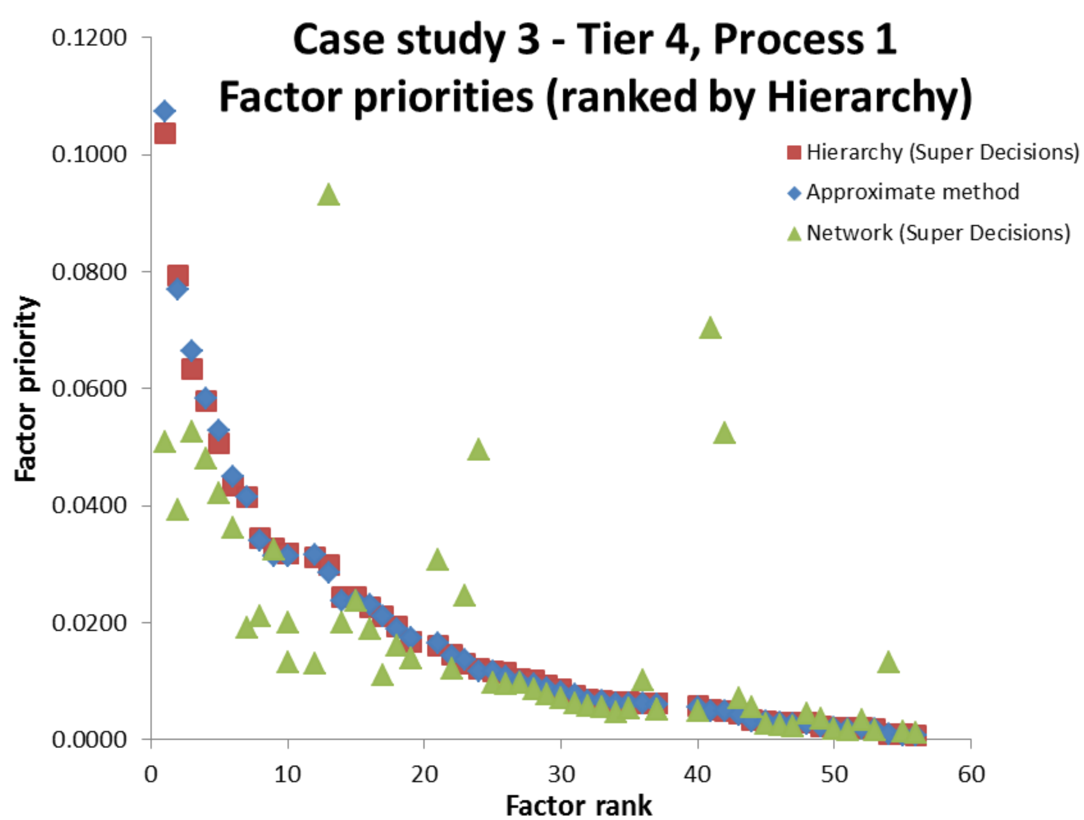

Figure 4-16 Case study 3 Tier 4, factor priorities vs. ranking

As it could be expected, the results by these two methods are different. 22 highest ranking factors by hierarchy and 23 highest ranking factors by network account for 80% of priorities, which is 1/3 of the 67 factors available in the model. Among the 23 highest ranking factors, the two methods had 20 factors in common. For the hierarchy, the overall ranking of factors confirms to their local ranking. In a network, a factor that influences multiple other nodes has multiple local rankings, as it belongs to multiple sets of factors that are being directly compared to one another. Therefore, in a network, the overall ranking may not confirm to all the local rankings. The sets of factors for which the relative global ranking is not the same as their local ranking in this case study are shown in Table 4-22. Relative global ranking means factor's global ranking relative to other factors of the same set. The differences are by one or two places, except for factor F72 Constructability, which ranked lowest of five factors with respect to the objective 'Quality,' but highest among those factors in the overall ranking. This factor was judged as very strongly more important (importance of 7) than factor 48 (Design expectations of the owner) with respect to factor 7 'Control time growth.'

Table 4-22 Case study 3 Tier 4, local and global ranking of castors

Factor	Local rank	Global rank	Relative global rank
With respect to 'Cost'			
16 Control cost growth	1	3	2
40 Multiple funding sources	2	8	3
20 Facilitate Early Cost Estimates	3	1	1
4 Lowest Cost	4	14	6
26 Optimize Lifecycle Cost	5	12	4
21 Delay or minimize expenditure rate	6	13	5
With respect to Quality			
48 Design expectations of the Owner	1	9	2
6 Quality and maintainability	2	15	3

70 Owner/user satisfaction	3	23	5
71 Utility and functionality	3	17	4
72 Constructability	5	6	1
With respect to 'Political considerations'			
45 Ability to award contracts based on best value	1	2	1
14 Competition	2	4	2
19 Stakeholder/community input	3	51	4
18 Small business impact	4	24	3
With respect to 'Lower cost'			
7 Control time growth	1	5	1
30 Promote early procurement	2	27	3
1 Shortest schedule	3	18	2
With respect to 'Lower cost'			
14 Competition	1	4	2
18 Small business impact	2	24	3
45 Ability to award contrasts base don best value	2	2	1
With respect to 'Project complexity'			
14 Competition	1	4	2
18 Small business impact	2	24	3
45 Ability to award contracts based on best value	2	2	1

In the ANP, 17 factors participated in the network relationships. 11 of them were among the 23 highest ranking factors, both by AHP and by ANP, i.e. regardless of those network relationships. The three factors that entered the highest 23 as a result of network (factors F14, F45 and F72) all had network connections, but one factor (F 30) dropped below rank 23 as a result of its network connection. Among the factors that participated in network relationships, 14 influenced one additional element each, though their network connections, and six were influenced by multiple other elements though their network connections. Three factors had both types of network connections. Considering changes in ranking for all the factors, fourteen had a higher rank by network than by hierarchy, three had equal rank by both methods, and 39 had a lower rank by network than by hierarchy. The factors that gained in rank by network satisfied one of two conditions.

Eight factors satisfied Condition 1 - they influenced one additional element directly through a network connection. Six factors satisfied Condition 2. They had no additional network connections, but they each influenced an element through their respective hierarchy connections, which, in turn, influenced an additional element through a network connection. However, there were six factors that satisfied Condition 1 and three factors that satisfied Condition 2 that dropped in rank a result of network. Seven factors that had the highest gains in both ranking and priorities satisfied the Condition 1 and the additional Condition 3 - they were not influenced by any additional elements. However, four factors also satisfied both Condition 1 and Condition 3 but they dropped in ranks and priorities by network compared to hierarchy. Out of the seven factors that had greatest gains in ranking and in priorities, five factors were unique in that they satisfied the additional Condition 4 - they were favored in at least one of their pairwise comparisons specific to the network. These were factors F20 (Facilitate early cost estimates), F45 (Ability to award contracts based on best value), F14 Competition, F72 (Constructability) and F26 (Optimize lifecycle cost), which ranked, 1st, 2nd, 4th, 6th and 12th respectively by network. These relationships are illustrated in Figure 4-17.

The rankings and ratings of PDS alternatives are shown in Table 4-23 and Figure 4-18. Even though the priorities of specific factors differ significantly between Hierarchy and Network, the ranking of PDSs was not affected. Since the range of factor priorities is somewhat smaller by network, the range of PDS priorities is also smaller. This indicates that this particular decision model, taking all the pairwise comparisons into account, has low sensitivity to priorities of particular factors.

Ranking by Hierarchy

Rank	Factor ranked by Hierarchy	Factors ranked by Network
1	7 Control time growth	20 Facilitate Early Cost Estimates
2	48 Design expectations of the Owner	45 Ability to award contrast based on best
3	16 Control cost growth	16 Control cost growth
4	13 High likelihood of change	14 Competition
5	40 Multiple funding sources	7 Control time growth
6	2 Project complexity	72 Constructability
7	1 Shortest schedule	13 High likelihood of change
8	6 Quality and maintainability	40 Multiple funding sources
9	12 Desire for builder's input in design	48 Design expectations of the Owner
10	70 Owner/user satisfaction	2 Project complexity
10	71 Utility and functionality	12 Desire for builder's input in design
12	38 Amount of overlap or design and construction that are feasible	26 Optimize Lifecycle Cost
13	20 Facilitate Early Cost Estimates	21 Delay or minimize expenditure rate
14	35 Third party agreements	4 Lowest Cost
15	4 Lowest Cost	6 Quality and maintainability
16	28 Stand alone project of part of a capital development program	35 Third party agreements
17	30 Promote early procurement	71 Utility and functionality
18	27 Minimize adversarial relationships	1 Shortest schedule
19	33 Control construction impact on operations	28 Stand alone project of part of a capital
19	47 Security	27 Minimize adversarial relationships
21	26 Optimize Lifecycle Cost	33 Control construction impact on operati
22	32 Efficiently utilize poorly defined scope	47 Security
23	21 Delay or minimize expenditure rate	70 Owner/user satisfaction
24	72 Constructability	18 Small business impact
25	42 Capitalize on familiar project conditions	38 Amount of overlap or design and constr
26	78 Owner's vision	32 Efficiently utilize poorly defined scope
27	37 FTA/EPA regulations	30 Promote early procurement
28	83 Owner's experience with design, construction and project type	60 Avoid conflict of interest
29	64 Complexity of decision making	37 FTA/EPA regulations
30	84 Encourage innovation	42 Capitalize on familiar project conditio
31	15 Availability of appropriate contractors	78 Owner's vision
32	17 Maximize Owner's involvement	83 Owner's experience with design, constr
33	31 Protect confidentiality	64 Complexity of decision making
34	36 Labor unions	84 Encourage innovation
35	5 Minimize number of contracted parties	68 Apportion risk equitably and share rew
36	60 Avoid conflict of interest	15 Availability of appropriate contractors
37	8 Maximize owner's controlling role	17 Maximize Owner's involvement
37	56 Ability to prequalify project team	73 Effective communication
37	57 Ability to prequalify subcontractors	31 Protect confidentiality
40	79 Desire to gain market position	5 Minimize number of contracted parties
41	45 Ability to award contrats basedon best value	8 Maximize owner's controlling role
42	14 Competition	56 Ability to prequalify project team
43	68 Apportion risk equitably and share rewards	57 Ability to prequalify subcontractors
44	73 Effective communication	79 Desire to gain market position
45	59 What feels comfortable to the owner	36 Labor unions
46	39 Ability to participate in multiple trade builder supplier evaluation	24 Desired contractual relationship
47	19 Stakeholder/community input	55 Opportunity to partner
48	24 Desired contractual relationship	75 Trust and respect
49	55 Opportunity to partner	59 What feels comfortable to the owner
50	29 Shifting roles and responsibilities	39 Ability to participate in multiple trade
51	23 Experience with particular PDS and forms of contract	19 Stakeholder/community input
52	75 Trust and respect	29 Shifting roles and responsibilities
53	34 Agency goals and objectives	23 Experience with particular PDS and for
54	18 Small business impact	34 Agency goals and objectives
55	76 Alignment of objectives	76 Alignment of objectives
56	74 Collaboration of project team	74 Collaboration of project team

Legend: Factors that satisfy the following conditions

- Condition 1 but not 2, 3 or 4 (green)
- Condition 2 and 3 (yellow)
- Conditions 1 and 3, but not 4 (blue)
- Conditions 1, 3, and 4 (red)

Figure 4-17 Differences in factor ranking between Hierarchy and Network

Table 4-23 Case study 3 PDS' ranking and ratings by hierarchy (approximate method and by Super Decisions and by Network).

PDS #	PDS	Ranking			Rating		
		Approx. method	Super Decisions		Approx. method	Super Decisions	
			Hierarchy	Network		Hierarchy	Network
15	Integrated Project Delivery	1	1	1	72.9342	72.9228	69.7443
6	CM @ Risk	2	2	2	64.1485	64.1242	61.9048
12	Fast Track	3	3	3	60.7167	60.5901	58.8603
13	Design-Negotiate-Build	4	4	4	50.4490	50.7093	49.6911
10	Traditional with staged development	5	5	5	43.2685	43.5079	40.8102

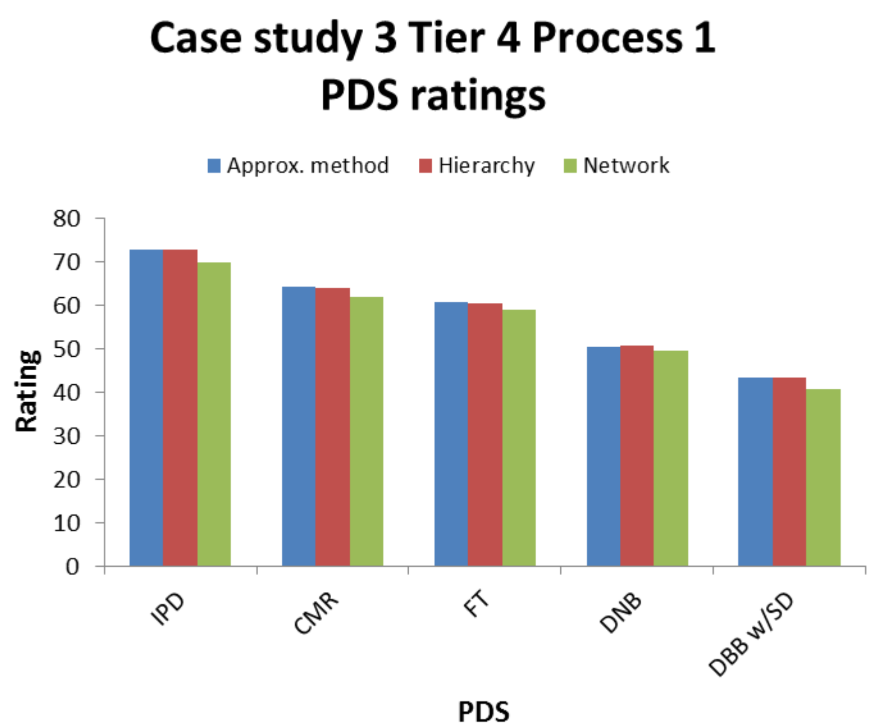

Figure 4-18 – Case study 3 Tier 4 Process 1 PDS ranking

The ANP in this example favored the factors that participated in network connections by influencing additional elements, were judged as more important in the pairwise comparisons for those connections, and were not influenced by additional elements through network. All such factors had significant gains in ranking and priorities. The only other factors that gained in ranking were those that did not participate in network connections but were, though their hierarchy connections, connected to nodes which in turn influenced other nodes though their network connections. Such factors gained in rank, except for factor 12 (Need or desire for builder' input in design), which dropped in rank, and two of such factors stayed at their bottom rank. Similar effects could be expected for other network connections, but these findings cannot be generalized without further studying this and other examples.

To evaluate whether the AHP or the ANP is more accurate, it is necessary to evaluate which results of factor ranking and priorities make more sense. In this case study, results by AHP make more sense. For example, factor F20 (Facilitate early cost estimates), ranked highest by ANP, with a priority of 9.32%, and this result does not reflect the decision maker's intuitive ranking of available factors. However, this finding is related to the connections made in this particular network model and to the associated judgements, and does not speak about ANP as a method in general. It highlights the importance of structuring the network very carefully, and the need to understand possible effects of connections in a network.

In this case the AHP and ANP resulted in the same ranking of PDS. In other cases, the results might be more sensitive to the priorities of particular factors. Further study of this network on other examples, or different networks using the same set of factors would be needed, for evaluation of these methods. In this example of ANP, some of the local rankings within clusters were overruled in the overall ranking, as a result of additional network-specific judgments. This reveals the sensitivity of ANP to the constructed interdependent relationships in the decision network. AHP requires fewer judgements and it is simpler to implement without special software and to integrate with a database of the PDS relative effectiveness values into a stand-alone application (Popic and Moselhi, 2014b).

Comparison with the project delivery system actually selected

The owner, Florida Department of Transportation actually selected Construction Management at Risk (CMR), based on a recommendation of a consulting firm (Earthtech). To evaluate PDS alternatives, Earthtech customized a PDS evaluation matrix developed by Sanvido and Konchar (1998), which evaluates three PDSs (DBB, DB and CMR) and rates them as excellent, fair, poor or not applicable, with respect to twelve criteria: Ability to meet schedule, Unit cost experience, Quality Experience, Control of Contractor selection, Control of designer selection, Early project team selection, Interaction in design phase, Early constructability input, opportunity to partner, Ability to prequalify project team, Ability to prequalify subcontractors, and Ability to obtain relevant experience, (Minchin, Thakkar and Ellis 2007). CMR was rated excellent for 11 of those 12 criteria, and fair for one (Unit cost experience). IPD, which was selected by the proposed DSS, was not widely known when PDS was selected for this project. Minchin, Thakkar and Ellis (2007) describe several advantages of CMR that are also found in IPD, and which are present in IPD to a greater degree according to IPD proponents. These advantages include, non-adversarial relationships that further collaboration in decision-making, reduced risk for every entity involved, early involvement and collaboration of major participants (owner, architect and CM), and owner's control of design, owing to direct contract with design professional, (Minchin, Thakkar and Elllis, 2007). IPD, like CMR, includes qualifications based selection of the entity responsible for construction, which was desired on this project.

In CMR, the CM and the owner have separate contingencies, whereas in IPD there is one contingency, which represents different approach to sharing risk and rewards. On this project, the scope of work was further divided into five GMP contract packages, with a staggered sequence, and the owner had hired a program manager for the wider scope described earlier. Multiple packages gave the owner the flexibility to switch to the traditional system, on any subsequent package, in case owner and CM could not agree on the price. At the time the case study was published, the first three packages proceeded under the CMR and the fourth package was under negotiation (Minchin, Thakkar and Ellis, 2007). To have such flexibility with IPD, the work would similarly need to be divided into separate agreements with attention to provisions for early termination, although this is not in the spirit of IPD. Minchin Thakkar and Ellis (2007) report that, for the first GMP package CM was brought on the team only after the design was complete, for the second GMP package - just before the design was complete, which allowed value engineering but not a constructability review, and on the 3rd and 4th package at the beginning of design phase "under a constructability contract separate from the GMP contract," (Minchin Thakkar and Ellis, 2007). In IPD, the contract for pre-construction services would not be separate from contract for construction, so integration would occur early, but it would possibly take longer to put together a team and negotiate the contract.

The proposed DSS allowed PPP to be considered, as well as a wider range of 16 non-PPP alternatives. The screening processes narrowed down the selection to five non-PPP alternatives, which were evaluated with respect to 56 factors. Considering top 10 factors which accounted for more than 50% of priorities by both hierarchy and network, IPD has greater REV than CMR for 9 of those factors, in both the hierarchy and the network model. Considering the 12 factors of the CII system, IPD had higher REV, for two factors, lower REV for 2 factors, the two PDSs (CMR and IPD) had equal values for 4 factors, and the remaining 4 factors were considered essentially the same as other factors of the proposed system.

4.4 Summary

In Chapter 4, implementation of the proposed DSS is presented. The proposed DSS is illustrated through three case studies - projects for which PDS selection was previously described using other methods. Case 1 is a private project, so Tiers 1, 3 and 4 applied. Case 2 is a public project, for which all five tiers and two processes of Tier 4 applied, and Case 3 is a public project for which Tiers 1 through 4 applied, with only the Process 1 of Tier 4. For Case 2 sensitivity analysis was performed for Process 1 of Tier 4. In Case 3, AHP and ANP were compared as methods of multi-criteria analysis in Process 1 of Tier 4. Results of the proposed DSS are compared with those obtained through other methods, and discussed.

5 CHAPTER FIVE: SUMMARY AND CONCLUSIONS

5.1 Summary

A decision support system for selecting the most suitable PDSs for capital projects has been developed. Different PDSs have various degrees of suitability for specific project conditions. Suitability of a PDS affects project's potential to achieve its targeted objectives and maximize its value. None of the available methods for PDS selection takes into account all important recent developments in project delivery, including Integrated Project Delivery (IPD) and the various models of public-private partnership (PPP). In this research a comprehensive decision support system (DSS) is developed for the selection of project delivery systems, which considers the PDSs that are currently being used, allows for expanded criteria relevant to project stakeholders to be considered, and embraces current industry trends.

The proposed DSS consists of five tiers and operates in two modes. Mode 1 targets elimination of non-applicable and unrealistic solutions and Mode 2 employs multi-criteria analysis, within a narrowed search field. Tier 1 assists in determining whether one PDS or multiple PDSs should be used on the project being considered. Tier 2 applies to public projects only. It determines whether PPP should be considered and it identifies the applicable PPP models, and the factors for multi-criteria analysis (MCA) of PPP models. Tier 2 considers resources for procurement process, project size, 20 high-level suitability screening criteria, and interest in the market. Tier 3 identifies applicable non-PPP alternatives and factors for their multi-criteria analysis, by means of ten key inputs. Tier 4 has two processes of MCA. Process 1 pertains to non-PPP alternatives and uses AHP. This portion of the proposed DSS is a development based on a decision support system developed by CII (2003). If PPP is considered, Process 2 is applied, which pertains to PPP alternatives, and uses ANP. Process 1 and Process 2 result in ratings and rankings of PDSs in order of suitability in their respective categories. If PPP is not considered, Process 1 recommends the most suitable PDS. If PPP is considered, Tier 5 is the final step in the process. It includes both qualitative and quantitative analyses of the most suitable PPP and non-PPP alternatives. Qualitative analysis of Tier 5 uses an integrated ANP model, which combines the most important factors for PDS selection from Process 1 and Process 2 of the Tier 4, and evaluates the short-listed PDS alternatives, PPP and non-PPP, by the same criteria. A method for combining the results of qualitative and quantitative analysis is proposed.

AHP and ANP, which are based on pairwise comparisons, are used as methods with a high level of objectivity, for determining relative weights of selection factors (criteria) used in the MCA. Relevant modules of the proposed DSS have been implemented in an automated spreadsheet, which integrates the screening process through Key Inputs, the AHP which determines priorities of selection factors, and the database of relative effectiveness values (REV) of PDS alternatives, to calculate the rating and ranking of alternatives. The proposed DSS was applied to three case studies. The DSS is flexible and it allows new developments in project delivery and selection of PDSs to be incorporated.

5.2 Conclusions

Although the results of applying the proposed DSS to the three case studies were not identical, they were, however, consistent with those obtained by other methods under the same conditions. For Case Study 1, the order of the two highest ranking alternatives is reversed from the order resulting from the CII method, which was originally applied. The results of multi criteria analysis of Tier 4, Process 1, suggest that this MCA model may favor IPD. IPD was not widely known. It was not considered in the CII method. When the proposed system was applied to Case 2 and Case 3, for which IPD was considered in the MCA, this PDS ranked highest in both cases. Its highest rank was not sensitive to the variation in judgement of cost versus quality, according to the sensitivity analysis performed for Case 2. This is not surprising, as IPD is the most recently developed project delivery system and it was designed to overcome the limitations of the previously known PDSs. At this time, there is relatively little performance data for IPD projects. Few have been completed, and many IPD pilot projects may not provide highly relevant data, as they are small and relatively simple. The preliminary REVs for IPD, included in the proposed DSS are based primarily on theoretical understanding and they represent expectations.

The advantage of the proposed DSS over other similar methods is that it makes available to the user a wide range of selection factors that may be relevant, and thus it accommodates the complex nature of the problem. The developed system, through its multi-tier and two modes of operation, allows the decision process to be progressively more focused on the most relevant choices.

Regarding AHP and ANP, when a hierarchy and a network model were applied to the same decision problem, the ranking and priorities of selection factors were, as expected, different between the two methods. The ANP favored those factors that influenced multiple other elements, through interdependent connections added in the network, that were judged to be more important in the respective network-specific comparisons, and that were not influenced by additional elements through network connections. AHP preserves the local ranking of factors. In the ANP example analyzed, some of the local rankings were overruled in the overall ranking, as a result of additional network-specific judgments. This reveals the sensitivity of ANP to the constructed interdependent relationships in the decision hierarchy. The AHP is simpler to implement without special software and simpler to integrate with a database of the PDS relative effectiveness values into a stand-alone application. In the example analyzed, despite the differences in factor priorities, the resulting ranking of PDSs was the same for both AHP and ANP. Furthermore, in the example examined, factor ranking by AHP made more sense than by ANP. This suggests that AHP may be more suitable for the analysis of non-PPP alternatives, but further study is required to reach a conclusion.

Regarding PPP; based on the analysis of the Canadian PPP Projects database, eight PPP models were identified, as the commonly occurring combinations of responsibilities for project aspects that are transferred to a private partner through a single agreement. PPP has seen its widest use in the sectors of hospitals and health care, where BF and DBFM are used most frequently, and in transportation, where DBFMO is used most frequently. Other trends in the use of PPP models were identified and some of the criteria for selecting PPP models were articulated based on these trends.

5.3 Contributions

The contributions of this work can be summarized as follows;

- Inclusion of PDSs that have not been considered by previous decision support systems, such as, IPD, Owner-build, Design-negotiate-build, EPCM and eight models of public-private partnership.
- Expanded range factors for multi-criteria analysis of PDSs, including 67 factors pertaining to selection among non-PPP alternatives and 61 factors pertaining to selection among PPP alternatives.
- Screening criteria which streamline the process, including 10 key inputs pertaining to non-PPP alternatives and 20 pertaining to PPP alternatives.
- A decision process to determine whether components of a project should be delivered under a combination of more than one PDS.
- Structure of hierarchy and network models for multi-criteria analysis, to evaluate relative importance among a large number of factors.
- Preliminary default REV of 16 non-PPP PDSs with respect to 67 selection factors, expanded from CII IR-165-2, (2003). Therefore, an original set of 240 values was expanded to 1072.

- Evaluating the appropriateness of AHP versus that of ANP in selecting the most suitable project delivery system.
- Model for qualitative assessment of PPP and non-PPP project delivery systems, by the same criteria.
- A conceptual method combining results of qualitative and quantitative analysis, including calculation of relative weights of qualitative versus quantitative values.
- An automated software tool, which facilitates the application of the proposed DSS.

5.4 Recommendations for Future Work

- The proposed preliminary REVs should be validated through a method, such as a survey of experts. In the future, as more IPD projects are completed and operated, their performance data should be collected and analyzed to compare IPD projects to similar projects delivered under other PDSs.
- Develop other network structures for the same set of factors and evaluate their merits. This could lead to developing an optimal network or hierarchy structure for this decision problem.
- Default pairwise comparison judgments among PPP alternatives with respect to selection factors, or default REVs of PPP alternatives could be established, to reduce the effort needed in the decision process, and to provide greater consistency between decision problems. However, this may not always be applicable, as the effectiveness of a PPP model with respect to certain factors may depend on the project circumstances.

- A principle and a method to convert monetary values of quantitative VFM analysis into non-dimensional scaled ratings should be developed, which would enable aggregating qualitative and quantitative results in a consistent manner.

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6 APPENDIX A – Factors for PDS selection

1 – Shortest schedule

This factor, also referred to as *delivery speed* is the most frequently occurring factor in literature concerning selection of PDS, and in some cases in practice, it has be the single most important factor to drive the PDS selection (Brannan, 2011, US DoT, 2006). The CII (2003) defines this factor as "early completion is critical to project success." In such a case the project delivery and contract strategy that ensures shortest reasonable schedule should be selected. The PDSs that allow overlapped sequence of design, procurement and construction, as well as elimination of protracted bidding processes are advantageous with respect to this factor (CII 2003). Moore (2000) defines this factor as: "Schedule - Can the project be delivered in a linear sequence or a fast track approach is needed?" Mearing (2004) defines it as "Schedule/necessity to overlap phases – Is overlap of design and construction phases necessary to meet schedule requirements?" Morris and Singel, (2007) suggest that involvement of contractor sufficiently early in design can lead to shorter construction schedule. This factor is closely related to factor 38 - Amount of overlap of design and construction phases that is feasible.

2 – Project complexity

The CII (2003) describes this factor as "project delivery and contract strategy facilitate efficient coordination and management of non-standard project design/engineering and/or construction." Project complexity may be due to the function of the facility, combination of functions, site, integration with existing structures, historical preservation requirements, new technologies or integration of horizontal and vertical construction and other project characteristics. Short schedule may give rise to complexity. Important concern with complex projects is to ensure that teams are qualified for the project. In traditional (DBB) method, the owner may set minimum qualifications requirements. Many public owners are required to award a contract to the lowest bidder who meets such qualification requirements, but this may not be the optimum choice. Other PDSs allow the owner greater control of the selection process. Complex projects are also better served by those PDSs that facilitate integration of design and construction. For many complex projects, strong involvement of owner and users in design process is critical, and in such cases PDS must allow the needed owner and user involvement.

3 – Reduce risk or transfer risk to contractors

The CII (2003) describes the factor Reduce risks or transfer risks to contractors, by stating that, if this factor is important to the owner, he wishes to assume minimal risk on the project, and that the project delivery and contract strategy (PDCS) should reduce risk to the owner or transfer a high level of cost and schedule risks to the contractor. Moore (2000), points that for the success of a project it is important that risks should be allocated fairly, which can be accomplished through contract negotiations and contract terms, by following the principles that no party should accept risks that they do not understand, or risks beyond their control, or accept responsibility for problems created by other parties (PSMJ Resources, 2000, Moore, 2000). Risk and rewards should be proportional to all parties and risk allocation should create a winning situation for all parties (PSMJ Resources, 2000, Moore, 2000). The owner's approach to risk allocation may be essentially to transfer risks much as possible or to share risks and potential rewards with the contractors. However, if the owner chooses to transfer to the contractor those risks that the contractors are not able to control, he should expect that contract prices would include contingencies to handle those risks. In DBB, owner retains a significant amount of risk. He can usually transfer only portion of the risk for design omissions to the design professional. The owner also faces the risk of inferior performance by low bidder. The construction manager in CMR takes various risks, and he often guarantees a maximum price. The reasoning is that he has an active role in design and thus can control the cost as the design evolves. However, since the GMP is established based on partial design, the GMP typically contains a contingency for incomplete design. If the actual cost is below the GMP, it may be difficult for the owner to recoup savings, even if the shared savings clause exists, because the profit that the CM (contractor) can realize by using up the GMP may be more attractive than the potential gain from shared staving. The CM can find ways to claim the project costs up to the GMP amount. So, the owner may end up paying for some items that he does not need, in return for price certainty. On the other hand, the CMR method is able to reduce risk for all parties by fostering communication and collaboration (Minchin, Thakkar and Ellis 2007). In DB the owner transfers the responsibility for design and therefore the risk of design errors or incompleteness to the contractors. This is advantageous to the owner, but there is a trade-off, as the owner gives up a certain degree of control of design. USDoT (2006), in a survey of U.S. state transportation agencies who participated in a federal aid highway program, found that opportunity for risk transfer is one of the main reasons for selecting

DB (after urgency of project and opportunity for innovation) with the importance of 4.2 on a scale from 0 to 6. One of the principles of IPD is to enable all participants including owner, and design and construction teams to share risk equitably and receive rewards for successful project performance in form of savings (for the owner) or profit (for other participants). The more responsibilities assigned to a single entity, the more risk is transferred. The contracts that involve responsibilities for financing and operation such as DBFOM are on the far end of the spectrum of risk transfer. This factor is related to factor 29 Shifting roles and responsibilities, and factor 80 Owner's preference for single point of responsibility for design and construction.

4 – Lowest cost

CII (2003) defines this factor as: "Minimal cost is critical to project success", with an example that if the return on investment is at a minimum, the lowest cost is critical to ensure return on investment. CII (2003) gives the highest REV of 100 to DBB with early procurement, followed by DBB with 90 and DB, multiple DB and Turnkey with 80, whereas Parallel Primes and DBB with Staged Development have 0 REV.

5 – Minimize number of contracted parties

CII (2003) defines this factor as: "Owner prefers minimal number of parties to be accountable for project performance." Turnkey and DB satisfy this factor best, whereas Parallel Primes does not satisfy this factor.

6 - Quality, maintainability

Konchar and Sanvido (1998), when comparing performance of different PDSs measure quality in terms of the following seven metrics: start-up quality, call backs, operations and maintenance, envelope roof structure and foundation, interior space and layout, environment, and process equipment and layout. Love and Skitmore (1998) list quality as one of the client's requirements defined as "contractor's reputation, aesthetics and confidence in design," and as one of the criteria for selecting a procurement method, defined as the level of quality and aesthetic appearance required in the design and workmanship. Mahdi and Alreshaid (2005), list design quality as a selection criterion within the category of design characteristics, defined by a question: "is it available in house or does the owner need outside resources to verify design quality," and they list construction quality as a criterion in the category of the contractor characteristics. USDoT (2006) lists quality of completed facility as a PDS selection factor, where the level of quality can be measured in both qualitative and quantitative terms, and includes: owner satisfaction - meet or exceed expectations, meet or exceed standards, and user satisfaction.

Quality as a factor in PDS selection refers to the quality of design, and that of construction materials and assemblies. Quality of design refers to how well the design meets owner's needs and objectives, with the understanding that the design process may also include discovering and articulating of those needs and objectives. Quality of design pertains to functionality, efficiency of space, efficiency of various building systems (such as mechanical, electrical, fire protection), efficiency in use of materials, and how well the design fits the intended purpose. Design also responds to the owner's expectations in the sense of delight, aesthetic qualities, the overall experience of space or place, and the image statement. Quality of design also refers to the quality of construction documents their clarity, completeness, consistency, level of coordination, and amount of errors. Quality of construction refers to level of workmanship, precision, amount of rework, adherence to industry standards, and execution according to drawings and specifications. Quality of materials and assemblies refers to quality of components, their durability, and respect of allowed tolerances. Maintainability refers to the ease of maintenance - how easy it is to replace the parts, and to clean, and how well the materials and assemblies stand multiple cycles of cleaning and wear and tear.

Certain levels of quality in both design and construction are necessary, and high levels of quality are always desirable. However, highest level of quality is not always necessary. The highest level of quality may not offer significant benefit over an adequate level of quality, and the cost difference may not be justified. Speculative building owners are often less concerned with quality. Also, durability of components should be in accordance with expected useful life of the facility.

The project delivery systems that better satisfy the criteria of quality and maintainability are those that are based on higher level of integration of design and construction, and that also provide for adequate owner involvement in design. Those project delivery systems that involve operation and maintenance within the same contract as design and construction are more likely to provide higher quality, they motivate the contractor to reduce long-term costs.

7 – Control time growth

CII (2003) defines this factor as: "Completion within schedule is highly critical to project success," with the comment that "single-source responsibility, such as that in DB or Turnkey leads to better control of time growth, whereas agents (CM and PM) do not have responsibility for time growth

8 - Maximize Owner's controlling role

CII (2003) describes this factor as: "Owner desires a high degree of control/influence over project execution," with comments that single source PDSs minimize owner's role, agents (PM or CM) reduce owner's role and PDSs where owner takes on some major procurement activities lead to increased owner's controlling role. Owner may have various degrees of control over design, quality of construction and selection of project team participants including the design team, contractor, trade contractors and suppliers. The differences between various PDSs are pronounced with respect to owner's control in these categories. Owner's control of design may be particularly important not only if the owner has high ambitions regarding design, but also if the owner has a responsibility towards a larger community regarding building appearance or other types of impact on its environment. In DB and other single source PDSs the owner has least control of design process and design details. Also, he cannot select the design team, but if the selection of DB team is based on qualifications, he controls the selection of the team as a whole, and in that way, he has more control over selection of constructor then with price based competition in DBB. DBB allows the owner the greatest control of design (Touran et al, 2009a,b). This factor is closely related to Factor 17 – Maximize Owner's Involvement and Factor 48 Design expectations of the owner.

9 - Capitalize on well-defined scope

This factor is present if project features are well defined at the time of award of design and/or construction contract (CII, 2003). The scope includes performance requirements. The success of DB and the various PPP models that include design depend on the scope being well defined. This means that, based on the information that the owner provides in an RFP or similar document, price can be established, design can proceed and the resulting design and construction would satisfy the owner's needs and meet performance requirements without a change in price. If it is not possible to define the scope sufficiently, a reasonable and common practice is design process proceed to a certain degree without a price commitment, which allows the owner to define the project further and to balance the scope and cost. The PDSs other than those in design-build category are more suitable in such situation. Private owners may have more flexibility for changes in scope, as they usually have a greater ability to accept the associated cost consequences than the public owners. This factor is opposite of factor 32 Efficiently utilize poorly defined scope, and it is related to factor 41 Low likelihood of change.

10 - Owner staff - number and qualifications are limited

Each construction project requires its owner to perform certain duties during design and construction. The time and knowledge required on part of the owner depends on the size and complexity of the project, and also on the project delivery system. An owner seeks to select a project delivery system, appropriate for his staff resources and the project demands. An owner may also choose to augment his staff resources, if necessary to meet the project demands, or hire a consultant a PM or CM to assist him in performing his duties. Generally, public agencies have limited staff resources, and they prefer to minimize project delivery demands on their staff. In CMR, the owner needs to oversee the work of the CM and also manage the process by which the constructor gives input to the designer, and the way these inputs are received, analyzed and implemented. (Touran, et al. 2009b). In any PDS where contract price is negotiated, such as the GMP in CMR, the owner's staff need to be sufficiently knowledgeable for such negotiations. In DB, preparing an RFP and evaluating proposals based on qualifications or best value, requires highly qualified owner staff. Public owners that undertake many construction projects tend to put their more experienced staff on DB projects, because this PDS requires understanding of conceptual design, conceptual estimating and performance criteria (Gransberg and Molenaar, 2007). The PPPs require greatest sophistication of owner's staff as they require not only technical expertise but also capabilities in financial analysis on part of the owner. Even if the owner uses consultants, he must be able to understand and evaluate their work. This factor is related to factor 17-Minimize owner's involvement.

11 - Legal and statutory constraints

This criterion was identified as a Key Input. In the multi-criteria analysis, it is not one single factor, but it represents several factors. This criterion refers primarily to the public owners in those jurisdictions where the competitive bidding is required for all public projects, which is based on the reasoning that an open competitive process provides for highest level of transparency and best stewardship of public funds. In such cases the traditional DBB may be the only choice available. However, more and more governments and are allowing other types of PDSs either, in general or thorough special programs. When regulatory restrictions exist, the owner may still perform the PDS selection process without considering such restriction, if there is a possibility to obtain a special permission to use a different PDS, should such choice be justified as the most appropriate for the project.

12 - Need or desire for builder input during design

The input of the constructor in design is beneficial, and sometimes necessary, as the constructors' unique knowledge of construction, or the information on particular means and methods of construction can help achieve better constructability and optimize the design considering multiple objectives and constraints. Various PDSs offer various levels of opportunity for constructor input in design. Legal requirements for separate contracts for design and construction, and for competitive bidding, or owner's preference for this type of arrangement, are in opposition with this criterion. Higher level of builder input represents the involvement of trade contractors.

13 – Ease of change incorporation

CII (2003) defines this factor as "an above-normal level of changes is anticipated in the execution of the project." Love, Skitmore and Earl (1998) as well as Chan, Yung, Lam, Tam and Cheung (2001) list flexibility for changes after start of construction, whereas Mahdi and Alreshaid (2005) list flexibility to redesign after construction cost commitment and potential for design changes during construction as factors for PDS selection. Gordon (1994) points that changes can arise due to strategy – if the owner is not the user of the facility, he may allow users to modify specific portions of the project, or due to low definability – owner's indecisiveness, permit requirements, market fluctuations, time constraints, or unknown site conditions. According to Gordon (1994) the PDSs including a construction manager and multiple primes are flexible to changes, whereas DBB, DB and Turnkey are flexible if reimbursable methods of compensation are used, but they are not flexible if firm price (lump sum) methods of compensation are used. Love and Skitmore (1998), surveyed the Australian construction industry participants, and found that, regarding flexibility to changes after start of construction, Management Contracting (the term used in Australia for Multiple Primes with CMA) is the most flexible, whereas Turnkey is least flexible. Miller et al. (2009) point that in Management Contracting, the owner takes most of the risk for project cost and schedule, which points to the natural trade-off between flexibility and certainty of cost and schedule. CII (2003) comments that project phasing may allow more time to solidify scope and avoid changes during procurement and construction, that it is more difficult to coordinate multiple contractors than a single contractor in case of changes, and that single source of responsibility limits owner's ability to request changes without claims of major impact in cost and schedule. According to CII (2003), DBB, DBB with PM and DBB with CM are the most flexible, whereas Turnkey is least flexible (CII 2003). The disagreement among the sources regarding Multiple Primes PDS is probably because of different definitions and understanding of this PDS. CII (2003) implies that owner is responsible for managing the multiple prime contracts, whereas Gordon (1994) suggests that there can be a GMP with multiple primes, which would suggest that a CM guarantees the price, which corresponds to CMA or CMR delivery in the CII classification of PDSs. Mearing (2004) points that if there is a significant potential for changes during construction, qualifications based selection (QBS) should be used. IPD is intended to overcome the challenges the PDSs that existed before it. IPD seeks to reduce potential for changes during construction through intense early planning and use of technological tools such as BIM for better design coordination. Proponents of IPD also claim that IPD performs better than other PDSs on projects with high uncertainty, principally by means of one general project contingency (as opposed to multiple contingencies incorporated in various cost items), open book accounting, the spirit of open communication, collaboration founded in incentives, trust and 'best for project philosophy'. Essentially, if owner causes a change, he should pay for it. However, if owner's budget is constrained, as is almost always the case, those PDSs that are more flexible, enable the owner to give up some features of the project, as may be practicable, considering the timing of the changes, in order to pay for changes that are necessary. Change may also be due to fast-tracking. In fast-track projects, changes during construction are more acceptable to all participants, since construction starts based on incomplete design. CII (2003) clarifies that this factor is not to be confused with factor 32 Efficiently utilize poorly defined scope, since the scope could be well defined, and yet, high level of changes could arise during the project execution. This factor is opposite to factor 41 Capitalize on expected low levels of change. It is related to factors 7 Control time growth and 16 Control cost growth.

14 - Competition

Love, Skitmore and Earl, list “price competition (covering such issues as value for money, maintenance costs and competitive tendering)” as one of the selection criteria (Love Skitmore and Earl, 1997, NEDO 1985, Skitmore and Mardsen, 1988 and Singh 1990). Chan et al. (2001) conducted a Delphi survey, in which price competition as a criterion was expressed though a question “How important it is to choose your project team by price competition, so increasing the likelihood of a low price?” (Chan et al., 2001). In that survey, price competition ranked highest among the second-tier criteria (criteria with significant level <0.05), whereas there were three criteria in the first tier (significant level > 0.05): quality, client’s involvement and size of the project). Mahdi and Alreshaid list the selection factor ‘Allowance for competitive bidding,’ in the area of regulatory factors. (Mahdi and Alreshaid, 2005). A Design-Build Effectiveness Study, prepared for the US Department of Transportation, Federal Highway Administration (2006) lists competition among prospective bidders as one of the criteria to assess the advantages and disadvantages of design-build versus design-bid build, in the highway design and construction industry, where competition includes:

- Individual firms or teams providing planning, architecture, design, construction and inspection services
- Large, medium small and disadvantaged firms,
- Domestic or international firms or teams

The concern, when it comes to highway projects, in the U.S., is that innovative project delivery methods (which, in the context of public projects, often means a delivery method other than the traditional design-bid-build), would place local firms at a disadvantage versus larger national firms that have more experience in preparing DB proposals and delivering projects under the DB system, (USDoT, 2006). This is also the case with large public projects in general.

Two parallel reports of the Transportation Research Board of National Academies, one dedicated to transit projects and the other one to airports, both list the competition as one of the issues in project delivery (Touran et al, 2009a,b). These publications point that the choice of PDS may contribute to a higher or lower level of competition for the project. As these are public projects, they may be subject to a regulatory requirement for ”free and open competition.” As competition keeps prices in check, reduced competition associated with a PDS is regarded as a disadvantage. Moreover, some project delivery systems may lead to inadvertently packaging the projects into large sizes, which also reduces competition (Touran et al., 2009b). Among the major project delivery categories, DBB ensures a high level of competition, as it offers a highest likelihood of a large number of qualified bidders. However, the drawback may be that in order to limit the package size, the owner is in a position to handle multiple prime contracts which increases his management demand (Touran et al., 2009b). The CMR method offers less competition at the level of general contract, which is usually negotiated, but the owner may require competitive bidding among the trade contractors. The DB may mean reduced competition due to the size of a bid package and the bid preparation costs. The DBOM contracts further reduce competition due to additional competences required. Proponents are usually consortia and in practice only two proponents usually compete in such contracts. The project nature itself, which may involve specialized technical systems, for example airport airside structures and equipment may pose limits on competition (Touran et al. 2009a).

Competition may refer to the entire project or program scope or to specific portions of the scope. Open solicitation, means greatest likelihood of competition. This is the case with DBB. DB entity may be selected based on an open solicitation, but in such cases the competition is generally less, because it takes more effort to prepare a DB proposal than a bid for construction of a comparable project, and there would likely be fewer qualified and interested proponents. With DB, the design-builder usually solicits bids from trade contractors, but the owner cannot mandate the open competitive process, and the DB contractor may choose to negotiate some of the subcontracts. Within DBB, there may be little competition for specific trades. However, if there is only one bid for the general contract, this may be a signal to the owner to reconsider the situation. It may mean that the bidding climate at the project location is unfavourable, or that contractors view the project as highly risky, as the contract terms, including the compensation approach, may be misaligned with particular risks of the project. On certain projects design concept may be selected through a design (architectural) competition, which may be single-or multi stage, and may require architectural teams to assemble teams of consulting engineers. DB solicitation represents a design competition when the owner does not include a concept design in the RFP, or when the proponents are expected to propose improvements to the owner-provided reference design, in order to provide best value. Both architectural and DB competitions are often not open, but candidate firms or teams are invited, based on qualifications. Such competitions may include stipends to candidates, in order to ensure a reasonable number of entries, as the preparation of entries requires significant resources. In case of any type of competition, and particularly in the case of competitive bidding for construction contracts, having too many competitors can cause potential bidders to lose interest and become less committed as the chance of winning gets slimmer (Russell, Tawiah and De Zoysa, 2006). To attract an optimum number of competitors, the owner should package the project and establish terms to generate maximum interest. Breaking the project into smaller ones may discourage international competition whereas bundling the project may exclude the local competitors who lack the experience and resources to participate, (Russell, Tawiah and De Zoysa, 2006). In conclusion, competition as a selection criterion refers to the owner's desire to enable the optimum competition for the project, in order to benefit from competitive pricing and to ensure that contractors are qualified for the project. Owner's concern is to not restrict competition unreasonably by his choice of project delivery method.

15 - Availability of qualified contractors

This criterion has been formulated as "How important is it to have a plentiful supply of competent contractors to work for the procurement system?" (Chan, et al., 2001). This criterion refers to construction contractors including general contractors, construction managers and trade contractors. The qualifications of contractors pertain to the characteristics of the project such as the project size complexity, and building type and construction type. It is desirable that the contractor have experience with project of similar characteristics. The owner is also concerned with the financial stability of the contractors and their bonding capacity.

Contractor qualifications also include their experience with specific project delivery system (Mahdi and Alreshaid, 2005), and the ability of the owner or the contractors to assemble teams required for certain project delivery systems such as design-build or integrated project delivery. With the traditional DBB, the owner may express specific qualification requirements in the bidding documents regarding the contractor or subcontractor experience. A private owner may invite only certain contractors to bid. In any project delivery system where the selection of contractors is not based on the lowest responsive bid, the owner can define specific qualifications of contractors as criteria in the process of evaluation and selection of contractors.

This factor is closely related to the factor 2 Project complexity and factor 14 Competition. If the project is relatively simple, then the availability of qualified contractors is not an important consideration. If the owner determines that a non-traditional project delivery system such as DB or IPD would be most suited for the project, without considering the availability of experienced contractors, and if he does not expect to find local contractors who are both qualified for the project and capable of working within the desired delivery method, then the owner must evaluate where the potential contractors would come from, whether the remote or international contractors, familiar with non-traditional PDSs and qualified for the project, would be interested in the project. The interest of contractors may be due to project size and prestige or due to market conditions. Contractors not experienced with the less traditional PDSs may be interested in the project if they wish to expand their experience with PDSs and if they evaluate the risk as acceptable.

16 – Control cost growth

CII (2003) defines this factor as "Completion within original budget is critical to project success." This factor is related to Factor 13 – Ease change incorporation.

17 - Maximize Owner's involvement

CII (2003) defines this factor as "Owner desires substantial use of its own resources in the execution of the project". To satisfy this factor, PDS should to promote strong owner involvement in detailed design and construction. Procurement during design phase would increase owner's involvement, whereas single source project delivery systems reduce the opportunities for using owner's resources. (CII, 2003) The degree of owner involvement can vary through various phases. Traditionally, the owner plays a much more active role in design than in construction. The intensity of owner's involvement in design depends on the demands of the project, its functional complexity and uniqueness, and owner's ambition regarding design. The process of designing the physical space also represents an opportunity for the owner to analyze his operations and processes and improve them. If the project is routine, there is less need for owner's involvement. Some owners have internal capabilities to perform construction phase duties which are usually performed by design professional or CMA, such as approving product submittals. In multiple prime PDS, the owner takes on great responsibilities and risks of managing and coordinating all the prime contractors, unless a CM is retained for those duties. Some owners perform design, construction or both design and construction with their own resources. This is usually the case with relatively simple projects based on prototype designs, such as big box commercial buildings, or with real estate development companies who have internal design and construction divisions. IPD requires owner's continuous commitment. Owner is required to establish project metrics at an early stage, he has an active role in evaluating and influencing design alternatives, and he assists in resolving issues that arise on the project, to a greater degree than on other PDSs (AIA National/AIA California Council, 2007). With and PDS, the owner is responsible for communications and negotiations with external parties, such as community groups, but one or more other key participants may assist him or take a major role in managing those external relationships, as may be appropriate. This factor is related to factor 8 Maximize owner's controlling role, factor 10-Owner's staff number and qualifications, factor 25 – Minimize owner's involvement, Factor 43 - Minimize owner's controlling role.

18 - Small business impact

This factor may be important for public owners, as they may be subject to statutory requirements to have a certain level of participation of small and minority businesses on their projects. Private projects that receive public subsidies may be subject to similar requirements. Such requirements can be met with any project delivery system. They can be included in general contracts for construction or for design and construction. However, Touran et al. (2009a,b) indicate that as the owner has less control in the DB approach than in the DBB and CMR, the enforcement of disadvantaged business participation may be more difficult in the DB approach than in the DBB and CMR approaches. The requirement for disadvantaged business participation may limit the opportunities to take advantage of established relationships between general contractors and subcontractors, and thus diminish some of the benefits of DB and IPD.

19 - Stakeholder and community input

This factor responds to a question of how well a PDS enables the owner to take into account and manage community inputs in a meaningful and transparent fashion. A PDS should enable the owner to successfully manage project related agreements with third parties such as political entities, utilities, adjacent communities, and neighbors involved in the project or affected by it (Touran et al. 2009a). This factor is important for large projects and projects with noticeable impact on their neighbourhood or wider environment, whether physical, economic, political, aesthetical, spiritual or other. This factor also refers to the permitting process. The linear sequence of design and construction, which is the characteristic of DBB, allows the time to receive and incorporate community input into design, more than the other PDSs. However, the process of negotiations with the community and stakeholders may seriously extend owner's schedule. The CMR project delivery system may offer an advantage with respect to this factor if the

responsibility for negotiations with the community is part of the CMR pre-construction services. In the DB delivery, the owner has to identify community concerns with respect to the project before issuing the RFP. He needs to include sufficient information in the RFP, to avoid costly and disruptive change orders (Touran et al. 2009b). The owner may include in the RFP a requirement for public information and outreach program to facilitate stakeholder and community input during design and construction. The DB contractor may have long standing relationships with third party stakeholders, and, in such a case, may be in a better position to negotiate with them than the owner. Which PDS would best responds to this criterion needs to be evaluated on a case by case basis.

20 - Facilitate early cost estimates

CII (2003) defines this factor as: “Owner critically requires early and reliable cost figures to facilitate financial planning and business decisions.” According to CII (2003) reliable cost estimates are in fact contractor’s bids, and with serial sequence of design and construction, reliable cost estimates can be obtained only after design completion. Mahdi and Alreshaid (2005), list ‘Precise cost estimates before contract signing,’ as a factor in PDS selection and Touran et al. (2009a) similarly list ‘Early cost precision.’ In DBB, the engineer’s or architect’s estimate based on complete design before bidding does not reflect the market conditions. If budget is fixed, and if the lowest bid exceeds the budget, the owner has an option to redesign, or rebid at a later date. In CMR, a cost commitment in the form of GMP is usually negotiated at some stage of design development before design completion. The drawback is absence of competition, which represents a difficulty in establishing a validity of the GMP. If the GMP negotiations fail, the owner can pay the CMR for his preconstruction services and bid the project competitively. DB with a firm fixed price as the compensation method, offers the earliest knowledge of cost, compared to other delivery methods (Gransberg and Molenaar, 2007), whereas DB with qualifications based selection and negotiated price is similar to CMR regarding the early price certainty. The key to early cost precision in DB is precisely defined scope, (Touran, et al. 2009a). CII (2003) similarly gives low REV to DBB and other PDSs where sequence of design and construction is linear, a high REV to the single source PDSs, and a relatively high REV of 70 to CMR. IPD is intended to provide early reliable price. In IPD, target price, which includes the cost of work, non-incentive based compensation (fees for services) and the project contingency, is established in the conceptualization stage, with the input from all key participants. The design process is continually informed by the inputs regarding cost, schedule and quality impacts of the development of design, so that the target price can be respected and maintained. Incentives exist for all participants to work towards achieving the target price. Even though the natural tendency of the owner is towards a lower price and, and that of the other participants towards a higher price, these opposing tendencies can be managed through careful team selection, open book estimating and proper use of independent consultants. (AIA National/AIA California Council, 2007)

21 – Delay or minimize expenditure rate

CII (2003) defines this factor as: "owner's cash flow for the project is constrained," with a comment that the ease of manipulating cash flow varies for different PDSs, and that higher execution speed as well as early procurement mean higher expenditure rate. According to CII, the single source PDSs are least effective with respect to this factor, whereas DBB and Fast Track are the most effective. Konchar and Sanvido (1998) list 'intensity' as one of the PDS performance metrics, and define it as 'the unit cost of design and construction work put in place in a facility per unit time". Their survey of 351 U.S. building projects found that DB has greater intensity than DBB on multi-story dwellings, simple office and complex office projects, and also greater intensity than CMR on simple office and high technology projects.

22 - Sustainability

Environmental sustainability may be one of project objectives, and it represents a factor in PDS selection. Sustainability rating systems rate projects with respect to certain aspects of sustainability. Certain sustainability rating may be owner's choice. It may be legislatively required for public owners or private owners who receive public subsidies, or it may qualify for government incentives. In the U.S. and Canada the LEED (Leadership in Energy and Environmental Design), has been the prevalent rating system. The owner may also define his own sustainability goals, if he is not subject to regulatory requirements for sustainability, or of he wishes to exceed regulatory requirements. According to Krorkmaz et al. (2011), project delivery systems that offer higher levels of team integration are more likely to achieve or exceed the sustainability goals. Collaborative delivery methods and the use of Qualifications Based Selection show a higher rate of success in achieving sustainability goals (Molenaar, Gransberg, et al. 2009, Lynch, 2009).

23 - Experience with particular PDS and forms of contract

The owner may have experience with particular PDS and forms of contract which may be positive or negative. Such prior experience influences the likelihood of using the same PDS again. Some of the researchers characterise this factor as important (Masterman, 2002, Ibbs, 2011), or as the main influencing factor (Masterman and Gameson, 1994, Love, Skitmore and Earl, 1998). Skitmore and Earl point that some of the clients experienced in construction take the ‘habituation’ approach to project delivery selection - selecting the most familiar methods of project delivery. These researchers refer to Brensen and Haslam, who point that such approach is inappropriate when projects types are different (Brensen and Haslam, 1991, Love, Skitmore and Earl, 1998). Ibbs (2011) points that experiences and solutions form past projects may not be applicable to current projects as differences exist between previous and current projects. The prior experience with a PDS is more pertinent when the conditions of the past projects are similar to those of the project being considered. If an owner organisation had a negative experience with a particular PDS, it should make an effort to understand the nature and causes of the problems encountered, whether they were largely due to PDS selected or due to other causes. The benefit of using a familiar PDS is that owner's organization does not need to go through a process of learning about an unfamiliar PDS, and that it has an opportunity to improve the application of an already familiar process. This factor should not represent a primary factor in the selection process, but it may aid in an otherwise difficult choice.

24 - Desired contractual relationship and ability to recoup savings

Mahdi and Alreshaid (2005) state that contractual relationships is “dependant on the owner’s selection of the construction entity,” and that contractual relationship “will affect what information is required to be provided and when.” The owner may have a preference for a certain contractual relationship. If this preference is substantiated, it may help the owner in a decision to choose a particular PDS. However, in principle, the contractual relationship should serve the goals and the specific circumstances of each project. Using a familiar form of contract saves the owner the effort of understanding and examining a less familiar contract, but a less familiar contract may serve the project better. Joint Committee of the ACI-NA, ACC and AGC (2012) include 'Desired contractual relationships and ability to recoup savings,' as a factor in PDS selection in the category of owner's internal resources. The ability to recuperate savings is advantageous to the owner. The owner is more likely to recuperate savings if the contractor is motivated to achieve savings, which is the case when savings are shared between the owner and contractor. A shared savings clause may be included in any contract for construction or for design and construction. However, opportunities for savings are less with the traditional DBB, as they are limited to construction phase, since contract is based on design that is essentially complete. During the bidding phase, it is not in bidders' interest to propose cost-saving changes, because, if the owner was to accept them, the information would need to be distributed to all bidders and the bidder who proposed the change would still be competing for the project. After the award of contract, the contractor may propose the cost saving changes. He may be more motivated to do so if he is entitled to part of the savings. The process to get such changes approved may interfere with the schedule, to which the contractor is bound, it may have implications on design, that the owner would need to accommodate, at his own cost, which may, in turn, affect the schedule further. It is more effective to enable contractor's input, which may include savings ideas during the design process, so that it can be properly evaluated and integrated by all the participants affected. The project delivery systems CMR, DB and IPD allow greater builder input in design, and therefore offer a higher potential to recuperate savings. The existence of shared savings clause in the contract, or other contractual provisions that reward contractors based on savings, improves the likelihood of achieving savings.

25 – Minimize Owner's involvement

CII (2003) defines this factor as: "owner desires a minimal use of its own resources in the execution of the project." According to CII (2003), Design-Build and Turnkey best satisfy this factor, whereas Parallel Primes does not satisfy this factor. Even with DB, owner's involvement may be significant on projects of greater complexity and size. USDoT (2006) in its study of design-build effectiveness on highway projects recommends that trained and capable staff of the owner (state government contracting agency responsible for the project) should be designated during procurement and contract administration phases. US state highways are an example of projects where it is customary for the state agency (owner) to perform design in house when DBB delivery method is used. For such owners, DB reduces the demand on owner staff, by transferring responsibility for final design to design-builder. Single point of responsibility in DB relieves the owner of any issues between designer and constructor. However, this means that the design professional is no longer representing owner's interest during construction and the owner needs to put his own effort to monitor progress and quality. For example, USDoT requires that quality assurance be the responsibility of the contracting agency on DB projects. The AIA standard form A141 Agreement Between Owner and Design-Builder, assigns to the owner the duties for "(1) review of submittals, (2) review of proposed changes to the documents, (3) periodic site visits, (4) rejection of nonconforming work, (5) inspections and certifications for substantial and final completion, and (6) review of pay applications," which are duties of design professional in DBB (Quataman, 2005). The owner may use a consultant to perform these duties. This factor is opposite of factor 17 - Maximize Owner's Involvement. It is related to factor 10 – Owner staff number and qualifications.

26 - Optimize Lifecycle Cost

Lifecycle cost of a capital project includes first costs (such as land acquisition, design and construction), long term costs (operation, maintenance, replacement, repairs) and decommissioning. There is usually a trade-off between first costs and long term operation and maintenance costs. Higher first costs of more durable materials and equipment or more energy-efficient systems, may be offset by reduced long-term costs. An owner may have the knowledge to estimate lifecycle costs of various alternatives for certain systems in an early planning stage, and he may be in a position to allocate budget to such systems to optimize lifecycle cost. More often, it is not possible to make such estimates until the design progresses to a certain level. Some parameters are known, such as the planned useful life of the facility. Others, such as energy costs are not certain, and some parameters are somewhat arbitrary and subjective, such as discount rates. Project delivery systems favorable with respect to this factor are those that that facilitate owner access to information pertinent to lifecycle cost throughout the design process, and particularly early in this process. This helps the owner to evaluate alternatives and make informed decisions with lifecycle cost in mind. However, it is not necessary to calculate lifecycle costs to embrace the principles of optimizing long-term performance such as energy efficiency, or cleanability. Owners may choose such principles without necessarily calculating a return on investment, particularly because the principles of environmental responsibility are gaining presence and importance for owners of facilities.

In PDSs where owner has no control over detail design, even if performance criteria for design and construction are well defined, the owner has less ability to affect lifecycle cost. Characteristic of a PDS that also contributes to optimizing lifecycle cost is owner's control over team selection, as this allows the owner to select teams with experience in optimizing lifecycle cost. Above all, project delivery systems that financially motivate contractor to minimize lifecycle costs are the most successful in satisfying this factor. Those are the PDSs that make the contractor responsible for maintenance and some or all aspect of operations, which are found within public-private partnership category.

27 - Minimize Adversarial Relationships

Adversarial relationship between projects participants are a disadvantage to the project. They may lead to claims and disputes, or a lack of collaboration may affect the quality of design and construction. In the least, when relationships are adversarial, opportunities for creative collaboration and synergies are less. Those project delivery systems that encourage collaboration between the parties are most likely to reduce the possibility of adversarial relationships (Touran, et al 2009a,b). These include CMR, DB and EBOM (Touran et al 2009a,b).

28 - Stand-alone project or part of a capital development program

Whether a project is stand-alone or part of a capital development program affects management requirements. A stand-alone project implies assembling resources and effort one time and for a relatively short period. The opportunities for economies of scale from owner supplied equipment are less (Joint Committee of the ACI-NA, ACC and AGC, 2012). A project which is a part of a capital development program implies assuming resources (usually external to the owner), spread over a number of projects and over a longer period. This means that it may be cost effective for the owner to utilize his own management staff or hire project management services, and reduce the management need for designer and builder. The economies of scale may lead the owner to do some of his own procurement (Joint Committee ACI-NA, ACC and AGC, 2012). If a project is part of a capital development program this would suggest that the owner may choose to use the services of a program manager, or dedicate his own management team, and do his own procurement of certain items. Program management does not imply any specific PDSs for projects within the program.

29 – Shifting Roles and Responsibilities, Clarity of Defined Roles (Owner is comfortable with shifting roles and responsibilities)

Mahdi and Alreshaid (2005) list the factor Clarity of Defined Roles as one of the contractor characteristics. This suggests that the roles of various contractors (which may include the designers) may be more or less clearly defined on a project. The Airport Owner's Guide to Project Delivery Systems explains how roles and responsibilities vary from one project delivery system to another, and suggests that this needs to be considered during the PDS selection process, (Joint Committee ACI-NA, ACC and AGC, 2012). This factor also refers to the trend away from the clearly defined and widely understood roles and responsibilities on the traditional project delivery systems, particularly DBB, towards less traditional roles associated with the new developments in project delivery such as the IDP. One of the principal purposes of contracts is to clearly define roles and responsibilities, and contracts have proven to be of utmost importance in construction industry throughout decades. However, some of the proponents of IDP suggest that the IPD achieves its best results when the participants step out of their traditional roles and advance the collaboration (AIA Center for Integrated Practice, 2011). IPD applied in its full form includes waivers of project related claims among the IPD team members, and acceptance of internal dispute resolution mechanisms. One of the innovative aspects of the IPD is that it allows for all the members of the IPD team, including designers, to tie their financial success to the overall project success. Team members put all or portion of their profit at risk, and they are entitled to share in the potential savings, (Joint Committee ACI-NA, ACC and AGC, 2012). This factor asks the owner to determine how comfortable he is with roles and responsibilities on the project shifting from what they would traditionally be, with the potential benefit of greater exchange of ideas and knowledge, which represents and improved process and can lead to better overall product.

30 - Promote early procurement

CII (2003) defines this factor as, "Project delivery and contract strategy promote early design and purchase of long-lead equipment or materials." This factor is related to time performance and the desire to reduce schedule. Project delivery systems that facilitate that certain design decisions be made early, to the degree that work packages can be procured are more highly effective with respect to this factor. This factor gains importance in situations of high inflation or instability in the market, where risk exists that it may be more difficult or more costly to procure specific items in as the project progress. Also, it is be important when long lead items are present, or items for which price and/or availability are uncertain.

31 – Protect confidentiality

CII (2003) defines this factor as: "Confidentiality of business/engineering details of the project is critical to project success," with the clarification that confidentiality refers to process technology, not the finished product of a completed and operating production. CII (2003) suggests that for confidentiality, pieces of confidential information should be separated so that no single entity has access to all documents. PDSs that include competitive lump sum bidding, which may be DBB or DB, require all bidders to see all documents, and therefore are not effective in protecting confidentiality (CII, 2003). CII gives lowest REV of 0 to DB and Turnkey, and highest REV of 100 to Parallel primes, but also a high REV of 90 to DBB and DBB with early procurement.

32 - Efficiently utilize poorly defined scope

CII (2003) describes this factor as "project features are not well defined at the award of design/construction contract". DBB, DBB with CM and DBB with PM are well suited for this situation, whereas DB, Multiple DB and Turnkey are not suitable. (CII, 2003)

33 – Control construction impact on operations

This factor applies to projects in which construction activities occur within or in close proximity to operating facilities. This may mean restricted hours for certain construction activities, or a need to schedule disruptions to existing operations with user approvals. Existing operations may also pose restrictions on site logistics such as access or staging area. This factor may lead to phased construction. Several stages of temporary structures may be required. Security requirements of the existing facility pose additional challenges to construction activities. These conditions primarily affect the schedule but also cost. On one hand, restrictions such as restricted times of day for construction, or security procedures may cause longer schedules for certain activities. On the other hand, accelerated schedule for certain activities may be required, to minimize the duration when the operations of the existing facilities are affected. Disturbance to neighboring properties needs to be to minimized and managed, as well as possible disruptions to city functions (streets, utilities, public transportation). Special permits and notices may be necessary and it is customary for a contractor or a CM to act on owner's behalf in obtaining necessary approvals. The PDSs that are better capable to handle these conditions are those that allow owner's involvement in construction, builder's input in design and those that assist the owner in dealing with third parties. The PDSs with multiple prime construction contractors are less suited to controlling impact on operations. This factor is related to factors 1 Shortest schedule, 7 Control time growth, 17 maximize owner's involvement, 25 minimize owner's involvement, and 35 third party agreements and 72 constructability.

34 – Owner goals and objectives outside of the project

This factor often applies to public owners. It refers to the owner's goals and objectives, which are not related to a specific project. For example, a public agency's goals may be encouraging the economic growth of the community of increasing vibrancy of the community. They may arise from statutory requirements that the agency is subject to, such as providing equal opportunity. A corporate owner may be committed to sustainable development or to specific principles of social responsibility. Agency goals should be distinguished from the goals of the project itself, which are usually expressed as cost, time and quality objectives. (Ghavamifar, 2009, Touran et al, 2009b). A project delivery system may align well with owner's goals and objectives or it may add challenge to achieving them. Touran et al, (2009b) suggest that CMR and DBB have high potential to satisfy this factor, whereas DB has low potential. This factor is related to the factors from the category Political considerations (14 Competition, 18 Small business impact, 19 Stakeholder and community input, and 46 Domestic or international firms or teams). It is also related to the owner's control of design (factor 8 Maximize owner's controlling role). Touran et al (2009b) point out that PPP models that include operations may limit the agency's power to serve the public.

35 - Third Party Agreements

This factor answers to the question whether the project delivery system facilitates agreements with third parties involved in the progress of the project, such as political entities, utilities, and railroads. This factor is important for projects that are affected by third party agreements, such as transit projects (Touran et al., 2009b). DBB allows more time to reach agreements but presents a risk that frequent stakeholder input can disrupt the schedule. CM in CMR can assist the owner in communicating with the third parties and facilitate the agreements. DB allows shorter time to arrive to agreements but the contractor may be more expeditious than the owner in reaching agreements. In DBOM (as an example of PPP) the contractor becomes even more directly interested in some of the agreements than the owner, as he is responsible for operations, and needs to have significant control over such agreements. In PDSs where contractor is responsible for operations, the owner handles those agreements that he is more directly interested in, similar to DB or DBB (Touran et al., 2009b).

36 – Labor unions

Presence and strength of labor unions for particular trades varies from one location to another. How do labor unions affect the choice of a PDS? Ghavamifar (2009) as well as Touran et al. (2009b), discussing PDS selection for transit projects explain the relationship as follows. Public agencies when seeking federal grants need to demonstrate that workers protected by the unions are not adversely affected by their project, including their choice of PDS. If there are labor union issues in a locality it may not be possible for at CMR to guarantee the maximum price, as me may perceive the risks associated with labor unions as high. On the other hand, labor unions may look favorably on those delivery methods that value more highly qualified workers, such as CMR and DBB, as the unions proclaim their members to be more qualified than non-union workers. In particular jurisdictions such as California, state engineers have their own union, and this may be of concern if engineering design is awarded as part of a design-build contract to out-of state engineers. In PDSs that include operations and maintenance, which are certain PPP models, there is a greater concern over labor unions as the employment of operations and maintenance workers already employed by an agency is protected by the law. This necessitates an agreement between the private contractor and the unions to guarantee the required amount of labor at specified rates. This factor is often not important in PDS selection, but project circumstances should be evaluated to determine if this factor needs to be considered, and how it may affect the suitability of each PDS being considered.

37 – Environmental regulations

Touran et al. (2009b), in a research focused on transit projects, list FTA/EPA (Federal Transit Administration and Environmental Protection Agency) regulations in the U.S. as a factor in PDS selection. Complying with regulations is a design requirement and obtaining permits may affect project cost and schedule. According to Touran et al. (2009b), the more familiarity that permitting agencies have with a PDS, the less delays there would be in the permitting process. DBB is very familiar to permitting authorities, CMR somewhat less familiar and DB is the least familiar, although permitting agencies are becoming more and more familiar with all PDSs. Moreover, if the owner transfers the responsibility for obtaining environmental permits to constructor, which may be the case with DB, or with PPP models that include DB, and if the constructor is not well equipped for this task, delays can be serious (Touran et. al, 2009a,b).

38 - Amount of overlap of design and construction that is feasible

The relative importance of this factor refers to what amount of overlap is feasible for the project, and the relative effectiveness of PDSs with respect to this factor refers to what amount of overlap is feasible for a PDS. Gordon (1994) suggests that owner's decision to overlap design and construction ('fast-track') should involve financial analysis of the possible cost of fast tracking versus the value of early completion, as well as the technical and regulatory feasibility of fast-tracking. To overlap design and construction saves time, but only a certain amount of overlap is feasible. The owner would usually find it desirable to save time. However, there may be reasons against overlapping design and construction. If the owner is not certain of his source of funding for the entire project, or at least for a phase of the project that can be completed and used to serve the initiated purpose, then the owner is taking large risk by starting construction. In the worst case, construction that cannot be completed may have to be demolished in order make another use of the site, which represents additional cost. Three may be a regulatory requirement for the DBB delivery system, which does not allow overlap of design and construction. Also, the owner may not wish to take any risk for starting construction before the design is complete, because construction that is placed based on incomplete design adds a constraint to subsequent development of design and may result in less than optimal design solution or lesser quality.

The amount of overlap of design and construction that is feasible depends on the nature of the project. For example, if there is demolition or site remediation work, this can be handled by the owner as a separate project before the design is complete, or it can begin early as part of the main project if the contract is awarded before design is complete. The projects of lesser complexity and linear projects, such as roads, lend themselves to design and construction overlap. In general, the trend of the recent decades has been towards some degree of overlap. Even on complex projects, construction starts before design is complete, and it is accepted that design may be somewhat compromised, that some redesign may be required to accommodate the construction in place or the purchased material or equipment items, or that there may be some construction rework, to adjust to the developments in design. It may be difficult to establish responsibility for additional cost associated with fast-tracking. In this respect, the collaborative nature of the relationships is particularly important. Some degree of overlap of design and constructions is usually feasible. Overlap does not occur in DBB, but it can occur in other PDSs.

39 – Ability to participate in multiple trade builder/supplier evaluation

This factor refers to owner's internal resources (Joint committee of the ACI-NA, ACC and AGC, 2012) to evaluate the contractors and suppliers of various trades. The Owner-build and Multiple primes PDSs require most owner's resources in this respect, and the owner can hire a PM or a CM to assist with such selection. In IPD, the selection of IPD team is paramount to project success, and this requires owner's strong active role. An IPD team may include major trade contractors or suppliers as prime participants. In other PDSs, owner is usually not required to evaluate trade contractors and suppliers, but he may desire to participate in their evaluation and have a certain level of control. The owner has greater ability to do this with negotiated contracts, such as in DNB and CMR, where some of the trade contractors may be selected with owner's participation before GMP is established. In any PDS which includes prime contractors and subcontractors, the owner needs to communicate and his requirements regarding subcontractor qualifications, the method of their selection, and the owner's level of participation and control in such selection process before contract signing. In any PDSs, the owner may require that certain trade contractors and suppliers be selected from the lists of contractors or suppliers pre-qualified by the owner. This limits competition but it gives more confidence to the owner that work would be completed and meet his quality expectations. The owner's ability to participate in multiple trade and supplier evaluation implies that he has staff knowledgeable about specific trades and materials and familiar with industries in question. If the owner has such capability, he may take advantage of it by choosing a PDS that allows him the corresponding participation. If the owner has a low ability in this respect, than the PDSs that don't require any of his participation have high relative effectiveness values and conversely, PDSs that require his participation have low REV. This factor is related to Factor 10 – Owner's staff number and qualifications, Factor 8 Maximize owner's controlling role and Factor 17 – Maximize owner's involvement.

40 – Multiple funding sources

This factor represents a funding constraint (Joint committee of the ACI-NA, ACC and AGC, 2012). Multiple funding sources may represent a combination of cash from one or more partners, and borrowed funds. This factor may be associated with limited cash flow (in which case it would be related to Factor 21 - Delay or minimize expenditure rate) and Factor 64 Complexity of decision making. Many projects are funded from multiple sources, and this is more likely the larger the project, and for public projects. PPPs incorporate elaborate financial structures, which usually include both public and private funds. In most cases, multiple funding sources as a solution to project funding, do not play a significant part in PDS selection. However, if the funding commitments for the entire project cannot be obtained in time of awarding contracts, it would be prudent to break the project up into phases, such that the funding for the first phase is certain, and that the first phase can be built and operate even if subsequent phases do not get built. This is not always possible. In an extreme case, if the funding is not certain, the construction may stop due to non-payment and all the work put in place could become a loss. Multiple funding sources also represent a higher administrative burden and therefore a higher demand on the owner's staff. The existence of this factor represents an element of project complexity. If multiple finding sources have different levels of certainty, Phased construction, consisting of different contract packages which can include different PDSs for different phases is more suitable than one single contract.

41 – Capitalize on expected low levels of change

CII (2003) defines this factor as "a below-normal level of changes is anticipated in the execution of the project," therefore the project delivery system that allows the owner to take advantage of low risk environment would be suitable. As this factor is opposite to factor 13 - Ease change operation, the most suitable PDSs are Multiple DB and Turnkey whereas DBB, DBB with PM and DBB with CM are not suitable (CII, 2003).

42 - Capitalize on familiar project conditions

CII (2003) defines this factor as "local conditions at project site are favorable to project execution." This factor similar to factor 41 Capitalize on expected low levels of change, with the same set of most and least suitable PDSs. Relative effectiveness values of other PDSs are different with respect to these two factors. PDS 10 Traditional with staged development, also referred to as Phased construction, has a low REV of 10 with respect to factor 42, and a moderate REV of 60 with respect to factor 41.

43 – Minimize owner's controlling role

CII (2003) describes this factor as "owner desires a minimal level of control/influence over project execution." This may be a condition when the owner does not have the staff capabilities to effectively exercise control, or he may wish to transfer significant portion of the risk to the other members of the project team. This factor is opposite of Factor 8- Maximize owner's controlling role. It is related to Factor 25 – Minimize owner's involvement. PDS 11 Turnkey has the highest REV of 100 with respect to this factor, whereas PDS 2 Traditional with early procurement and PDS 12 Fast track have 0 REV with respect to this factor (CII, 2003).

45 - Ability to award main contract(s) based on best value or qualifications (Qualifications-based selection, QBS)

Price is often the primary factor in awarding contracts. Government agencies are often required to award contracts for construction based on lowest price. However, there has been a tendency of governments to allow selection based on best value, which means that criteria other than lowest cost may be considered including project management, quality control and team reputation. In the case of contracts that include design, the quality of design is also a factor, (USDoT, 2006). Value based selection is possible with all PDSs except DBB. The benefit of the value based selection depends on how well the selection process is designed and carried out.

46 - Domestic or international firms or teams

This is factor belongs to the category of equity of procurement process for prospective bidders (USDoT, 2006). The concern is that in non-traditional PDSs the award process may be less equitable. When the selection process is based on qualifications or on relationships it is difficult for small little known contractors to get selected. The construction contractors that compete internationally are typically large. Regarding design, on the other hand, smaller firms are not uncommon, and may successfully compete for projects of significant size. A public owner may be subject to statutory limitations or political pressures to work with domestic contractors. Private owners of large projects with impact on local economy may find that awarding some of the work locally helps their relationships with the community and local authorities Selection of suppliers is usually much more liberal. Many products and especially equipment used in construction are made in only few locations in the world. With the large DB projects, and particularly, the PPPs that include financing by contractor, proponents are likely to be international. Teams are formed specifically for every project, and, for very large projects, only a few teams in the world get formed that qualify financially. In addition to financing as an obstacle to local participation, competing for DB and PPP projects requires a significant investment of time and resources on part of the contractor. For large projects, there may not be many domestic firms or teams competing, as they may not be able to afford the costs of pursuit, and the competition becomes international. To offset this, to make the process more equitable for the contractors and to ensure a reasonable number of proponents, the owner may offer stipends to all the short-listed proponents.

47 – Security

Certain projects have high security standards. These include airports, prisons, consulates, stadiums, arenas, museums, industrial and energy plants, water treatment, banks, casinos, certain research facilities, military facilities etc. Touran, et al. (2009a) who studied PDS selection for airports, point that government security requirements can change at any time, and they may require that a project in any stage of its lifecycle adapt to the new regulations. This necessitates flexibility, which represents Factor 13 (Ease change incorporation). Another aspect of security is a need to obtain security clearances for employees, which has to be planned to avoid delays. The interviews of airport officials that Touran et al. (2009a) performed, found that CMR offers greatest flexibility due to close collaboration among team members, and similar to this is DB with qualifications based selection and GMP (Touran et al, 2009a). DBB offers great flexibility during design but less during construction, whereas DB with a fixed price contract based on schematic design offers least flexibility. PDSs that allow time between contractor selection and start of construction such as CMR and DB, have the advantage of more time to complete employee security checks (Touran et al, 2009a).

48 – Design expectations of the owner

Dorsey (1997) lists design expectations of the owner as a factor for PDS selection. Moore (2000) lists ‘uniqueness’ as a consideration in project delivery selection with questions: “Is design a driver for this project? Are construction processes a driver?” This factor refers to aesthetic aspects of design, and those aspects are very important if the owner desires high aesthetic quality, expression, special experience, or if a project is in a very important place, a historic place or a unique natural landscape, and the design may be subject to special approval process and public scrutiny. Design as a project driver may also represent owner's desire to incorporate sustainable features such as daylighting, natural ventilation, rainwater harvesting, solar energy, or innovation in other respects. This may require special design expertise and high integration of the entire team including various design disciplines, construction trades and manufacturers. When unique or highly expressive design is important, the owner needs to be able to select the design team and to be involved in the design process and have strong control of design. The owner needs to dedicate staff with appropriate qualifications and decision authority to the project. In some cases, the owner may hold a design competition to solicit creative and unique ides, which also requires funds and staff resources. Single source PDSs are less suited if design is very important, because they do not facilitate owner's close involvement in design. However, this does not mean that the owner cannot expect high quality of design with single source PDSs. If DB proposals are evaluated based on best value, as is often the case with PPPs, in selecting the preferred proponent, the owner can assign high importance to design-related criteria, such as design team's portfolio of similar projects, strength of architectural concept, originality and innovation. However, the number of proposals may be small and the choices limited, as the requirements for technical and financial qualifications of the entire team are usually high, and competing is expensive. If design is unique and innovative, price based competition is not the most suitable way to select contractors, as the low bidder might not execute the design to the expected level of quality, which would compromise the concept. Qualification based selection in general, and especially for the building systems critical to the design concept, is more appropriate. CMR and IPD are more suited than DBB. This factor is closely related to Factor - 8 Maximize owner's controlling role.

53 - Asset life – Expected useful life greater than 20 years

The longer the expected useful life, the more important is the lifecycle cost, which includes, aside from the first cost, the operation, maintenance, replacement and decommissioning costs. The presence of this factor contributes to the importance of factor 26 – Optimize lifecycle cost for which REV may be established. This factor is mentioned by PPP Canada (2011) as a high level suitability screening criterion for PPP models. Based on the expected useful life, it can be determined whether a contract that includes long-term financing is possible. Relative effectiveness of PDSs is not measured with respect to this factor.

54 – Desire to take advantage of and strengthen positive existing relationships

Moore (2000) lists 'Relationships' as a consideration for PDS selection, with a question: "Does the owner have relationships with particular designers and /or contractors?" Traditionally, it has been very common for owners to select design professionals with whom they already have positive experience. Regarding contractor selection, this principle makes sense, particularly if projects are similar, and if owner is less concerned with taking advantage of competition among the contractors. The option to select a contractor without some form of competitive process is often not available to public owners. Positive relationships build trust. Using familiar contractors eliminates the need for the owner to advertise the project and evaluate bids or proposals, which saves time and resources. If there is a high level of trust, respect, and familiarity, negotiations regarding contract terms and price are likely to be simpler and quicker than if the parties are encountering each other for the first time. If the owner wishes to check the validity of the price being negotiated, he may carry out simultaneous negotiations with multiple contractors, without formally advertising the project (CSI, 2011). Owners with large and varied building programs may have long standing relationships with several designers or contractors. PDSs that include negotiated contracts such as CMR and DNB, but also negotiated DB or Multiple primes satisfy this factor. In IPD, selecting the right team and establishing trust are critically important. IPD proponents suggest that it is preferable to select team members based on past experience of working together. In IPD, not only the owner but also other team members can participate in identifying potential additional team members. Past relationships among various professionals and firms can help to assemble the team. This factor is opposite to Factor 14 – Competition, but the two factors do not exclude each other, as competition may occur on various levels, and even if the owner does not seek competition for the general contract for construction he may seek competition among subcontractors of particular trades and suppliers.

55 – Opportunity to partner

Partnering suggests sharing financial risks and rewards to a higher degree than in a traditional contract for construction. Minchin, Thakkar and Ellis (2007) state that this factor does not apply to DBB, whereas DB and CMR are excellent with respect to this factor. Also all PPP models satisfy this factor.

56 – Ability to prequalify project team

To prequalify project team means to not allow an open competition but to first establish, based on qualifications, that the firms competing for direct contracts with the owner are capable of performing the project. According to Minchin, Thakkar and Ellis (2007), this ability does not apply to DBB, whereas DB and CMR are both excellent with respect to this factor.

57 – Ability to prequalify subcontractors

To prequalify subcontractors means to ensure that subcontractors are capable to perform the work on the particular project, while meeting the quality, schedule and budgetary goals. This is usually done by soliciting prequalification statements from subcontractors, which include statements of their experience comparable to the project, references, financial stability, qualified personnel, and available workforce. CMR provides higher ability to prequalify subcontractors than DB and DBB, (Minchin, Thakkar, and Ellis, 2007).

58 – Pre-construction service needs

Pre-construction services include the services that an entity or individual knowledgeable and experienced in construction may provide to the owner and design professional during design. These services include cost estimating, scheduling, constructability reviews and value engineering. They services may be provided by the same contractor that would construct the project or manage the construction, if that contractor is selected, or they may be provided by a consultant, in case of competitive bidding, so that all bidders have the same knowledge of the project when the bidding starts. The CMR or a contractor selected for the project is in a better position to provide reliable cost estimates and schedules than a party who acts as an advisor only. Pre-construction advice is always valuable, but its importance is greater with greater complexity and uniqueness of the project. Sanvido and Koncahr (1998) indicate that DB and CMR have an excellent rating in early constructability input, whereas DBB had a fair rating in this respect. This factor has a very similar meaning to factor 12 – Builder input in design, and therefore these two factors are merged and included in the multi-criteria analysis model as factor 12.

59 – What feels comfortable to the owner

Moore (2002) mentions that ‘Comfort Zone’ or owner’s “gut” feeling of what feels comfortable is a consideration in PDS selection. This is a subjective factor but it may be important to some owners. This may refer to the owner’s level of comfort with unfamiliar or less familiar PDSs, which represents not only owner’s attitudes towards change in general, but also his judgement whether the project in question is suitable for trying a less familiar PDS. Organizations tend to test new methods on less risky projects, usually relatively small and simple projects. For example, even though IPD is regarded to be most suitable for large, quick and uncertain projects, several of the IPD case studies presented by the AIA, AIA Minnesota, and School of Architecture – University of Minnesota (2012) are small and simple projects with little uncertainties, and they represent pilot projects for their owners. The decision-maker needs to consider whether additional effort such as staff training is necessary, in order to use a less familiar PDS. This factor represents a screening criterion - PDSs can be ruled out before the multi criteria decision process starts, and it can also be considered in multi-criteria analysis. This factor is closely related to factor 23 – Experience with particular PDS and forms of contract.

60 – Avoid conflict of interest

An example of potential for conflict of interest exists with DB. Design team, which is a part of the design-build entity, is responsible for providing a design that satisfies the owner's requirements stated in the RFP, while being ultimately responsible to the design-build entity to not exceed the budget. There is a possibility of interpreting the RFP such that the resulting design does not meet owner's expectations. Another example is CMR which may have an advisory role to the owner and be in an agency relationship in the early stage of the project, but becomes a vendor to the owner in the subsequent stage.

64 – Complexity of decision making

Many public owners and in some cases private organizations have multiple levels of approval process regarding design and construction projects. If owner's decision making is complex, this is an additional challenge for the project delivery process. Complex decision making is not necessarily a disadvantage for the project, as it may ultimately lead to better, outcomes. In a sequential project delivery (DBB), the impact of delays during design is usually less serious than with overlapped sequence of design and construction. If the project is not very urgent, the owner may accept that design schedule gets extended. During construction, contractor is responsible for the schedule and he may claim additional time or impact costs for delays caused by the owner. Because of this, and because it is not expected that many owner's decisions would be required during construction (except in special circumstances, such as in response to uncovered unforeseen conditions), owners have a simpler decision–making process in relation to construction than in relation to design. In those delivery systems that involve overlap of design and construction, once the contractual time for construction starts, a delay in any decision may have cost and schedule consequences. DBB is more suitable than other PDSs if the owner needs to maintain his complex process of design review and approval.

65 – Project Location

Project location may have an influence on Factor 11 – Legal and regulatory constraints, Factor 15 - Availability of appropriate contractors, Factor 69 – Market conditions, or other factors that may be identified, but it is not itself a factor for PDS selection, and therefore it is not included in the multi-criteria analysis model.

67 - Project Size

In the Delphi Survey by Chan et al (2001), project size has been identified as a selection factor, if "the building is a large-scale project in terms of GFA (gross square footage) and/or contract sum." The threshold of what constitutes a large project was not defined. CII (2002), in a study titled Measuring the Impacts of the Delivery System on Project Performance – Design Build and Design-Bid-Build defines there size categories: less than $15 million, $15 to 50 million, and more than $50 million. Project size may be relative to the project type, industry and the owner. Megaprojects are defined as those with total capital cost of more than one billion U.S. dollars (Merrow, 2011).

Lynch (2009) states that although the Design-Bid-Build method is used by many public agencies for most small and medium-sized projects by default, the agency should weigh the costs and benefits of various delivery methods and then make the delivery method decision. (Lynch 2009). PPP Canada includes the project size as one of the screening criteria for suitability of the project for PPP - “Is the project’s size sufficient to support the P3 costs? (PPP Canada, 2011). The same criterion applies to other delivery PDSs of higher level of sophistication, which include higher costs in planning and managing such as the DB, CMR or IPD. In the CII’s Benchmarking and Metrics Database, among the data collected between 1996 and 2002, when considering the DB and DBB delivery systems, the relative share of DB projects increased with project size across three cost categories defined in this section, and the average cost of DB projects was significantly larger than that of DBB projects (CII, 2002). Additional discussion of this factor is in sections 2.3.3. and 3.4.3. This factor acts as a key input (screening criterion) in PDS selection.

68 – Apportion risk appropriately and share rewards

This factor is opposite of Factor 3 - Reduce risk or transfer risk to contractors. The explanation for this factor can be found in the discussion of Factor 3. The PDS that satisfies this factor best is IPD. In Owner-build and Parallel primes the owner accepts significant risk that may or may not be proportional to the reward that the owner can expect in form of savings. CMR satisfies this factor better than DBB and DNB, and single source PDSs do not satisfy this factor.

69 - Market conditions

This factor refers to the condition of extremely competitive market, when large numbers of contractors and subcontractors are competing for few projects. This occurs in economic recessions, such as the one that affected the world and particularly the United States in 2008. In such times, public projects are much more likely than private projects to be starting and facing the delivery method decision. The effect of such conditions on the performance of various project delivery systems is described in the publication "Building Capital Projects in Tough Times,' which is intended for public owners (Lynch, 2009). Concepts discussed by Lynch (2009), may apply to the private projects as well, especially, to projects of higher complexity, where the qualifications and competences of contractors, are a significant concern. Market conditions may change throughout the various stages of project delivery. Projects of longer durations are therefore more susceptible to the changing conditions, and they may benefit from a project delivery systems that allows the project team to adapt to changing market conditions.

In a highly competitive market, the advantage of design-bid-build project delivery system is that high competition leads to lower prices. However the disadvantages are the higher likelihood that contractors unfamiliar with the project type would be bidding, higher likelihood that the low bidder is in some way inadequate, and higher likelihood of claims due to financial stress. In such market conditions, constructor's input in design is even more important than it is otherwise, because the constructor can help the owner and the design team select materials, systems and design details to take advantage of the increased competition. This is one of the advantages of the CMR delivery method, (Lynch, 2009). The disadvantages of Design-build in such conditions are that if the contract price is set early in the process and the costs drop sharply, the DB team may not be motivated to look for project savings. Also, “in a market that is changing rapidly, owners may lose the opportunity to take advantage of the market changes after the DB team is selected.” (Lynch, 2009)

In a tight market, even though the competitive bidding process gets the benefit of competitive pricing, the disadvantages of the competitive bidding are exacerbated. Therefore, in such market, there are fewer situations where design-bid-build is appropriate. Lynch (2009) emphasizes the importance of a careful selection of project delivery system in the conditions of tight market. He lists most advantages and fewest disadvantages for the CMR, followed by DB, followed by DBB (Lynch, 2009).

70 - Owner/user satisfaction

Owner/user satisfaction is considered among the thirteen critical success factors for value creation, according to Brennan (2011), who studied complex military medical projects. Brennan found that DB, DBB, and IPD have different relative effectiveness values with respect to the critical success factors. Brennan distinguishes between the micro viewpoint, which considers success in terms of time, cost and quality from the macro viewpoint. From the macro viewpoint, satisfaction is a measure of how well the completed project meets the original concept in practice, and it is one of the two ultimate measures of project success. The other measure is whether the project is completed. Brennan views maintaining customer satisfaction as one of the operational costs of a facility and points to the significance of the project delivery team's role in shaping long-term value-creation. Factors 6 Quality and 71 Utility and functionality contribute to this, and this factor contributes to Factor 26 Optimize lifecycle cost. Brennan (2011) found through a survey that IPD is the most effective with respect to this factor (REV 4 on a scale of 1 to 5), followed by DBB (3.4) and DB (3.33).

71 - Utility and functionality

Utility and functionality as one category represent one of the thirteen critical success factors for value creation established by Brennan (2011) through a three-round Delphi survey. Utility according to Vitruvius is one of the three principal values, along with beauty and structural soundness, conceived by design and created by construction. (Vitruvius, Brennan, 2011). According to Brennan whose research focuses on complex military medical projects, utility is one of the long-term measures of value, since problems regarding utility and functionality may only appear after the facility has been in use for some time (Brennan, 2011).

Functionality may also include the flexibility for future changes. This is especially important with certain building types, including large hospitals. These facilities typically have long lifecycles, whereas the technologies associated with the equipment, processes and the support systems essential to their function constantly evolve, and the buildings must be highly adaptable to sustain state-of-the art medical care and implement best medical practices (Brennan, 2011). Utility and functionality depend directly on the appropriateness of design - how well the design responds to the functional requirements of the facility. The appropriateness of the design, in turn depends directly on how well the functional requirements were established and how clearly they were articulated. According to Brennan (2011), IPD has the highest REV (3.95 on a scale of 1 to 5), followed by DBB (REV of 3.35) and DB (REV of 3.15), considering these three PDSs.

72 – Constructability of design

According to Dorsey (1997), constructability is the process of evaluating design in terms of safety and scheduling as well as quality and cost, in which the designers and constructors work together from the outset to determine the building systems. One of the goals of design as defined by Kim (2010) is to maximize constructability of buildings. Best economy and safety of construction requires a good balance between the cost and the productivity of the materials, equipment, and technology (Kim, 2010). The applicability of any material equipment/tool or technology, which, affect the overall construction productivity economy and safety depend on the specifics of design (Kim, 2010). The PDSs that facilitate higher constructability of design are those that offer better integration – builder's input in design. This factor is closely related with factor 12 Need/Desire for Builder's Input in Design. Brennan (2011) found that IPD had the highest REV (3.8 on a scale of 1 to 5), followed by DB (REV of 3.7) and that DBB had the lowest REV of 2.83 among these three PDSs.

73 - Effective communication

According to Brennan (2011) effective communication is among the thirteen critical factors for creating value in complex military medical projects. Brennan (2011) established REVs with respect to this factor on a scale of 1 to 5, as 4.23 for IPD, and 3.2 for DBB and for DB. This factor contributes to minimizing adversarial relationships.

74 - Collaboration of Project Team

Lynch (2009) suggests that "some projects benefit greatly from collaboration and thus, as a result of a more integrated process, end up delivering a better value." According to Lynch, the process that includes contractor selection based on low bid does not provide for team collaboration (Lunch, 2009). Collaboration is among the essential qualities of the IPD (Brennan, 2011). IPD encourages collaboration as it depends on collaboration more than do the traditional PDSs. According to Brennan (2011), IPD has the highest REV of 4.28 on a scale of 1 to 5, DB has a REV of 3.13, and DBB has the lowest REV of 2.63, with respect to this factor. This factor contributes to minimizing adversarial relationships.

75 - Trust and respect

Trust and respect are essential in any business relationship. IPD relies on trust and respect to a greater degree than other PDSs. IPD seeks to provide better conditions for trust and respect than the traditional PDSs through appropriate incentives (Brennan 2011). Brennan (2011) established REVs of 3.93 for IPD, 2.85 for DB, and 2.75 for DBB, on a scale of 1 to 5. This factor relates to sharing risk and rewards, and to factor 54 Desire to take advantage of and strengthen positive existing relationships.

76 – Alignment of objectives

This factor refers to the alignment of project goals and objectives among the project stakeholders. This is, as well, one of the defining characteristics of the IPD (Brennan, 2011). Common goals are established through incentives. The REVs are 3.93 for IPD, 3.03 for DBB, and 2.9 for DB (Brennan 2011). This factor is related to sharing of risks and rewards and to factor 55 Opportunity to partner.

78 - Owner's vision

Owner's vision is considered among the top thirteen critical success factors for value creation in complex military medical projects, according to Brennan (2011). Effectiveness of PDSs with respect to this factor is a measure of how well a PDS ensures that the owner's vision is fully realized by the project delivery process. Brennan (2011) describes how owner's vision is realized in IPD, in the following way. The owner provides the mission and vision which establishes the stated goal - purpose of the project. All participants must adopt this goal to meet the needs of the owner and to fulfill their contracts. Owner's vision as the main project goal must be shared by all parties to successfully deliver the project, (Brennan, 2011). The REVs are 3.9 for IPD, for 3.6 for DBB and 2.85 for DB (Brennan, 2011).

79 - Market position – Desire to gain experience with a new PDS

This factor represents owner's desire to try a new PDS, in order to improve delivery of future projects. This factor may be important for owners who build many projects. A PDS may be customary and familiar for some project types, but new to the project type in question. At the time of this writing, the IPD is a new and little known project delivery system designed to overcome significant drawbacks of previously known PDSs. Some owners anticipate that by employing IPD, they may increase the likelihood that best design and construction firms would be interested in their projects and future collaboration, (AIA, AIA Minnesota and School of Architecture–University of Minnesota). Market position was a factor in choosing IPD for the owners of 11 out of 12 projects documented in IPD Case Studies (AIA, AIA Minnesota and School of Architecture–University of Minnesota (2012), and for five of those owners it was the most important, or critical motivating factor.

80 – Preference for single point of responsibility for design and construction

An owner may have a preference for a single point of responsibility for design and construction, such as in design-build method. This is advantageous since the owner is not responsible to the contractor for the quality and completeness of design. Owner needs to recognize that such an arrangement carries a potential for conflict of interest, as described in the discussion of factor 60 Avoid conflict of interest. Factor 60 and factor 80 are in opposition to one another. Both these factors can be included in a multi-criteria analysis process and their relative importance for the project compared.

82 - Maximize value

This factor refers to the ability to realize greatest value for the funds invested. According to Forbes and Syed (2010) the construction owner’s perception of value occurs when results exceed expectations. Each owner organization has certain system of values, whether this is explicitly defined and stated, or only reflected in their decisions and actions. If this factor is important to the owner, it means that the owner may be willing to increase the budget or extend the schedule, if he perceives that high value would be added to the project. In such case, a project delivery system needs to be flexible to accommodate changes in scope and quality during design and even during construction, as may be evaluated appropriate and agreed to by the stakeholders. When this factor is important, each response to uncertainties should be considered from the standpoint of maximizing value, while opportunities should be recognized as well as risks. The PDSs that facilitate owner's involvement in design and construction, but that also facilitate integration of design and construction are best suited to satisfy this factor. Firm price contracts are less conducive to maximizing value for money, because the owner is not entitled to savings in the cost of work, unless such savings result from an agreed on reduction in scope or quality, or a value-engineering effort. Maximizing value is the goal of the multi-criteria analysis in Tier 5.

83 - Owner experience with design and construction and particular project type

This factor has two states, 'high' and 'limited,' and a set of relative effectiveness values for each state. If the state is 'high', the PDSs most effective are those that allow the owner to take advantage of his experience with design and construction and the project type in question. If the owner organization is experienced, if there is continuity and knowledge transfer within the owner's team, and if resources can be made available for the project, than the owner is less likely to need the services of an agent such as construction manager. Conversely, if the state of this factor is 'low,' than the PDSs that compensate for owner's lack of experience are highly effective. This factor is related to factor 10 Owner's staff number and qualifications are limited.

84 – Encourage innovation

Russell, Tawiah and De Zoysa (2006), in examining the relationship of innovation and project delivery system on public infrastructure projects, define innovation as "use of advanced technologies, methodologies, and creative concepts that result in a positive incremental change in basic project performance metrics. Such metrics include time, cost (capital and life cycle), revenue, quality, scope and capacity (including service levels), safety, and environmental impact." Tawiah and Russell (2008) point that innovation is often not one of the primary objectives in selecting a project delivery system. It is relevant if the project offers a potential for innovation (Russell, Tawiah and de Zoysa, 2006).

Russell, Tawiah and De Zoysa (2006) classify innovation in construction industry into four major categories: product, process, organizational-contractual, and financial-revenue. Product innovations refer to the use of advanced products (materials, assemblies, tools and equipment) as well as different ways of delivering services in the operations and maintenance phase. Process innovation can belong to one of the three groups; logistical technologies, site preparation and assembling technologies and it may also involve the use of emerging technologies such as the information technology in the design and management of a project. The organizational-contractual innovation may involve improvements of organizational practices by the use of technology or negotiating the assignment of risk. Financial-revenue innovation may involve new financial arrangements and creative revenue streams. Russell, Tawiah and De Zoysa (2006), examining public infrastructure projects, identified 22 factors or conditions that represent either drivers or inhibitors of innovation as a function of project delivery system and project context. These factors were organized into four groups as shown in Table 6-1.

Among these factors, the following nine factors can be related to the choice of project delivery system, and they are described briefly.

- Responsibility integration
- Nature and composition of project team
- Source and extent of competition
- Number of competitors
- Proposal evaluation criteria and relative weights decision-making and negotiation
- Statement of product solution
- Statement of process solution
- Penalties for inadequate performance
- Reasonableness of assigning risk to public and private sector and attitudes toward risk.

Table 6-1 – Factors that act as drivers or inhibitors of innovation (Russell, Tawiah and DeZoysa, 2006)

	Innovation type			
Factors (drivers or inhibitors) for innovation	Product	Process	Organizational–contractual	Financial–revenue
Project type	primary	primary	secondary	primary
Project scale	primary	primary	primary	primary
Project complexity– uniqueness	primary	primary	little or no	secondary
Responsibility integration	primary	primary	primary	primary
Nature and composition of project team	primary	primary	primary	secondary
Opportunity for other projects of similar type	primary	primary	little or no	secondary
Source of competition	primary	primary	secondary	primary
Number of competitors	primary	primary	secondary	primary
Project performance requirements, thresholds, constraints	primary	primary	secondary	secondary
Requirements for broader socioeconomic benefits	secondary	secondary	little or no	secondary
Statement of product solution	primary	primary	little or no	little or no
Statement of process solution	secondary	primary	little or no	little or no
Product risks	primary	primary	primary	secondary
Process risks	secondary	primary	secondary	little or no
Natural environment risks	primary	primary	little or no	little or no
Certainty of economic environment	secondary	primary	secondary	secondary
Certainty of political environment	little or no	little or no	secondary	primary
Certainty of regulatory environment	secondary	secondary	little or no	secondary
Certainty of stakeholder environment	secondary	secondary	little or no	secondary
Reasonableness of risk assignment	primary	primary	primary	primary
Penalties for inadequate project performance	primary	primary	secondary	secondary
Proposal evaluation criteria, decision and negotiation processes	primary	secondary	secondary	primary

Note: [dark shading], primary importance; [light shading], secondary importance; [white], little or no importance.

Responsibility integration represents bringing together specialists of all project phases (design, construction, facilities management, service delivery, marketing) to work concurrently in a multi-disciplinary team, to optimize project performance. Greater integration may be a driver for innovation especially in design. To encourage innovation, proposal evaluation criteria should encourage integration of project functions (Russell, Tawiah and de Zoysa, 2006).

Nature and composition of project team refers to individuals on a project team, their training and their personality traits, which are critical for innovation. Furthermore, alignment of individuals' and firms' objectives with project objectives is critical to innovation. Project team must include innovation champions on part of the owner and other key participants and it should create an environment that allows innovation to come from various sources (Russell, Tawiah and de Zoysa, 2006). It is possible to influence the composition of project team by means of selection process and evaluation criteria.

Source and extent of competition and the number of competitors are closely related. Competition encourages experimentation, diversified sources of design ideas and search for ways to offer lower prices, which can lead to innovation. However, price-based competition can discourage innovation, because the consequences of failure in creating and implementing innovation can be damaging to the innovator. If a broad pool of competitors is interested in a project, this is likely to lead to the novel ideas. National or international competitors may be discouraged if there are efforts to boost the local economy, and this reduces the opportunities to bring innovations already proven elsewhere to the project in question. Greater number of competitors encourages innovation. However, when the number of competitors is very high, the low chance of winning discourages bidders. There should be an optimum number of competitors to encourage competition and innovation (Russell, Tawiah and de Zoysa, 2006).

The factor Proposal evaluation criteria and relative weights, decision making and negotiation, is favorable to innovation when selection of a proposal is not based on price only, but also considers additional criteria such as past experience and innovation record, and lifecycle approach to project decision making. Also, if the owner proposes a risk-reward structure favorable to contractors' pursuit of innovation, and if he communicates a willingness to negotiate terms, this creates climate suitable for innovation (Russell, Tawiah and de Zoysa, 2006).

Statement of product and statement of process solutions are closely related. If objectives or performance requirements are stated, rather than a specific solution prescribed, this enhances the opportunity to explore a wider variety of product and process solutions (Russell, Tawiah and de Zoysa, 2006).

The factor Penalties for inadequate performance refers to those PDSs that include responsibilities for operation and maintenance by the contractor, which are in the public-private partnership category. Since payment is contingent upon agreed-to performance, the contractor is incentivised to achieve required performance. Achievement of performance goals may provoke novel means. However, as innovation carries for the contractor both the risk of not fulfilling expectations and the risk of not getting paid due to unsatisfactory performance, this can be an inhibitor of innovation. Adequate risk and reward scheme would determine whether this factor is a driver or inhibitor of innovation (Russell, Tawiah and de Zoysa, 2006).

According Russell, Tawiah and de Zoysa, (2006), willingness to share risk and potential rewards for innovative solutions can be a powerful driver for innovation, and this is related to the risk attitudes of project stakeholders and their understanding of the relationship between risk and innovation.

Some of the factors described are drivers of innovation, whereas for some of the factors, the state of the factor determines whether it is a driver or inhibitor. Each PDS has a degree of ease or difficulty to bring the innovation factors to their states that encourage innovation. The relationships between PDSs and innovation factors were the basis for assigning relative effectiveness values to PDSs with respect to the factor Encourage innovation.

Other factors, due to space limitations, are not described in this appendix.

7 APPENDIX B

7.1 Tier 4, Process 2, Partial network diagrams

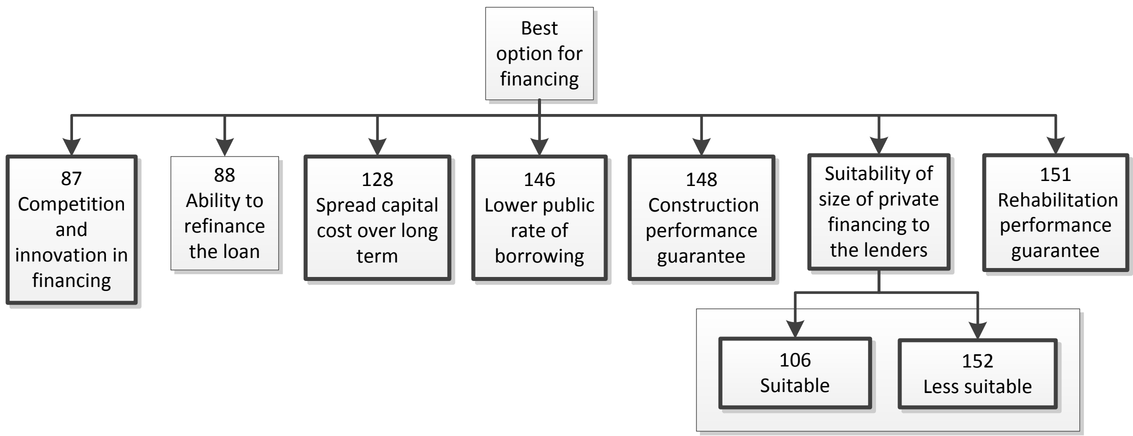

Figure 7-1 Tier 4 Process 2 partial network diagram

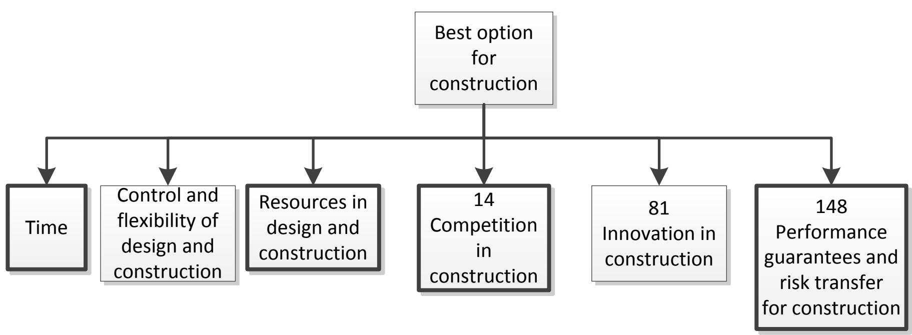

Figure 7-2 Tier 4 Process 2 partial network diagram

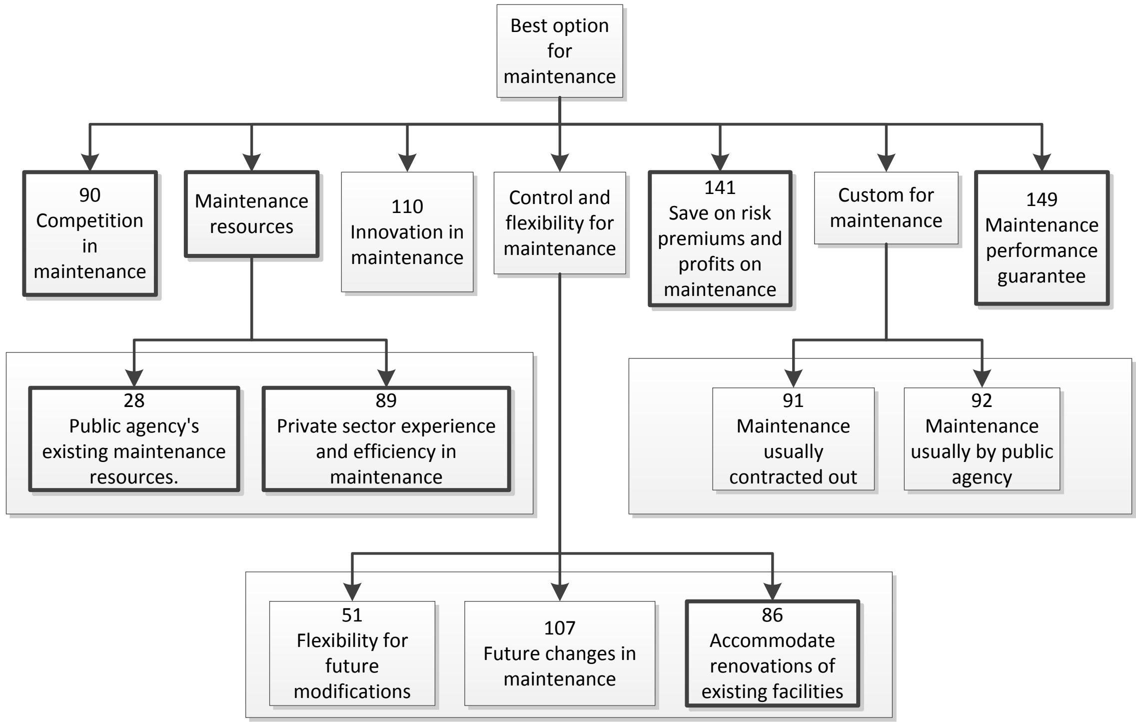

Figure 7-3 Tier 4 Process 2 partial network diagram

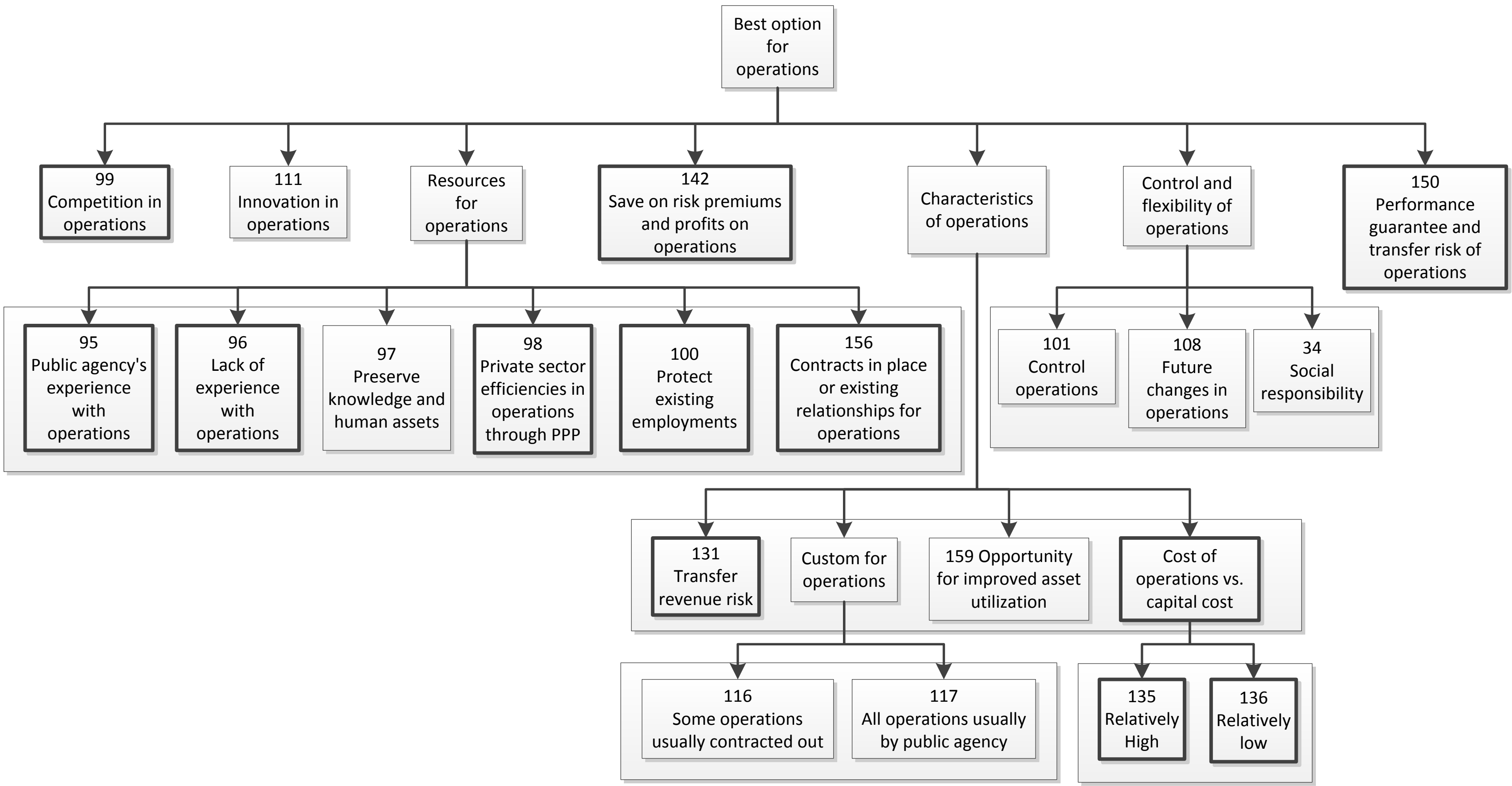

Figure 7-4 Tier 4 Process 2 partial network diagram

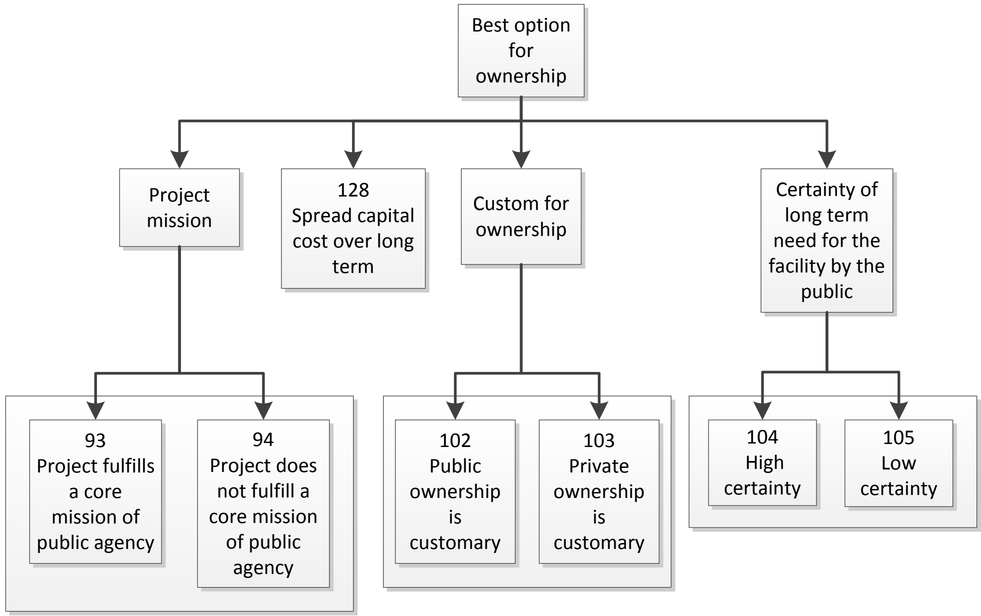

Figure 7-5 Tier 4 Process 2 partial network diagram

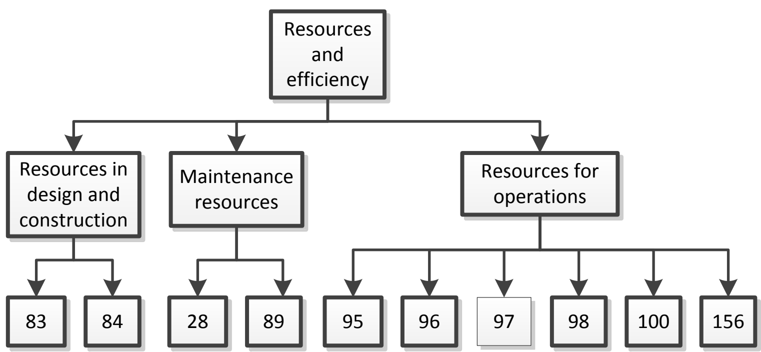

Figure 7-6 Tier 4 Process 2 partial network diagram

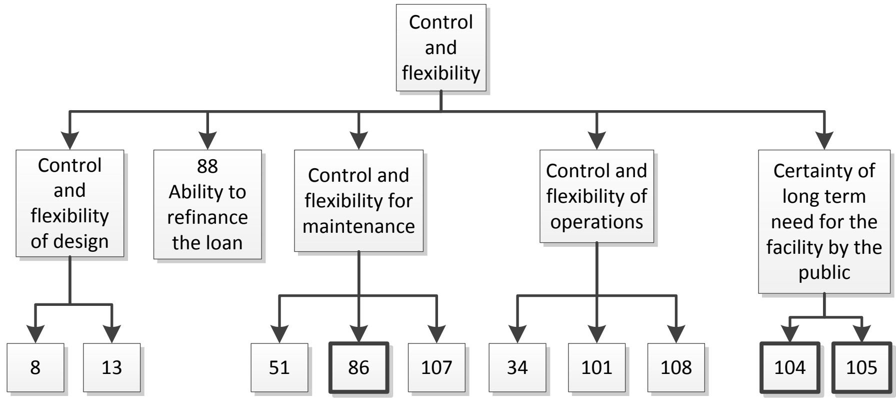

Figure 7-7 Tier 4 Process 2 partial network diagram

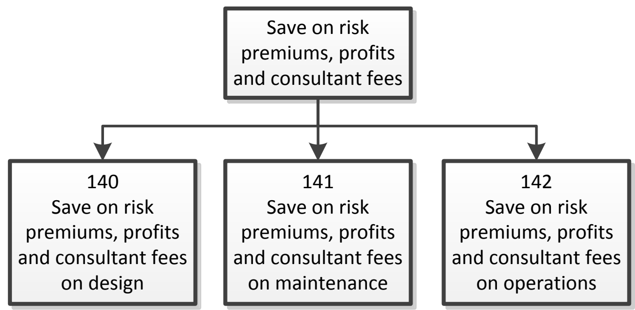

Figure 7-8 Tier 4 Process 2 partial network diagram

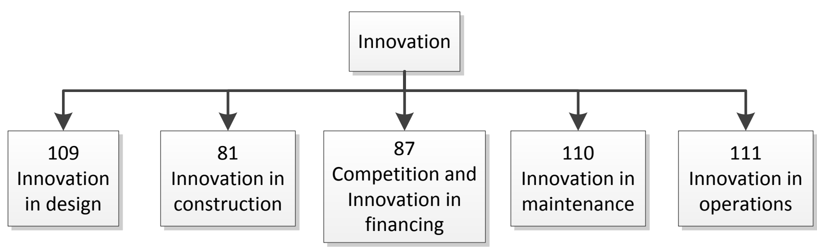

Figure 7-9 Tier 4 Process 2 partial network diagram

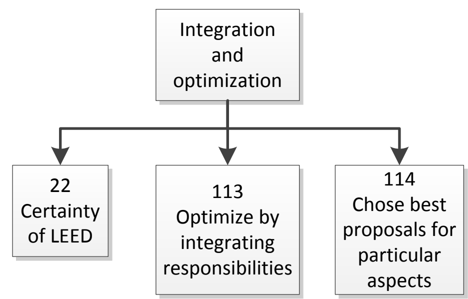

Figure 7-10 Tier 4 Process 2 partial network diagram

7.2 Tier 5, Partial network diagrams

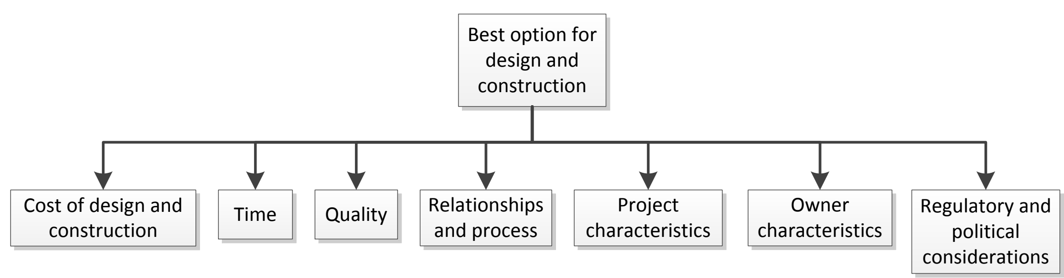

Figure 7-11 Tier 5 Stage 1 partial network diagram

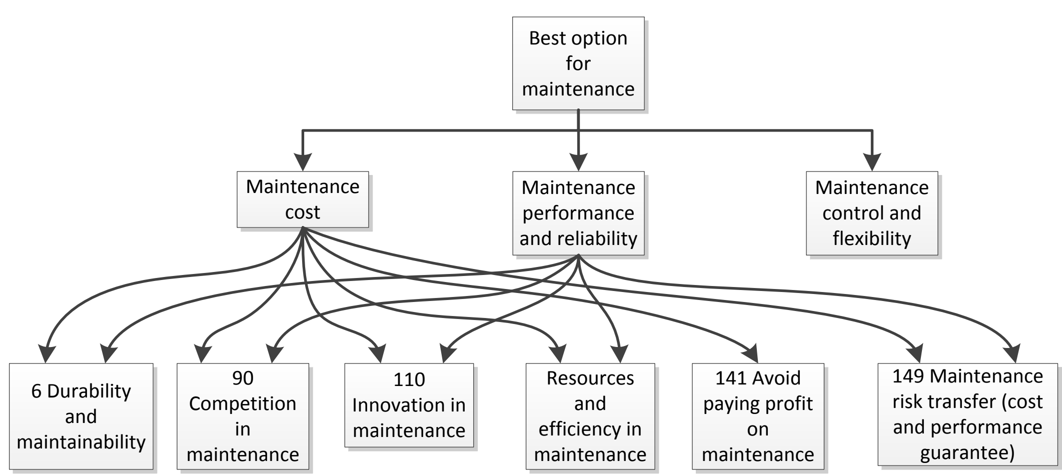

Figure 7-12 Tier 5 Stage 1 partial network diagram

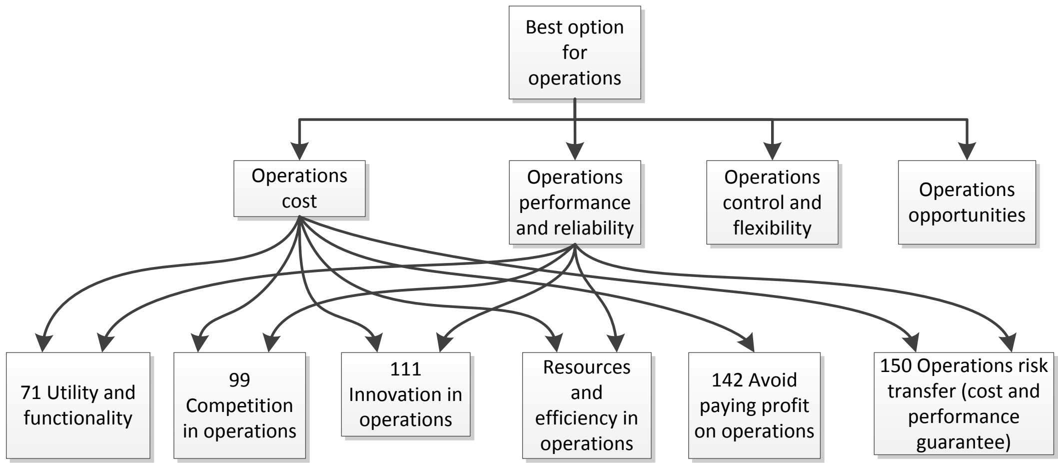

Figure 7-13 Tier 5 Stage 1 partial network diagram

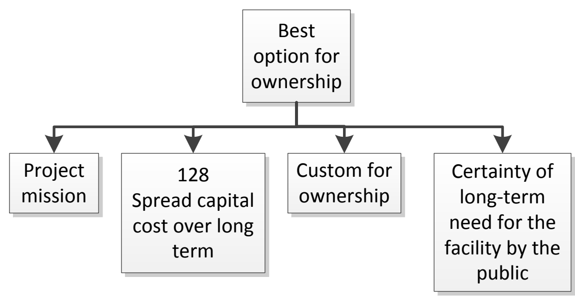

Figure 7-14 Tier 5 Stage 1 partial network diagram

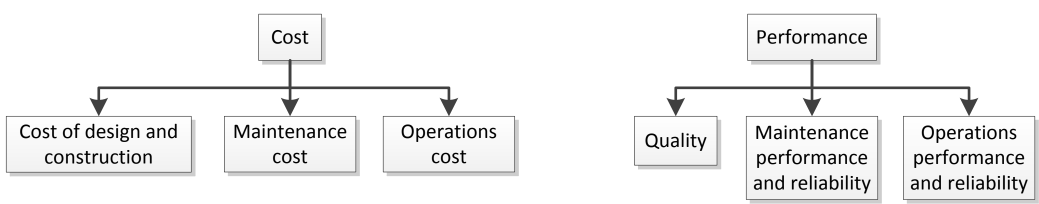

Figure 7-15 Tier 5 Stage 1 partial network diagram

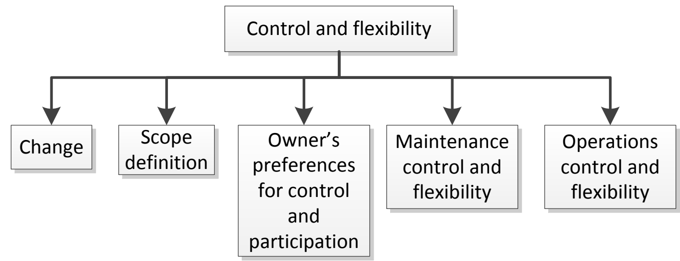

Figure 7-16 Tier 5 Stage 1 partial network diagram

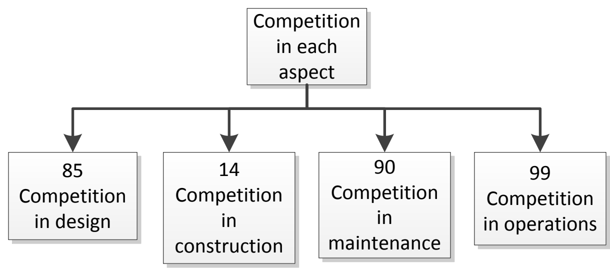

Figure 7-17 Tier 5 Stage 1 partial network diagram

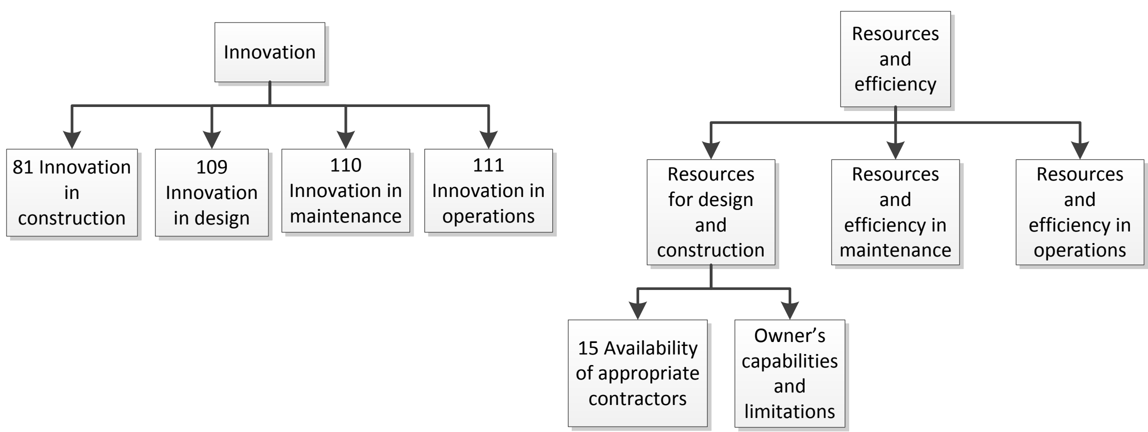

Figure 7-18 Tier 5 Stage 1 partial network diagram

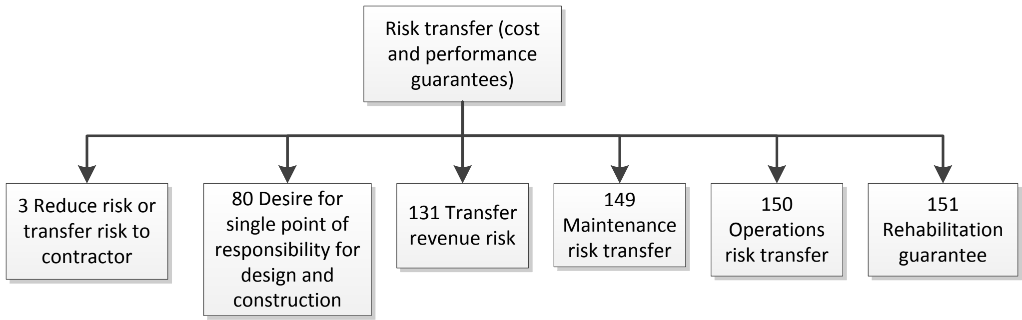

Figure 7-19 Tier 5 Stage 1 partial network diagram

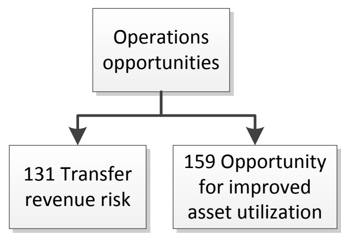

Figure 7-20 Tier 5 Stage 1 partial network diagram

7.3 Description of software tool

6	Is the owner comfortable with exploring an unfamiliar method of project delivery on this project? NO	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
	Please enter 1 below each PDS's that th owner is confortable with	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
	Please select estimated project size.																	
		1	1	1	1	1	0	0	0	1	1	0	0	1	<$10	1	1	1
7	$10-$50 MILLION	1	1	1	1	1	1	1	1	1	1	1	1	1	$10-$50	0	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	$50	0	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1	>1	0	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1		0	1	1
8	Please select the level of project complexity MEDIUM	1	1	1	1	1	0	1	1	1	1	1	1	1		1	1	0
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
		1	1	1	1	1	1	1	1	0	1	1	1	1		0	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
9	Does the owner desire to transfer risk to contractors, as much as possible, or accept some of the risk?	0	0	0	0	0	1	1	1	0	0	1	0	0		0	0	0
	ACCEPT	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
10	Are there contractors available and qualified to deliver the project under the PDS considered? Indicate for each PDS. For IPD, do you expect to be able to assemble a suitable team for successful application of Integrated Project	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES		YES	YES
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
10		10	10	10	10	10	10	10	10	10	10	10	9	10		9	10	10
		0	0	0	0	0	0	0	0	0	0	0	1	0		1	0	0
		1	1	1	1	1	1	1	1	1	1	1	0	1		0	1	1
	Summary	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS applies	PDS does not apply	PDS applies	PDS does not apply		PDS applies	PDS applies

Figure 7-21 PDS AutoSelect Tier 3 Interface Key inputs 6 through 1

Reset matrix X

Subcluster	Risk and reward sharing	Criterion	Reduce or transfer risk to contractor	Desired contractual relationship and ability to recoup savings	Opportunity to partner	Avoid conflict of interest	Apportion risk equitably and share rewards	Desire for single point of responsibility for design and construction		Priorities	C.R.
3	Reduce or transfer risk to contractor	YES	X	X	X	X	X	X	KI	0.0000	
24	Desired contractual relationship and ability t	YES	X	1	1	1/3	1	X		0.1759	
55	Opportunity to partner	YES	X	1	1	1/3	1/2	X		0.1479	
60	Avoid conflict of interest	YES	X	3	3	1	1	X		0.4009	
68	Apportion risk equitably and share rewards	YES	X	1	2	1	1	X	KI	0.2753	
80	Desire for single point of responsibility for d	NO	X	X	X	X	X	X		0.0000	
		4	0.00	0.18	0.15	0.40	0.28	0.00		1.0000	0.0369

Matrix XI

Reset matrix XI

Subcluster	Avoid claims and disputes	Criterion	Minimize number of contracted parties	Minimize adversarial relationships	Priorities	C.R.
5	Minimize number of contracted parties	YES	1	1/3	0.2500	
27	Minimize adversarial relationships	YES	3	1	0.7500	
		2	0.25	0.75	1.0000	#DIV/0!

Matrix XII

Reset matrix XII

Subcluster	Collaborative Process	Criterion	Effective communication	Collaboration of project team	Trust and respect	Alignment of objectives	Priorities	C.R.
73	Effective communication	YES	1	3	2	5	0.4789	
74	Collaboration of project team	YES	1/3	1	1/3	1/2	0.0994	
75	Trust and respect	YES	1/2	3	1	3	0.2981	
76	Alignment of objectives	YES	1/5	2	1/3	1	0.1237	
		4	0.48	0.10	0.30	0.12	1.0000	0.0574

Figure 7-22 PDS auto Select Tier 4 Process 1 interface

8 APPENDIX C

8.1 Case study 2

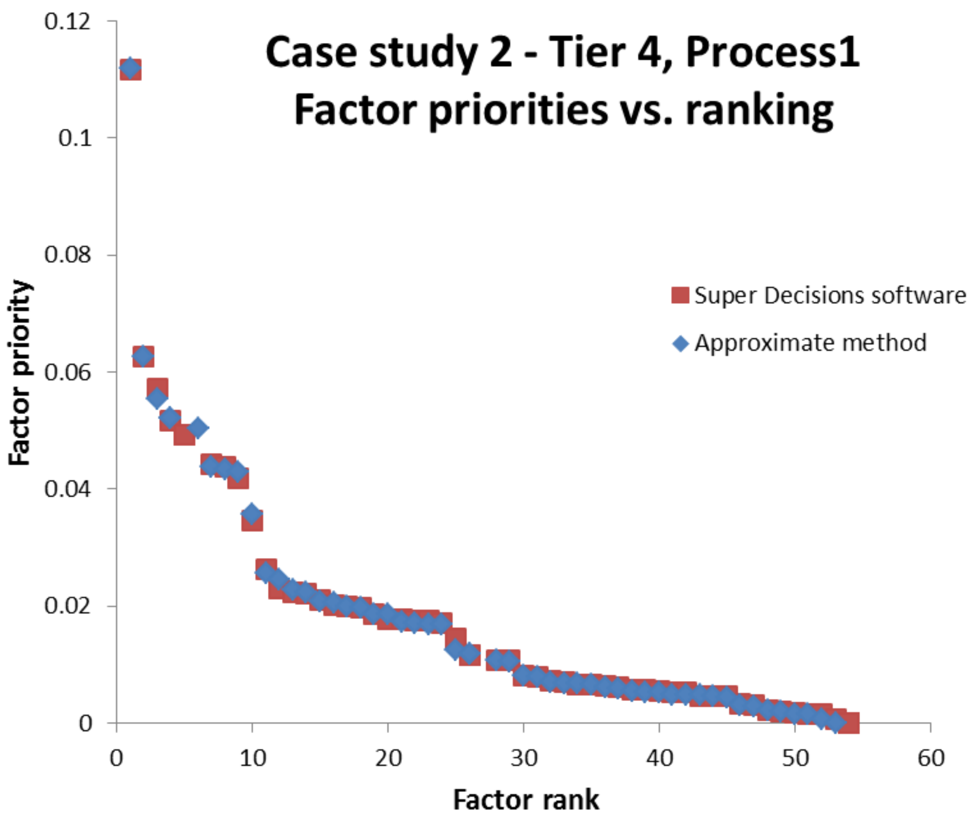

Figure 8-1 Case study 2 - Tier 4 Process 1, factor priorities vs ranking

Table 8-1 Case study 2 - User-defined relative effectiveness values

		Factors			
	Factor #	15	23	24	59
PDS #	PDS	Availability of appropriate contractors	Experience with particular PDS and forms of contract	Desired contractual relationship and ability to recoup savings	What feels comfortable to the owner
1	Traditional Design-Bid-Build	80	50	20	50
2	Traditional with early procurement	80	50	20	50
3	Traditional with PM (agent)	80	50	20	50
4	Traditional with CM (agent)	80	80	20	80
5	Traditional with early procurement and CM (agent)	80	65	20	50
6	CM @ Risk	50	50	80	35
10	Traditional with staged development	50	65	20	20
13	Design-Negotiate-Build	65	50	50	35
15	Integrated Project Delivery (Relational Contracting, Lean Design and Construction)	20	50	80	35

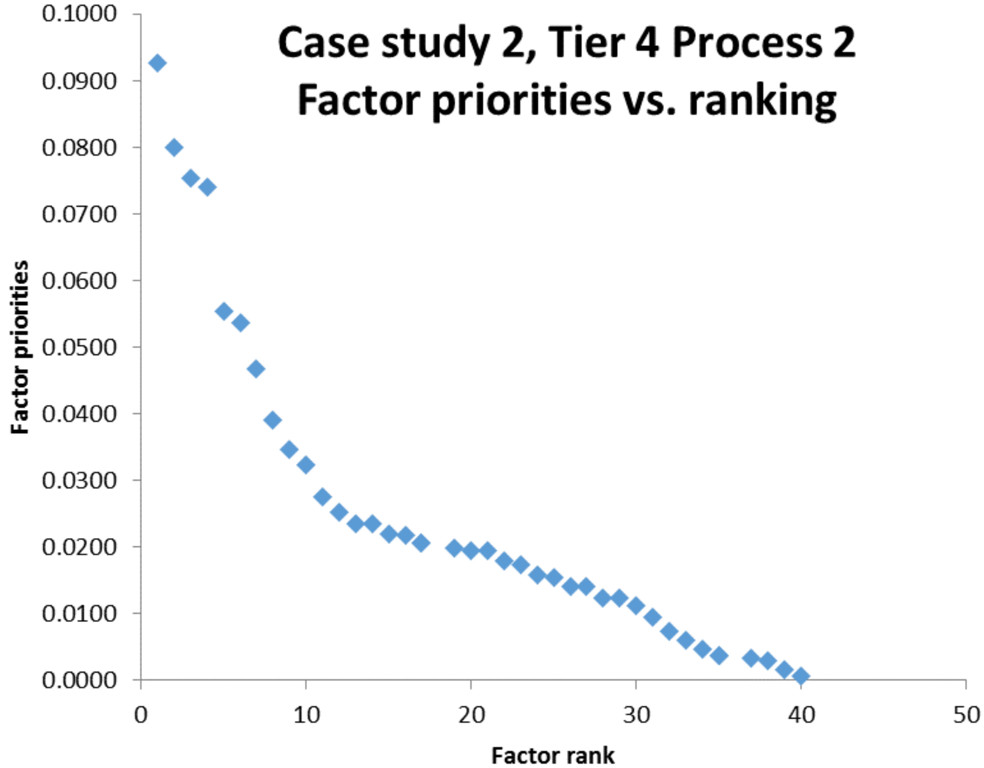

Figure 8-2 Case study 2, Factors for PPP selection priorities versus ranking

8.2 Case study 3 - Miami Intermodal Center

Table 8-2 Case study 3, PPP high level suitability screening criteria

#	High level P3 screening criteria	Answer	Explanation of answer	Result
122	Are there regulatory and public acceptance restrictions to transferring maintenance?	No	No restrictions to transferring maintenance	Maintenance can be transferred.
123	Are there regulatory and public acceptance restrictions to transferring operations?	No	Some operations will be by private parties but not through PPP	Only certain operations could be considered to be included in PPP.
124	Are there regulatory and public acceptance restrictions to transferring ownership of the facility?	Yes	This facility will be critical for access to and from airport, so it needs to be in public ownership.	Ownership cannot be transferred.
7	Is the completion date critical? If yes, which PPP models can deliver on time and which cannot?	Yes	It is very important to meet or exceed schedule, for which overlapped sequence of design and construction is needed.	Design should be transferred.
8	Enable the public owner to control detail design.	Yes	Owner wishes to have control of designer selection and of design process.	Design should not be transferred.
9	Is it possible to clearly define scope and performance requirements, so that detail design can be developed without significant owner participation?	No	Multiple stakeholders are involved, some of which would need to provide input in design.	Design should not be transferred.
133	Is it possible to separate operations from maintenance?	Yes		No restriction on PDS selection

132	Does project have significant maintenance requirements?	Yes	Maintenance requirements are significant.	No restriction on PDS selection.
50	Is the project separated of integrated with existing assets or networks?	Integrated	Some portions will be integrated with airport (MIA Mover), others with future development of MIC	Factor against transferring operations and maintenance
51	Will the performance requirements and use of the project be relatively stable over time? Can operational flexibility be maintained over the life of the contract at reasonable cost?	No	Volumes of passengers and traffic may grow of fluctuate, which would impact maintenance and operations requirements.	Suitability should be further evaluated though market sounding.
44	Is the refurbishment cycle for the project relatively predictable and stable?	Varies	For some portions and aspects it may be predictable, for some - not.	Specific aspects of maintenance should be considered separately.
125	Is it possible to set clear standards and performance requirements, monitor performance and hold the provider accountable for maintenance?	Yes		Maintenance can be transferred.
53	Does the asset have an expected useful life greater than 20 years?	Yes		Long term contract can be considered.
101	Enable the public owner to control operations and respond to potential changes of policy.	Yes	Different portions of operations will be carried out by different private parties.	Some operations may be transferred through PPP.
130	What is the size of operations? Are they too small for public agency to carry them out efficiently?	No	The operations that the owner may perform would probably be part of the operations for the airport complex, so their size is significant.	No restriction on PPP models selection.

131	Is the risk associated with operating the facility acceptable to the public agency?	Yes	The risks are acceptable to the public agency for those operations that the owner considers performing internally.	No restriction on PPP models selection.
126	Is it possible to set clear standards and performance requirements, monitor performance and have the provider accountable for operations?	Yes	Yes	Operations may be transferred
95	What is the level of the public agency's experience and knowledge with the service or operations that the project will support? Does the project involve technologies that a private party may be more familiar with? Does it seek new solutions that private party may be better able to provide?	Government has enough experience with operations.	Certain operations will be transferred to private parties but will not be part of PPP that integrates construction. Those are car rentals and Tri-rail system. Owner has experience and knowledge necessary for other operations.	No restriction on PPP model selection.
128	Is there need for long-term private financing?	No	At the time of the PDS selection decision, funding was secured.	No restriction on PPP model selection.

	Cost	Time	Quality	Relationships and process	Project characteristics	Owner characteristics	Regulatory and political considerations	Priorities	Priorities from Super Decisions software	Difference in priorities	Rank in cluster (approximate method)	Rank in cluster (Super Decisions)
Cost	**1**	1	1	3	1	3	3	0.2014	0.1972	-0.0042	1	1
Time	1	**1**	1	3	1	3	3	0.2014	0.1972	-0.0042	1	1
Quality	1	1	**1**	3	1	1	5	0.1852	0.1895	0.0043	4	4
Relationships and process	1/3	1/3	1/3	**1**	1/3	1	3	0.0786	0.0808	0.0023	5	6
Project characteristics	1	1	1	3	**1**	3	3	0.2014	0.1972	-0.0042	1	1
Owner characteristics	1/3	1/3	1	1	1/3	**1**	1	0.0786	0.0831	0.0045	5	5
Regulatory and political considerations	1/3	1/3	1/5	1/3	1/3	1	**1**	0.0534	0.0549	0.0015	7	7

Consistency ratio 0.03577

Inconsistency from Super Decisions 0.0356

Figure 8-3 Case study 3 Tier 4 pairwise comparisons at highest level of hierarchy/ network

8.2.1 Pairwise comparisons specific to network

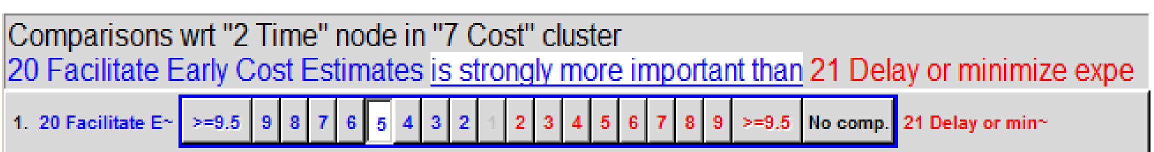

Figure 8-4 Comparison with respect to node 'Time'

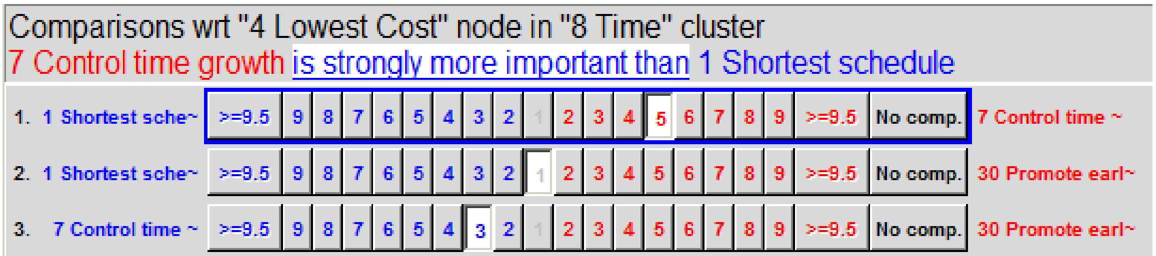

Figure 8-5 Comparison with respect to node '4 Lowest Cost'

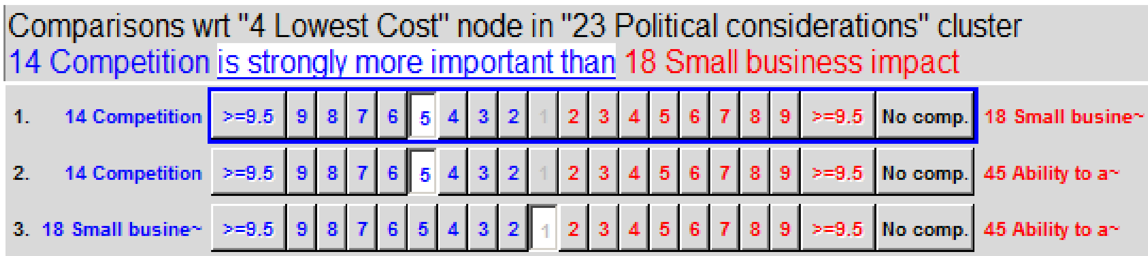

Figure 8-6 Comparison with respect to node '4 Lowest Cost'

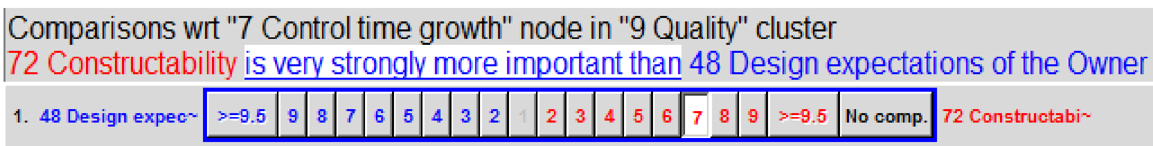

Figure 8-7 Comparison with respect to node 'Control time growth'

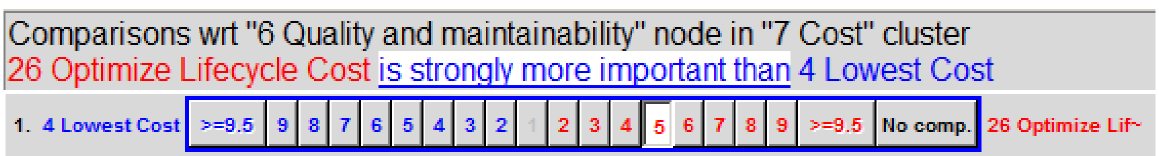

Figure 8-8 Comparison with respect to node 'Quality and maintainability'

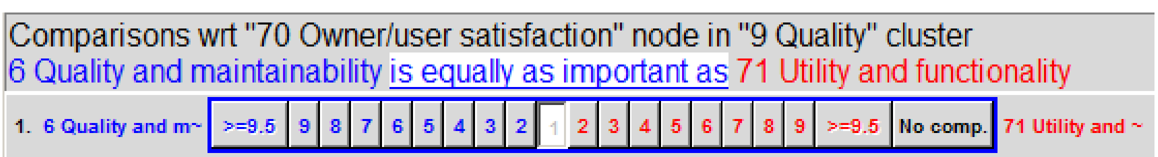

Figure 8-9 Comparison with respect to node '70 Owner/user satisfaction'

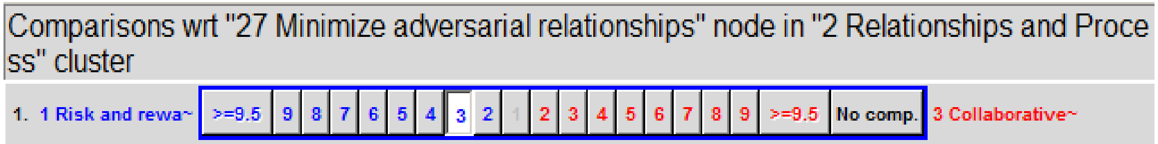

Figure 8-10 Comparison with respect to node ’27 Minimize adversarial relationships’

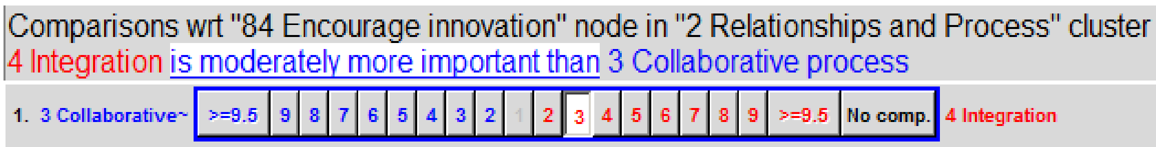

Figure 8-11 Comparison with respect to node ’84 Encourage innivation’

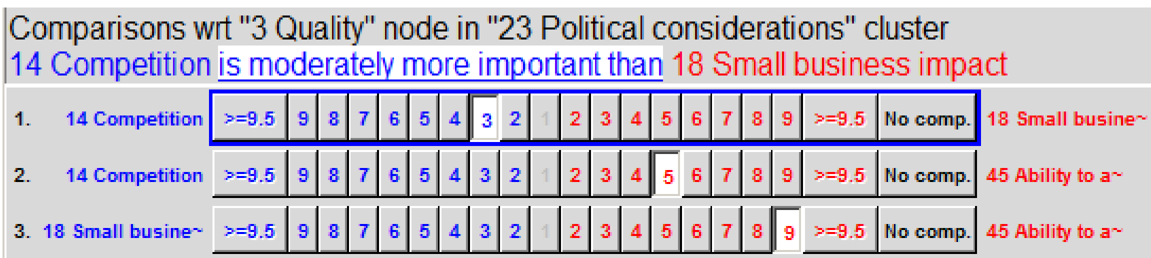

Figure 8-12 Comparison with respect to node ‘Quality’