Life Cycle Cost Analysis: A Decision Tool for Public Procurement Award

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List of Acronyms

BMS	Bridge Management System
CDR	Council for Development and Reconstruction
CIPS	Chartered Institute of Procurement & Supply
DB	Design Build
EBRD	European Bank for Reconstruction and Development
GDP	Gross Domestic Product
HCP	Higher Council for Privatization
IoF	Institut des Finances Basil Fuleihan
IRR	Internal Rate of Return
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
MDGs	Millennium Development Goals
MIRR	Modified Internal Rate of Return
M&R	Maintenance and Rehabilitation
NPV	Net Present Value
OECD	Organization for Economic Cooperation and Development
OPEX	Operating expenses
PFM	Public Financial Management
PPP	Public Private Partnership
RTG	Rubber Tyred Gantry Crane
SBD	Standard Bidding Document
STS	Ship to Shore Gantry Crane
TEU	Twenty-foot equivalent unit
TT	Truck Trailer
VFM	Value for Money
WB	World Bank

Abstract

Sustainable development has been tackled for the last four decades in various fields from education, management, climate change to politics all over the world. One of the major challenges faced by humanity nowadays is achieving the economic sustainability of our infrastructure facilities. To fulfill it, an economic tool called Life Cycle Cost Analysis (LCCA), which takes into account all costs of an asset during its lifetime, is being used. In some countries, this technique is being incorporated in the procurement. It is used as a decisive factor in the procurement of their infrastructure facilities to employ resources in the most efficient way, which is favored both economically and environmentally. This master thesis aims at examining the theoretical background and framework of LCCA models to assess the feasibility of incorporating it in public procurement in Lebanon. This is done through academic research, review of case studies for different types of infrastructures, and by inspecting the current state of practice of the LCCA in Lebanon using published guidelines and policies, in addition to conducting one-on-one interviews with key public sector personnel. Based on the assessment of incorporating the life cycle cost (LCC) viability within the current practices of procurement in the public sector in Lebanon, it is concluded that the new Public Private Partnership (PPP) law is the most appropriate channel for considering LCCA results in the procurement decisions.

Additionally, a case study of incorporating LCCA in infrastructure procurement was conducted. This was applied on the main component of the commercial sea port of Tripoli: Ship to shore gantry crane (STS) and Rubber tyred gantry crane (RTG) purchase. The LCCA outcome indicated that for a 20 years lifetime, a cost of $21/Local Twenty-foot equivalent unit (TEU), $10/Transhipment TEU for the STS, $6/local TEU and

$3/Transhipment TEU for the RTG will yield to an Internal Rate of Return (IRR) of 25%. This forms a Modified Internal Rate of Return (MIRR) of 16% and accordingly the concession period must be of 11 years minimum.

1. Introduction

A critical and important issue for the social and economic welfare of our current infrastructure systems is effectively managing the available resources and assets. The financial crisis, and the increase of the costs for serving the public and the growth in public scrutiny of government expenditures have resulted in having the decision-makers look for evaluation methods that can better deliver results while taking into account the long-term impacts of the public projects. Worldwide, more than USD 2.5 trillion are spent yearly on infrastructure including transportation, power, water, and telecommunication. However, the world is still facing endless deteriorating conditions of the infrastructure systems combined with an increasing global infrastructure funding gap. In order to simultaneously meet the growing needs and sustain economic growth, of an investment of USD 3.3 trillion is needed annually (Woetzel, Garemo, & Mischke, 2016).

In Lebanon, the condition of the infrastructure is among the poorest worldwide. According to the World Bank 2018 index, Lebanon ranks 130 of 137 in the quality of its infrastructure. This was caused by low public spending which results from the country's debt burden and lack of a long-term budget planning (World Bank, 2018). Besides, it was also found that without early consideration of all costs encountered during the lifetime of any public facility, the economic sustainability can never be realized. For this, an important economic evaluation tool "Life cycle cost analysis" (LCCA) is considered by agencies to avoid facing difficulties and to choose the best development path for creating and preserving sustainable assets while still ensuring a cost-effective project.

In fact, in the field of infrastructure planning and management, utilizing LCCA is considered a mandatory pre-requisite for achieving the sustainability of the infrastructure

facilities. The project that will provide the minimum cost of ownership which is consistent with its quality and function, will be chosen by taking into consideration initial costs, future costs such as maintenance, user and reconstruction over the life of the project segment. LCCA can be applied to study new projects or to protect existing assets. Even though LCCA model is readily available in textbooks, yet applying the model is not a simple routine. When attempting to apply LCCA for infrastructure facilities, several questions should be taken into consideration including: What are the economic parameters that will be used in the analysis and how do we estimate them? What are the costs that can or must be included in the analysis? Consequently, how do you estimate the fees (i.e., agency cost, user cost, and societal cost)? To answer these questions and by reviewing academic literature, diverse answers are found. Additionally, a general framework and guidelines for conducting LCCA for infrastructure facilities are presented. The framework aims to guide practitioners in infrastructure management who are attempting to conduct LCCA for their facilities, specifically in developing countries.

Even though the use of LCCA has been introduced for some time now, its implementation in procurement is not yet manifested. In procurement, the traditional practice has been to award the public contract to the lowest-price bid. Authorities claim that the least expensive bid ensures the achievement of budgetary savings. However, by accepting the lowest price bid, the best Value for Money (VFM) is not always reached. Although savings are realized to the purchase price, future costs will be generated by the use of these assets. These future costs include operational, maintenance, direct and indirect costs that will all be paid by authorities or end-users. Thus, from an economic perspective, this approach must be

modified by considering all of the costs during the life span of an asset, consequently incorporating the LCCA in the evaluation of the criteria for the final decision.

This master's thesis proposes a general framework and guidelines of the LCCA method for diverse types of infrastructure facilities and examines the feasibility of incorporating the LCC (Life Cycle Cost) results within the current practices of procurement in the public sector in Lebanon. In other words, this thesis will attempt to evaluate the bids according to their LCC which considers the operation and maintenance, procurement, and disposal costs.

The thesis is structured into nine sections with the following outline. The first section covers the introduction and scopes of the thesis; it also describes the background information and its boundaries for preparing the thesis. Details and steps of the research objectives and methodology are defined in section two. In the third section, an in-depth literature study is elaborated focusing on the main questions regarding the use of LCCA and its public procurement practices. The fourth section presents a developed general framework of the LCCA process. Section five introduces the role of public procurement practices in economic growth in Lebanon, goes through the procurement law in Lebanon and its development and lists the main guidelines and policies of procurement key players in Lebanon. In the sixth section, Public Private Partnership (PPP) is defined according to the international practice and Lebanese laws. Also, PPP models and risks are enumerated and the history of PPP projects in Lebanon is introduced besides the three current PPP Projects. Section seven describes the current state of the practice of LCCA in the procurement in Lebanon through in-depth interviews with key public sector personnel. In section eight, an application of the model in procurement of the marine port is implemented

on the purchase of STS and RTG cranes. This section also covers PPP in ports, concession period and the financial arrangements between the operator and the port. The last section wraps up the thesis paper with a main conclusion of the work.

2. Research Objectives and Methodology

There are two proposed objectives in this thesis:

The first objective is to propose a general framework and guidelines with deeper understanding of the LCCA process for different types of infrastructure facilities that can be utilized in Lebanon. This will be done based on the analysis of existing LCCA models for several types of infrastructures and on the general framework for conducting this technique for all types of infrastructure facilities. The purpose of this framework is to guide practitioners in infrastructure management in Lebanon who are attempting to conduct LCCA. To achieve this objective, the research will focus on reviewing LCCA models for different infrastructure facilities in order to combine the results into a general framework for all facilities.

The second objective is to investigate the feasibility of incorporating the LCC results within the current practices of procurement in the public sector in Lebanon. The research will look for answers for the following questions:

- What are the main types of procurement contracts currently used in public sector industries in Lebanon?
- What is the status of incorporating LCCA in procurement contracts in public sector industries in Lebanon?

The answers to the last question will put forward a proposal for incorporating LCCA in procurement.

To achieve the outlined objectives of this thesis, the proposed methodology consists of several steps which include:

- A comprehensive literature study focusing on:

  a) LCCA in academic research and case studies;

  b) LCCA theoretical background and framework; and

  c) LCCA in procurement in academic research
- A study of the current practices of implementing LCCA in Lebanon and on the methods of procurement applied in the public sector in the country. This is examined by revising guidelines and policies and by conducting in-depth interviews with key public-sector personnel. Meetings were done with personnel working in the procurement department of the Council for Development and Reconstruction (CDR), Institut des Finances Basil Fuleihan (IoF) and Higher Council for Privatization and PPP (HCP).
- The third component includes conducting a real-world case study for applying LCCA in the procurement process of infrastructure. The case study evaluates a main segment of the commercial sea port of Tripoli: STS and RTG purchase.

3. Literature Review

Sinha et al. define LCCA as a special case of economic efficiency analysis where the streams of the facility's benefits and costs extend over an appreciable length of time such as one life cycle of the facility. LCCA refers to the phased process of estimating the net present economic worth of a project by summing up the discounted expected value of all

LCCs and benefits incurred by all those affected as a result of putting the project into operation over its economic life span. Benefits are considered positive whereas costs are negative. LCCA can be applied at the project or network levels. Project-level LCCA focuses on specific facilities, such as a runway, bridge, building or road segment; whereas network-level analysis considers an entire inventory of facilities (Sinha & Labi, 2007).

At the onset, LCCA is used as an analytical tool to aid public officials in making informed decisions when selecting between competing alternatives for infrastructure projects. The LCCA as such can be employed to choose between alternatives at the planning phase of the project. It can be used during the lifetime of the project when faced with the choices of rehabilitation, renewal or replacement/reconstruction. Most LCCA guidance promotes its use to achieve one of these two objectives. The literature illustrates its wide use in three infrastructure sectors: roads (Goh & Yang, 2009), (FHWA, 2002), (CTC & Associates LLC, 2011); bridges (Hawk, 2003) (Zhang, Ye, & Yuan, 2013) (Ta, Orcesi, & Cremona, 2013); and buildings (Bowyer, et al., 2013) (El-Akruti, Dwight, Zhang, & Al-Marsumi, 2013), (Kibert, Olbina, Oppenheim, Ries, & Walters, 2010).

The research-led literature on the use of LCCA is limited for other types of infrastructure such as rail (Zoeteman, 2001); tunnels (Hunt, Nash, & Rogers, 2014), (Wang, Koizumi , & Tanaka, 2017); airports (Heuvinck, 2015), solid waste facilities (Zurbrügg, Caniato , & Vaccari, 2014); and water distribution (Campisano & Modica, 2012).

In recent years, the use of LCCA has expanded beyond its original intended use. Research has advanced on how this important tool be employed to optimize the timing of maintenance and rehabilitation (M&R) with various objectives and constraints, which include maximizing the welfare utility to minimizing the total cost (Ferreira & Santos,

2012). Furthermore, the research has ventured into applying the LCCA as a tool to prioritize rehabilitation activities at the network level under funding limitations and other constraints (Jawad, Ozbay, & Nassif, 2007). Combining LCCA and life cycle assessment (LCA) has gained much attention lately since applying LCCA alone will come short in assessing the impacts of the infrastructure on the environment (Liu, Davis, Love, Smith, & Regan, 2014). The LCCA-LCA hybrid model can capture the majority of the impacts of the infrastructure projects when applied comprehensively.

While LCCA is being introduced more widely, its application in procurement is still limited. The most procurement method used chooses the lowest initial cost, which is the cheapest and quicker solution. But the results of using this method have undesirable consequences such as higher capital expenditures (Highton, 2012) (SIGMA, 2016) (Tysseland, 2008).

In the building infrastructure sector, literature illustrates that the procurement of buildings is undertaken without considering the costs that would be incurred from acquisition to disposal. Previous studies show that between December 2007 and December 2008, the cost of materials increased by 3.5% per square meter, and the average building cost per square meter between 2000 and 2008 increased by 52%. Consequently, to lower LCC of new buildings, they should be procured based on the LCCA approach using renewable resources and embedded sustainability principles. Also, according to the US Green Building Council, environmentally sustainable buildings perform 50% better than traditionally procured buildings (Highton, 2012).

In the bridges infrastructure sector, Safi et.al introduces a complete approach to help agencies exploit their bridge management systems (BMSs) to procure the most cost-

efficient bridge design through fair design-build (DB) tendering processes. This approach includes the use of the LCCA technique and allows bridge procurers to establish monetary LCC-efficient benchmarks and embed them in tender documents as main specifications (Safi, Sundquist, & Karoumi, 2015).

Another publication from the Norwegian Ministry of Defense states that when procurement decisions are made, systems that yield the lowest possible LCC for the organization must be procured even if this means that initial procurement cost becomes higher (Tysseland, 2008).

Nowadays, there is a growing trend of using LCCA in procurement activities where the results of the model can be used as one of the evaluation criteria when selecting winning bids in infrastructure projects. In specific, LCCA is used as a main criterion in PPP in infrastructure contracts (World Bank, 2016), (Estevan & Schaefer, 2017). And, the new EU public procurement “DIRECTIVE 2014/24/EU” clearly includes, defines and foresees the use of LCC within the public procurement process. It also encourages the use of LCC during the awarding phase as a tool to get the “most economically advantageous tender” (Estevan & Schaefer, 2017).

The inclusion of all the costs in the procurement process is a way of visualizing hidden costs and bringing them into the procurement decision as shown in Figure 1 (Estevan & Schaefer, 2017).

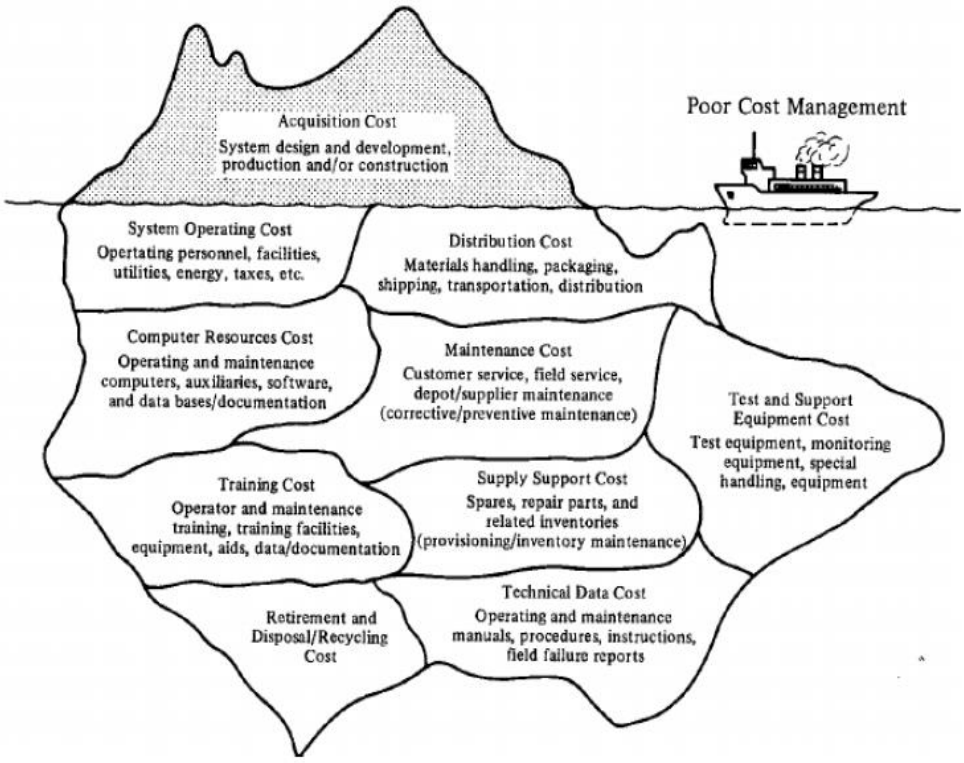


Figure 1: LCCA Hidden Costs **(Estevan & Schaefer, 2017)**

4. Developed LCCA Framework

Alternatives are usually defined with respect to agency costs, user and societal costs and the time when these events occur. Thus, the objective is to calculate and compare the total LCC for each of the alternatives. Still, the projected activities costs cannot be added together because money spent at different times have different present values. For that, LCCA estimates the Net Present Value (NPV) of each project by adding the discounted expected value of all LCCs and benefits to put the project into operation over its economic lifetime (FHWA, 2002).

LCCA model is presented in equation 1 where the alternative with the lowest NPV is chosen.

$$NPV = \sum_{t=0}^{T} \left[\sum_{k \in K} \sum_{j \in J} Cost(k, j, t) \right] \Big/ (1+r)^t$$

Equation 1

Where:

- NPV = Net Present Value in monetary units ($)
- k= Set of costs (i.e., Agency Costs, User Costs, Social Costs)
- j = Set of costs incurred by each entity in k and classified by their nature (i.e., user Costs can consist of vehicle operating costs, travel time costs, and crash costs)
- t = year at which the cost is incurred
- T = Analysis Period (years)
- r = Discount Rate (%)

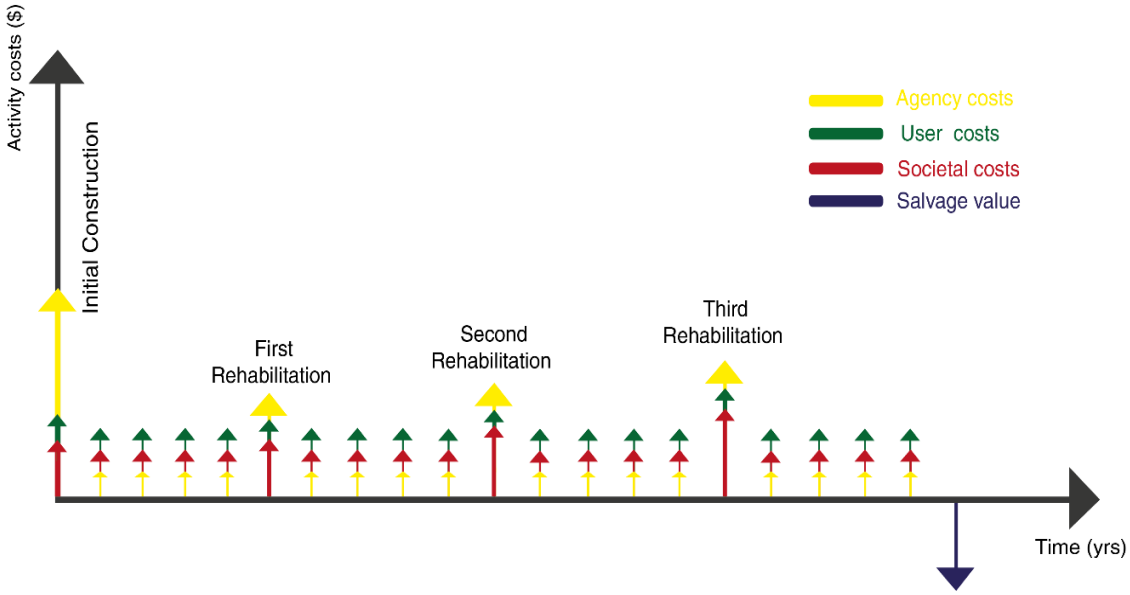


Figure 2: Expenditure stream diagram, costs, and timing in relation to facility condition

The expenditure stream diagram (Figure 2) is developed to help analysts in picturing the quantity, and timing of activities and expenditures projected over the life of the analysis period. The first of these activities include initial construction or major rehabilitation. Then

to provide a specified level of performance throughout its life, following rehabilitation activities are needed. M&R activities differ according to project alternatives. After defining the analysis period, the common timeframe for all alternatives is considered. The use, age, weather, and other factors lead to a decrease in the level of serviceability causing the asset to deteriorate thus leading the asset to fall. The rehabilitation or maintenance activities will increase the serviceability again until reaching the minimum acceptable serviceability level or the end of service life.

In order to conduct LCCA, a general framework was developed and presented. This framework was done to guide the practitioners in infrastructure management seeking to conduct LCCA for their facilities specifically in developing countries. Additionally, a comparative analysis between different types of infrastructure facilities will highlight deficiencies and snags in applying LCCA, to further drive besought research and advancement.

The steps of the developed framework of LCCA include:

Step 1: Determine LCCA Objectives

First, each LCCA study must have clear objectives, in specific why are we doing LCCA. LCCA study can capture dollar cost variations between alternatives and show which option will have the lowest overall cost (Babashamsi, Md Yusoff, Ceylan, Md Nor, & Jenatabadi, 2016).

Usually, the main objectives include:

- Choosing between alternatives for constructing the facility at the planning stage or during operation

- Bidding evaluation criteria
- Predicting future performance of facility(ies)
- Planning of future budget
- Optimizing M&R activities type and timing at the project level
- Prioritizing M&R activities at the network level

After determining the objective of running the LCCA of a facility, one of the ambiguities surrounding LCCA is to understand the basic economic parameters and to estimate them. These parameters are the discount, interest, inflation rates, and analysis period.

Step 2: Estimate Discount Rate (r) Interest and Inflation Rates

The discount rate is used to determine the current value of future cash flow. There are two types which include:

- Real (constant) discount rate: The real discount rate that has been adjusted to eliminate the effect of expected inflation should be used to discount constant-dollar or real benefits and costs.
- Nominal (current) discount rate: This type reflects expected inflation which is used to discount nominal benefits and costs. The nominal interest rate reflects the investor's time, value of money or opportunity cost. Market interest rates are nominal interest rates in this type (Blank & Tarquin, 2012).

The real discount rate can be estimated using equation (2):

$$r = \frac{i - f}{1 + f} \qquad \text{Equation 2}$$

Where:

- f = Inflation rate
- i = Nominal interest rate
- r = Real discount rate

Nominal interest rates and inflation rates are published yearly by National banks. These values can be utilized by analysts when conducting LCCA (Ozbay, Jawad, Parker, & Hussain, 2004). Few development banks and agencies provide values for the discount rate when evaluating proposed projects for funding (Jawad & Ozbay, 2006).

Step 3: Establish Analysis Period

By definition, the analysis period is the duration in years over which a facility, building, or component provides sufficient performance fulfilling the purpose for which it was built or acquired (Uddin, Hudson, & Haas, 2013). Many methods are introduced for estimating the analysis period such as survivor curve method, performance modeling, accelerated testing and reference to previous experience. When deciding the analysis period, the timeframe must be long enough to represent the actual service life of the alternatives under evaluation so as the issue of remaining service life can be avoided. On the other hand, it should not be extended for too long where the impact of discounting will marginalize any future costs. Projects in the public sector select a long period of analysis of 50 to 100 years to reflect the anticipated total life-span of the asset (cradle to grave). Whereas clients of the private sector select a shorter time frame linked to the need for shorter-term investment returns. If the period of analysis is unclear, the client may need to consider its likely long-term interest in the project in terms of physical, economic, functional, technological and social "lives" (Langdon, 2007). If alternatives have different service lives, then the equivalent annual value is recommended as economic indicator (Sinha & Labi, 2007). Service lives of various types of infrastructure facilities last over long periods of times as shown in Table 1.

Table 1: Expected service lives of infrastructure facilities

INFRASTRUCTURE FACILITY	COMPONENT	SERVICE LIVES
Roadway Pavement	Pavement	10-50
	Sidewalks	25-50
	Signage	10-15
	Traffic lights	15-20
	Street lights	15-30
Bridges	Decks	30-50
	Substructure	50-100
	Superstructure	40-75
Marinas	Piers	40-60
	Seawalls	40-60
	Boat ramps	10-20
Airports	Runway/taxiways/Apron	15-50
	Building	50-75
	Parking	40-60
Rail	Track	75-100
	Stations	50-75
Intermodal Facilities		75-100
Tunnels		75-100
Hydraulics Dams		50-200
Electricity/Transmission/Telephone Lines		75-150
Public Buildings		40-60
Water Distribution System		30-50
Sewer lines		40-90
Storm Drains		30-100
Culverts		30-45

<u>Step 4:</u> Determine Rehabilitation Activities and their Timing

To establish the cash stream of each alternative under evaluation, the type of M&R activities that the facility will undergo must be decided upon. This procedure can be simple where previous practices, recorded histories of facilities, or expert opinion can be employed to build the life cycle plan of alternatives. This approach can simulate the actual performance of facilities in the absence of developed performance models.

When infrastructure management systems are set, these performance models can be utilized to predict the future performance of the facilities, which can establish the M&R activity type and its timing according to agency's policy and benchmark.

Step 5: Determine Costs in LCCA

The costs in the LCCA can be borne by the agency, user of the facility or society as a whole.

A. Agency Costs

Agency costs are the charges that are assumed by the agency as a result of putting the facility in service at the outset and keeping it functioning efficiently or above the minimum acceptable level of serviceability. These are divided into capital costs, annual operating costs, annual maintenance and repair costs, non-annual replacement, upgrade or rehabilitation costs, and salvage value.

Capital Costs: The first component in an LCCA equation is capital costs. Capital costs or initial expenses generally representing the costs of initial design and construction.

Annual Operating Costs: The operation costs are annual costs, excluding maintenance and repair costs, involved in the operation of the infrastructure or facility. Most of these costs are related to energy, supplies, utilities, and labor.

Annual Maintenance and Repairs Costs: Maintenance costs are scheduled costs associated with the upkeep of the infrastructure or facility. Repair costs are unanticipated expenditures that are required to prolong the life of the facility.

Non-Annual Replacement, Upgrade, or Rehabilitation Costs: Rehabilitation costs are anticipated expenditures to major components of the infrastructure that are required to maintain the operation of the infrastructure or facility.

Salvage Value: The expected value of the facility at the end of the analysis period.

All these costs—except the salvage value—can be estimated from recent bids and historic records provided that inflation is accounted for. Most infrastructure agencies keep detailed records of such data and generally acquiring them is a straightforward matter. Engineering judgment can help in estimating such costs when new technology or materials are used in the project.

The salvage value is another cost component that is considered every so often as part of the agency costs. The salvage value is the value of the project at the end of the analysis period or represents what is the project worth. There is no general consent on how to estimate the salvage value, mostly because infrastructure projects are never terminated at the end of the analysis period. One approach for estimating this component is to account for the costs of demolition, removal and add/subtract the value of the recycled project waste. Another approach is to calculate the relative value of the remaining serviceability of the alternative with respect to the cost of the last rehabilitation activity. Each approach has its own drawbacks. One way to avoid such added dubious calculations is to adjust the analysis period slightly so that the serviceability is the same for all alternatives; that way the salvage value can be omitted from calculations.

B. User Costs

User costs in LCCA are the costs encountered by the project's users. These costs generally occur during the lifetime of the project. Some user costs could be tangible but the majority of them are intangibles. User costs are also estimated differently during the normal operation of the facility and during M&R activities. During normal operation, most user costs are expected to be equivalent for all alternatives in project-level secondary LCCA, which leads to the exclusion of this type of cost. On the other hand, user costs during rehabilitation activities can be substantial for different alternatives. Mainly, the difference arises from a disparity in the duration of rehabilitation activities (i.e., travel delay time during highway work zone operation of rehabilitation activities, downtime in power generation, downtime in water distribution). This type of cost surfaced with introducing it in the FHWA Probabilistic LCCA program, which incorporates a sub-module for calculating the user costs during work-zone operation.

C. Social Costs

Social costs, also named externalities, are the costs encountered by the society as a whole. These costs vary widely in nature. The most recognized—but rarely included in the analysis—are the costs of accidents (in transportation projects) and the costs of environmental impacts. The environmental impacts could affect the air, water, biodiversity, natural resources, noise and heritage. Among the listed impacts, only the costs of air pollution and noise have been monetized in infrastructure projects evaluation. Earlier research on LCCA attempted using these costs but the result of including these costs always overwhelmed the results. These trials have been almost abandoned and have replaced with conducting LCA (to account for the environmental impacts) in tandem with LCCA. Other

social costs could include comfort, barrier effects on non-users, social cohesion, equity, and integration. One main type of cost that has been noted to be the topic of extensive research is the cost of failure. This type has been mainly associated with LCCA in bridges and tunnels but there is no evidence that it is actually included in state-of-the-practice of LCCA at any level. Nevertheless, as in the cost of discomfort or reliability incurred by users, the inclusion of such costs depends mainly on proof that they vary among alternatives with different serviceability or performance. Table 2 lists the types of costs that were included in LCCA for different types of infrastructure.

Table 3 provides a brief recommendation for practitioners attempting to construct LCCA models for infrastructure facilities. The table relates the costs that can be included and which economic indicators to the objective behind conducting LCCA and the special conditions of the infrastructure project.

Table 2: Costs in LCCA for Different Types of Infrastructure Facilities

Infrastructure Type	**Agency Cost**				**User Cost**		**Externalities**		
	Capital Cost	Operating Cost	M&R Cost	Salvage Cost	During M&R	During Normal	Social Cost	Environ-mental Cost	Cost of Failure
Road Pavement	A	N	A	A	S	R	R	R	N
Bridges	A	R	A	A	S	N	R	LCA	S
Marinas	A	R	A	S	N	N	N	LCA	R
Airports	A	S	A	S	R	N	N	LCA	S
Rail	A	A	A	S	S	N	N	N	R
Intermodal Facilities	A	A	A	S	R	N	N	N	N
Tunnels	A	S	A	S	R	N	N	LCA	S
Electricity/ Transmission/ Telephone Lines	A	A	A	A	R	N	N	R	R
Public Buildings	A	A	A	S	R	N	N	N	N
Sewage Facilities	A	S	A	S	R	N	N	N	N
Storm Drains	A	S	A	A	R	N	N	N	N
Culverts	A	S	A	S	N	N	N	N	N
Water Networks	A	A	A	A	S	N	N	N	N
Hydraulics Dams	A	A	A	S	R	N	N	N	S
Power Plants	A	A	A	A	R	N	N	LCA	R
Solid waste Facilities	A	A	A	A	N	N	N	LCA	N

A= Always used, S=Sometimes used, R=Rarely used, N=Not recorded used, LCA=through LCA

Table 3: LCCA Objectives vs. Costs and Economic Indicators

LCCA OBJECTIVE	**Provision across alternatives**		**Cost to Include**			**ECONOMIC INDICATOR**
	Benefits	User Costs & Externalities	Agency Cost	User Cost	Externalities Cost	
1: Choosing between alternatives for constructing the facility at the planning stage or during operation	Similar	Different	X	X	X	NPV of costs separately
	Similar	Similar	X			Lowest NPV of costs
	Different, Monetized	Different	X	X	X	Higher B/C ratio
	Different & not monetized	Similar	X			Lowest C/E Cost effectiveness analysis
2: Bid evaluation criteria	Similar		X			Lowest NPV; Part of multi-criteria
3: Predicting future performance of facilit(ies)			X			Cash flow stream
4: Future budget planning			X			Cash flow stream
5: Optimizing M&R activities type and timing at the project level		Different	X	X	X	Depends on objective function
6: Prioritizing M&R activities at the network level			X			Depends on objective function

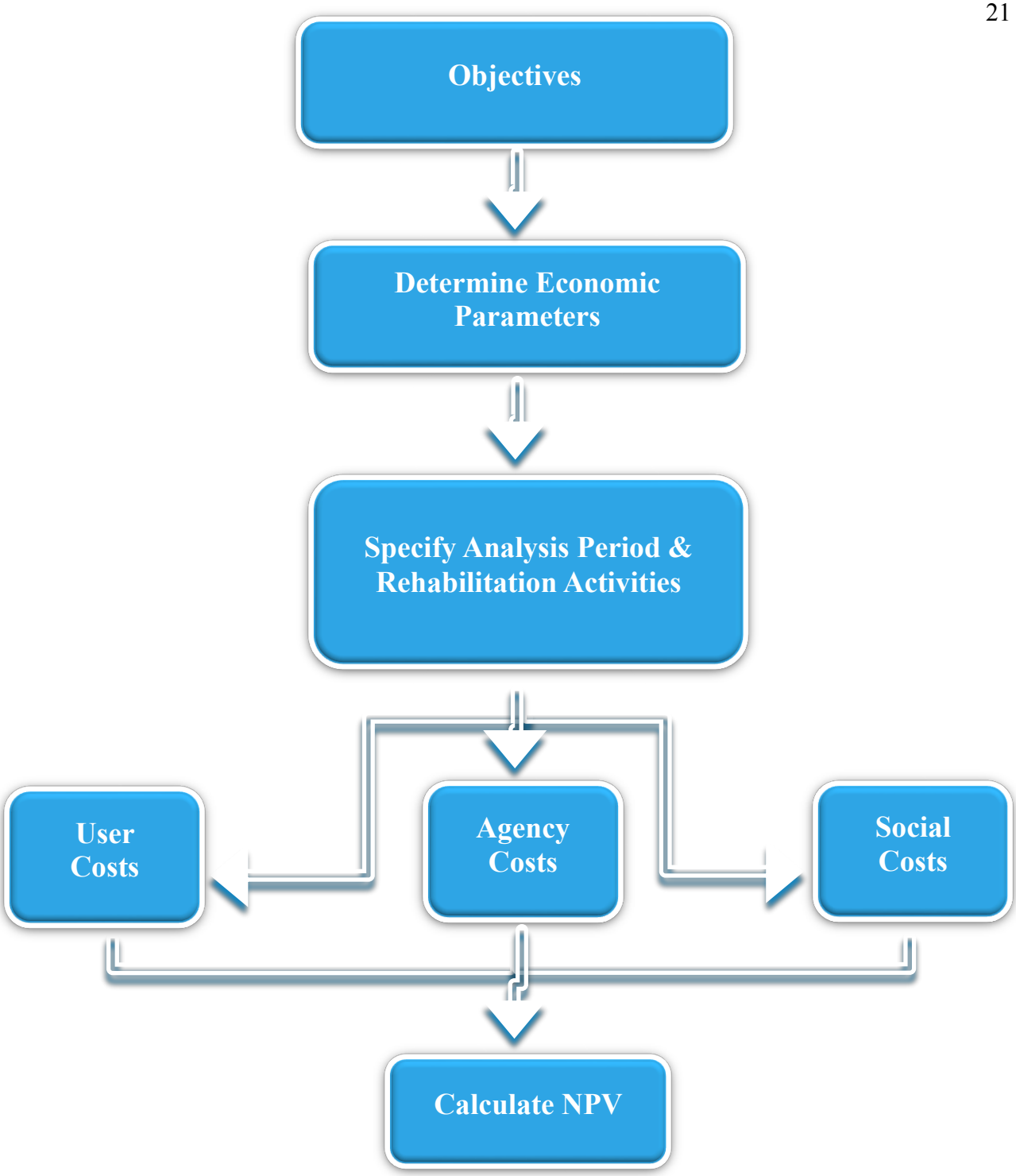


Figure 3: LCCA Framework

5. Public Procurement Practices in Lebanon

5.1 Role of Public Procurement in Economic Growth in Lebanon

The Organization for Economic Cooperation and Development (OECD) describes procurement as "*the process of (1) identifying what is needed; (2) determining who is the best person or organization to supply this need; and (3) ensuring what is needed is delivered to the right place, at the right time, for the best price and that all this is done in a fair and open manner".*

The procurement system is the main driver for economic growth and development to Government because it creates market competition and identical treatment among economic players.

On average public procurement accounts for 13% of the Lebanese budget and represents around 4% of Lebanon's Gross Domestic Product (GDP). The government, being the largest investor, procurement behavior in Lebanon has a direct impact on private sector competitiveness and innovation (IoF , 2013). In addition, this system allows efficiency and VFM in the governments' purchases and boosts citizen participation into public life. Thus, the key to improve the strategic and operational functions of Governments is public procurement.

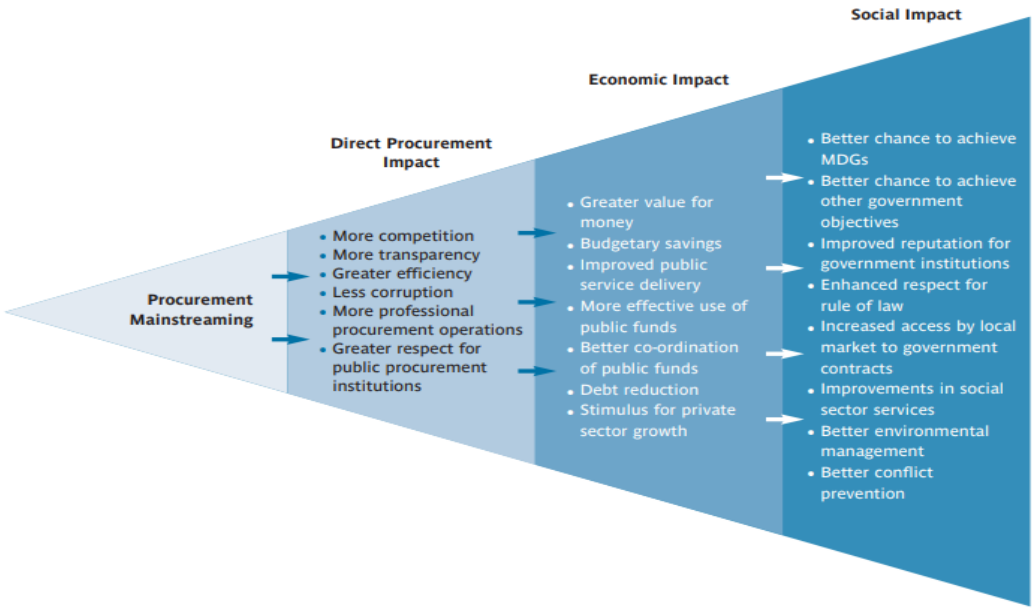


Figure 4: The torchlight: Impact of public procurement on economic and social development **(IoF , 2013)**

Figure 4 illustrates the direct impact of public procurement on economic and social development and links it to the better achievement of the Millennium Development Goals (MDGs).

5.2 Procurement Law in Lebanon and its Development

Lebanon faces a structural financial deficit and a high debt/GDP ratio. For a more evidence-based analysis to guide the public procurement improvement, accurate and comprehensive information about the size of public procurement is required. This also improves the quality of government services, provides greater value for taxpayers' money and improves citizens' well-being.

National consultants' studies showed that the state of procurement laws and regulations countries vary for country to country at the level of policies as shown in table 4.

Comparing to other Arab countries, Lebanese laws and regulations are outdated or under study for amendments, whereas all other countries have clear texts. Lebanon and Yemen have more than 75% of their procurement projects subject to competitive bidding but they are the only countries in the region that do not specify exceptions for competitive bidding.

Open competitive bidding ("Public Tender") is the most procurement method used by default but some cases require other methods as displayed in table 5. In addition, by studying Lebanon's market structure per type of contracts, table 6 shows that the CDR, Ministry of Public Works and the Tender Board have the highest average value and number of contracts.

Table 4: Procurement legislation in Arab World Countries **(UNDP, 2004)**

Country	**Transparency/ Accessibility of Laws and Regulations**	**Exceptions to Competitive Bidding Explained**	**Estimated % of Procurement Subject to Competitive Bidding**	**Typical Duration of Procurement**
Jordan	Transparent and accessible and rules are simple	Yes	Unavailable	30 days
Lebanon	Old and needs amendments(under study): some hinders work	No (Need change)	About 75% of all large procurements	Minimum 30 days
Morocco	Texts are precise but loopholes exist: noticeable progress in the Decree on Public Procurement since 1998	Yes (Follow World Bank and UNCITRAL guidelines)	66% in 2001	21 days for competitive bidding, 15 for acceptance, 20 for submission of bids
Sudan	Included in Financial and Accounting Act of 1977 and Regulations of 1978	Yes (Limited direct "non-competitive" purchasing specified in the regulations)	Currently trying to establish the proportion	Regulations specify the process should not exceed 14 days
Tunisia	Decree on public procurement of 2002, modified in 2003	Yes (Specifies the use of sole source contracts)	About 90% of large procurements	60 days (may be longer for important bids)

Yemen	Transparency exists in texts but not followed	No	About 90%	30 days

Table 5: Procurement Methods for specific cases **(IoF , 2013)**

Procurement Methods		Requirements
1	Restricted Tender	Bidding opportunity is limited to a specific list of bidders
2	"Request for Offers" or "Request for Proposals" or "Invitation to Bids":	A list of bidders is set by the contracting authority. This method is usually limited to a maximum of LBP 100.000.000.
3	"Contracting by Mutual Consent or Direct Contracting" or the use of negotiated agreements	Require the approval of the Council of Ministers (Method used for the procurement of Goods and Works).
4	"Shopping" or "Invoice Purchasing" or "Single sourcing"	For a value less than LBP 3.000.000.

Table 6: Lebanon's market structure for public procurement contracts per type of contracts **(IoF , 2013)**

Average value of contracts / Number of contracts	HIGH	LOW
HIGH	CDR Ministry of Public Works Tender Board	Tender Board Line Ministries
LOW	State Owned Enterprises (e.g. EDL)	Municipalities Public hospitals Small Ministries

When it comes to results, the criterion for choosing the winning bid is most often limited to the lowest price. According to a survey done by the IoF, 64% of respondents stated that they rely on the lowest price as the only criterion of selection is preventing them from controlling the quality of the procured goods. For these reasons, better criteria need to be adopted such that best VFM and LCC.

Lebanon has an outdated and shattered public procurement system. It suffers from a disordered legal framework and overlapping institutional mandates, with considerable capacity gaps, resulting in inefficiencies and high risks of corruption. The quality of the procurement system is below average as compared to the rest of the world and some MENA countries (MoF , 2019).

The Lebanese Government suffers from the absence of public procurement law and weaknesses in the area of procurement regulated by an outdated an unclear legal framework. The laws dating from 1959 and 1963 are obsolete and do not accommodate for new procurement trends like electronic procurement (E-procurement), sustainable public procurement or life cycle costing. The set of regulations found in various Lebanese laws include (IoF , 2014):

- The Public Accounting Law (Decree 14969 of December 30, 1963) constitutes the foundation of Lebanon's organizational and institutional framework for public procurement.

Other laws and decrees control the phases of the public procurement cycle, such as:

- The General Terms of Reference for Public Works Contractors (Decree of May 20, 1942)
- The Regulations of the Central Inspection Board (Decree 2460 of November 9, 1959)
- The Bidding System (Decree 2866 of December 16, 1959)
- The Administrative Terms of Reference for Army Works (Decree 11573 of December 30, 1963)
- The publication of the Annual Procurement Plan (Decree 13221 of June 28, 1963)
- The Prequalification of Contractors (Decree 3688 of January 25, 1966)
- The Disbarment from Participating in Public Bids (Decree 8117 of August 29, 1967)

- The Administrative Terms of Reference for Army Supplies (Decree 11574 of December 30, 1968)
- The Terms for Acceptance of Completed Public Works with Some Minor Flaws or Defects (Decree 14601 of May 30, 1970)
- The State Consultative Council (Decree 10434 of June 14, 1975)
- The Administrative Terms of Reference for Internal Security Forces Supplies (Decree 2868 of April 16, 1980).
- The Legislative Decree on the organization of the Court of Audit (Decree 82 of September 16, 1983)
- The Classification of Contractors and Consultants (Decree 9333 of December 26, 2002)
- The Identification of National Goods Benefiting from Preference in Public Tenders (Decree 10515 of July 23, 2003)

The fragmentation of the legislative framework has created holes that have allowed the public institutions to develop and follow their own set of procurement rules. Also, the public institutions and municipalities are given the choice to select between other options than public bidding such as Shopping or Invoice Purchasing or Direct Contracting. (IoF , 2014).

Based on an assessment done on procurement practices in Lebanon, the government decided to upgrade the system. In year 2009, the draft for Standard Bidding Documents (SBD) was prepared. Following that in 2012, the Council of Ministers approved the new Public Procurement Law and certified training in Public procurement in the Arabic language was delivered to public sector employees.

Public procurement improvement is the key to stop corruption as 57% of bribery cases detected worldwide are procurement related transactions. In Lebanon, corruption and the

inadequate supply of infrastructure are among the top problematic factors of doing business. The country ranks 105/137 on competitiveness, and 142/190 on doing business (MoF , 2019).

In June 2018, with the government being eager to make changes in the procurement sector, the Minister of Finance, Mr. Ali Hassan Khalil, committed to revise the procurement system to include modernization and reforms.

In January 2019, this commitment was reiterated in Article 4, titled "Structural Reforms" of the Ministerial Declaration of the Lebanese Government. It mentioned "the modernization of the public procurement legal framework and the preparation of SBDs to enhance transparency in public procurement" (MoF , 2019). Subsequently, the IoF was instructed (decision 109/1, dated March 4th, 2019) to:

1- Draft a new public procurement draft law based on eight guiding principles (Integration, Transparency, Competitiveness, Efficiency, Accountability, Integrity, Professionalism, Sustainability and Local Development)
2- Review and upgrade the five SBDs and draft a decree to make their use mandatory.
3- Implement the assessment tool "Methodology for Assessing Procurement Systems" MAPS II.

5.3 Procurement Key Players in Lebanon

The three key players in public procurement in Lebanon are CDR established in 1977, IoF founded in 1996 and HCP initiated in 2000.

CDR being responsible for most of the investment expenditures has been in charge of the large infrastructure and reconstruction projects and manages particularly the procurement components of a large share of international aid projects to Lebanon.

IoF was founded in 1996 in cooperation with the Government of France and renamed Institut des Finances Basil Fuleihan, in 2006. IoF has proven to be a sustainable source of high quality and specialized training, human resource management, communication, and documentation services and has contributed to the development of national capacities in Public Financial Management and Customs.

The HCP is in charge of preparing and tendering PPP projects. As a matter of fact, the long-awaited PPP law in 2017 provided the tendering process for PPP projects with transparency and professionalism by mandating the HCP as the country's PPP unit.

5.3.1 Council for Development and Reconstruction

At the end of 1976 and after the huge destruction of public institutions and infrastructures, the government decided to create a new public establishment to carry the vast task of the reconstruction of Lebanon. The CDR was established through Decree No. 5 dated 31st January 1977. (CDR, 2008)

The main tasks of the CDR were:

1- Planning: Organizing a plan and a time schedule for the commencement of reconstruction development

2- Funding: Guaranteeing the funding of projects

3- Implementing: Supervising the execution and utilization of these projects

Today, the CDR administration consists of three levels as shown in figure 5.

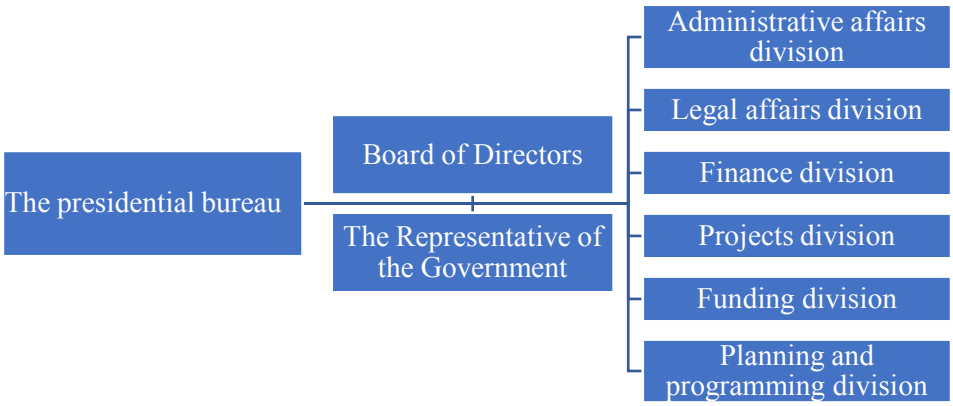


Figure 5: CDR Administration **(CDR, 2008)**

5.3.2 Institut des Finances Basil Fuleihan

The IoF is a civil service-learning center specialized in Public Financial Management (PFM): Audit & Control, Public Accounting, and Public Procurement. Diligent PFM practices and performing public service delivery are prerequisites of good governance.

IoF operates with local, regional and international experts, and offer the public sector including the Ministry of Finance a wide range of learning solutions personalized to their needs. They also include classical structured training programs and e-learning. In addition, they accompany public institutions throughout the learning cycle from needs assessment to impact measurement. (IoF, Learning , 2018)

In 2013, the Institute with the Chartered Institute of Procurement & Supply (CIPS) developed three levels of certified training as follows:

- Level 1: For all civil servants – Introductory/ Operational Level
- Level 2: For decision makers - Strategic Level
- Level 3: For Ministers and deputies - Think-tank

When it comes to the private sector, in 2015 the World Bank (WB) financed the development of workshops for Small and Medium enterprises to encourage them to enter

public procurement. Studies have shown that the national economies consist of 90% of Small and Medium enterprises. After these workshops, IoF published educational tools & guidelines for Small and Medium enterprises. This experience was presented during the SME's forum organized by the Ministry of Economy and Trade.

5.3.3 Higher Council for Privatization and PPP

To deal with the high fiscal deficit (10% of GDP) and high level of public debt (150% of GDP) in Lebanon, the Parliament passed the long-awaited PPP law in 2017. Thus, the government embarked on an ambitious Capital Investment Program (CIP) that was revealed at the CEDRE conference in Paris on April 6, 2018 (HCP, 2018).

In 2000, the HCP was established to plan and implement privatization programs and in 2017, PPP Law 48 assigned HCP as Lebanon's PPP unit. This law intends at reorganizing the PPP tendering process to allow more competition, to enhance its transparency and professionalism and avoid corruption. The board and committees responsible for the whole process are defined in table 7.

Table 7: Board and committees' organization **(HCP, 2018)**

HCP "BOARD "	Chair: President of the Council of Ministers Minister of Justice Minister of Finance Minister of Economy and Trade Minister of Labor Minister in charge of the sector under discussion
Secretariat General's team	Economic experts Financial experts Legal experts Media coordinators

	Research, administrative and IT assistants
Project Committee	Chair: Secretary General of the Council Representative of the Concerned Ministry Representative of the Ministry of Finance
Steering Committee	Chair: Representative of the Public Entity Representatives of the Concerned Ministry Council's Secretariat General Ministry of Finance Regulatory authority of the sector

6. Public Private Partnership

6.1 Definition

The huge and developing gap between infrastructure needs and the resources public sector have invested in meeting those needs is evident in different types of infrastructure like crowded roads, deteriorated bridges, hospitals and water facilities, and poor transit systems that are all in crucial need of rehabilitation and repair.

To solve these problems, PPP a long relationship between the public and the private sectors is a new global trend, accelerating and encompassing a wide range of infrastructure sectors. About 20% of infrastructure in British Columbia and Canada are developed following a PPP model (Deloitte , 2006).

PPP offers the possibility to access new financing sources and transfer certain project risks. PPP have become a preferred procurement method for public agencies and is being pursued by them because it allows them to access private capital, speed up project delivery, transfer risks to the private sector and it provides better essential public services (FHWA, 2012) (Liu, Davis, Love, Smith, & Regan, 2014).

PPP differs from traditional procurement where the public sector controls all phases of the infrastructure development process. With a PPP contract, a single private entity - or a consortium of several private companies - undertakes responsibility for more than one development phase, accepting risks and seeking rewards (FHWA, 2012). The definition of PPP under different laws will be elaborated below.

6.1.1 International Practice

In international practice, there is various definitions of PPP contracts from which common features are derived.

a. French law

In accordance with article 67 of French ordinance dated July 23, 2015, a partnership contract is described as a public contract which assigns an economic operator who participates through all or part of the design of works, development, construction, transformation, renovation, dismantling or destruction of works, equipment or immaterial goods necessary for the public service. They also must participate in all or part of financing (Vaissier, Le Bars, & Houriez, 2018).

b. World Bank's Reference Guide

According to the 3rd edition of the reference guide released by the WB in 2017, PPP is defined as "a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance." (The World Bank, 2017).

As stated by the WB, PPPs are defined in terms of:

- The type of asset involved

- The risk borne by and the role tasked to the private party
- The payment mechanism

c. European Bank for Reconstruction and Development (EBRD)

According to EBRD, PPP project is defined as a long-term contractual relationship between a State or a State-Owned entity and a private sector entity. The private sector must deliver and fund public services using a capital asset, sharing the associated risks with the private sector (EBRD, 2019).

As stated by EBRD, PPPs are defined in terms of:

- The services delivered or assets used
- Risks shared
- Funding made

d. European Investment Bank

PPP is defined as "the relationships formed between private sector and public bodies often with the aim of introducing private sector resources and/or expertise in order to provide and deliver public sector assets and services." PPPs are used in several countries to either build or upgrade existing public infrastructures (Liu, Davis, Love, Smith, & Regan, 2014).

6.1.2 Lebanese Law: PPP Law 48

In Lebanon, procurement of PPP contracts is governed by Law No. 48 dated as of September 7, 2017. Yet, there is no clear indication of the criteria based on which a contract qualifies as a PPP under Lebanese laws.

A "partnership project" is defined as any project of public interest in which the private sector participates through financing, management and at least one of the following:

design, erection, building, development, refurbishment, equipment, maintenance, rehabilitation and/ or operation.

Since the PPP law in Lebanon was initiated recently, limited projects are available to assist with the determination of major criteria for qualifying a project as a PPP project. But according to the international practice and laws, the following criteria were found to qualify a contract as PPP project: A global mission, a private financing, a risk allocation, and a relatively long duration.

According to the PPP law 48, the tendering process in Lebanon undergo the following procedures:

Step 1: Project Proposal and Approval

PPP project is defined in PPP law 48 as "Any public benefit project in which the private sector contributes financing and management and at least one of the following activities: design, installation, construction, development, restoration, equipment, maintenance, rehabilitation, and operation." (HCP, 2018)

For a PPP project process, a relevant public entity/ministry prepares a proposal including a pre-feasibility study and sends it to the Secretariat General of the HCP.

After examining the complete file, the HCP Secretariat General will submit its recommendations to the HCP Board. Subsequent to the HCP Board's approval to go on with the project, the HCP Board will form a project Steering Committee to review and follow up on the concerned project. The project Steering Committee then prepares a full feasibility study including the technical, economical, legal and financial aspects of the PPP

project, with the pre-qualification criteria, assessment of investors' interest and likelihood of attracting the required financing. Then, the report is hand over to the HCP board again.

The HCP board inspects the updated project file for the last time and decides whether to reject or to continue with the project; if accepted, the President of the Council of Ministers forwards the project to the Council of Ministers for its approval. And finally, when approved by the Council of Ministers, the HCP Secretariat General launches the process of selecting a private partner (HCP, 2018).

Step 2: Prequalification process

To select the Private Partner, a public invitation is published in the press, in specialized magazines and on the Council's website to interested parties in being candidates for the award of the PPP Project. This invitation shall include the prequalification criteria corresponding to the size and nature of the Project.

The Steering Committee reviews and evaluates the submitted pre-qualification applications and their supporting documents based on the published criteria. The Steering Committee announces the prequalification results that must consist of no less than three candidates (HCP, 2018).

Step 3: Launching of tendering process

At that point, the draft tender document is prepared and must include:

- The evaluation criteria specific to the PPP Project
- The procedures for bid submission

- The financial, technical and administrative elements of the project
- The procedures for inquiries, objections, and their settlement
- The draft Partnership Agreement and its annexes

Based on consultations results with the prequalified candidates, the Steering Committee finalizes the tender document and submits it to HCP Board. If approved, the Prime Minister submits the package to the Council of Ministers for final authorization.

Step 4: Bidding and selection of winning bidder

After approval of the PPP Tender documents from the Council of Ministers, the bidding process is launched. The HCP Secretarial General then evaluates the bids and prepares its evaluation report with its recommendation of the preferred bidder to the HCP Board. The winning bidder is the bidder who submitted the best proposal as per the evaluation of the Steering Committee based on the evaluation criteria specified in the tender document and the remaining bidders shall be notified about the reason of their failure.

The HCP Board can request the Steering Committee to negotiate with the winning bidder to improve some technical aspects. After that, the HCP Board approves the evaluation results indicating the winning bidder, then the relevant public entity signs PPP contract (HCP, 2018).

6.2 PPP Models

The most frequent PPP models used for new projects and existing ones are described below:

Figure 6: PPP Models for new projects and existing services and facilities **(Deloitte , 2006)**

- **Design-Build (DB) or Build Transfer (BT):** The private sector designs and builds the facility following the public sector requirements and performance specifications. The public sector which retains ownership, finances the project and takes responsibility for its operation and maintenance. This is usually done for a fixed price, which leads to transferring the risk to the private sector.
- **Design-Build-Maintain (DBM):** In addition to the requirement of a DB model, the private sector also maintains the facility keeping the responsibility of operation to the public sector.
- **Design-Build-Operate (DBO) or Build-Transfer-Operate (BTO):** The private sector designs and builds the facility in accordance with the public sector requirements and performance specifications. The private sector also operates the facility for a specified time keeping the title of the facility to the public sector.
- **Design-Build-Operate-Maintain (DBOM) or Build-Operate-Transfer (BOT):** In this model, the responsibilities of design-build type with the operations and maintenance of a facility is combined for a specified period by the private sector. At the end of the contract, the public sector retakes the responsibility of its operation.

- **Build-Own-Operate-Transfer (BOOT):** The private sector builds, owns and operates a facility for a limited period. At the end of that period, the ownership is transferred back to the public sector.
- **Build-Own-Operate (BOO):** the private sector accords the right of financing, building, owning, and operating the facility to the private sector. The private sector has control over all profits and losses generated by this facility and retains its ownership.
- **Design-Build-Finance-Operate/Maintain (DBFO, DBFM or DBFO/M):** The private sector provides the design, builds, finances, maintains and operates the facility. At the end of the contract, the facility is transferred back to the public sector that retakes responsibility for its maintenance and operation.
- **Service Contract:** The public sector enters into an agreement with the private sector that takes over a defined period the responsibility of providing services the government was performing.
- **Management Contract:** A contract is made between the public and the private sector where the latter is only responsible for the operation and maintenance of the facility under contract.
- **Lease:** The government leases an infrastructure asset from the private sector. The private sector might also operate and maintain the infrastructure asset.
- **Concession:** The private sector has an agreement with the government giving him the right to operate and maintain an infrastructure over a limited time period following the specification set forth by the government and under certain conditions.

- **Divestiture:** the public sector transfers partially or fully an infrastructure to the private sector. This contract will consist of clear conditions to ensure that people will continue to be served and improvements are always made.

6.3 PPP Risks

When working with a PPP contract, concerns about cost, schedule overruns, asset performance, maintenance, and operation are transferred from public owners to the private sector. In order to allocate and share some risks under any PPP model, three principles keys need to be highlighted to determine risk allocation between the public and private sector (ACEC, 2009):

1) Risk must be assigned to the sector who is best able to manage it
2) Risk matrix and qualitative/ quantitative analysis are required for both sectors in considering proper risk distribution
3) The party considering taking on a risk must be capable of identifying, quantifying, mitigating, managing and be compensated for it.

Figure 6 shows the level of responsibility and risk the public sector and private sector undertake depending on the PPP model used.

To determine the optimal risk allocation, an agency compares the public sector's ability to manage each risk to the ability of a potential private partner to do the same. Risks that are managed more efficiently by the private sector are transferred; whereas risks that the public sector can manage are retained. If a risk is difficult to manage, it should be shared between both sectors (FHWA, 2012). The risk assumed by the private sector can belong to the following categories:

Figure 7: PPP Risk Categories **(KPMG , 2017)**

For each PPP project, a risk register is prepared for all risk elements and the components of the risk register are shown in table 8.

Table 8: Risk Register **(FHWA, 2012)**

Risk Category	Type of risk (Figure 7)
Risk Topic	Identifying the specific risk
Risk Description	Summary of the potential loss if the risk event occurs
Risk Probability	Possibility of a risk occurring (high, moderate, low)
Potential Consequence	Impact of the risk
Allocation of Risk	1- Transferrable risks: risks fully transferrable to the private sector. 2- Retained risks: risks for which the public sector bears the costs. 3- Shared risks: risks that are shared based on a combination of the above two allocations due to the nature of the risk (earthquake risk)
Treatment Options	Risk mitigation
Risk Valuation	1- Qualitative priority ranking 2- Quantitative risk analysis: a- Formula-based analysis: calculate average risk impact b- Monte Carlo simulation

Some of the benefits offered by PPP projects are (Liu, Davis, Love, Smith, & Regan, 2014) (KPMG , 2017):

- Distribution of the design and construction responsibility to the private sector
- Reduces costs and improvement of management over a project's life-cycle
- Reducing governmental risks by transferring them to the private sector, thus maximizing the use of each parties' strengths
- Enhanced service quality and innovation by using private sector expertise and performance incentives
- Increase in accountability and transparency
- Reduce corruption
- Provides more sources of financing
- Encourage competition and infrastructure development
- Improve delivery mechanism

6.4 PPP History in Lebanon

Before the PPP Law 48 was enacted in September 2017, although the country remained without a legal PPP framework for a long time, the concept of PPP is certainly not new in Lebanon and the history of utilizing PPPs is shown in table 9.

Table 9: History of PPP Projects **(Daouk, Hayeck, Hajjar, & Takieddine, 2017)**

Beirut-Damascus road (Concession, 1958)	The first successful PPP concessions in the history of the Middle East.
Beirut Port (Concession, 1960)	A Lebanese company called "Compagnie de Gestion et d'Exploitation du Port de Beyrouth" was given the 30-year concession to expand and develop the port.
Electricity of Zahle (Concession, 1960s)	In the 1920s: Electricité de Zahlé (EDZ) was founded and started operating under a concession agreement with the Lebanese government. In the 1960s: a decree was issued by the government and EDL, turning EDZ into an electrical distribution utility that develops, operates and maintains the electric power networks in Zahle and 15 neighboring regions.
Libancell and FTML (BOT, 1994)	LibanCell and FTML built one of the two GSM networks in the country and served 400,000 mobile subscribers.
Solidere (1994)	Following the Lebanese civil war, Solidere was granted ownership of 291,800 m^2 of development land in Beirut Central District (BCD).
LibanPost (BOT, 1998)	Through a BOT agreement with Canada Post and SNC Lavalin, LibanPost is now a private multi-service operator.
Tripoli Water Authority (Management Contract, 2002)	A 4-year management contract was awarded to Ondea (French organization) by the Ministry of Energy and Water (MEW) and the CDR for the Tripoli Water Authority at a cost of 8.9 million euros, financed by the French Development Agency.
Beirut International Airport (Concession, 2000)	Several concessions were done in 2000 to expand Beirut International Airport, including the car park and the aircraft refueling facilities.
Beirut Duty-Free (Concession, 2003)	A 15-year concession was granted by the Government to Phoenicia- Aer Rianta Company (PAC). In April 2017, the contract was awarded again to PAC for four years.
Mecanique (BOT, 2003)	FAL a Saudi Company was awarded a 10-year BOT contract consisting of financing, building and operating a vehicle inspection facility. In 2012, the contract was extended on a 6-monthly basis.
Mobile Operators (Management Contract, 2004)	A 4-year renewable Management contract was awarded for Lebanon's mobile operators, Touch and Alfa.

Power-Generating ships (Lease, 2012)	Karpowership was awarded a contract by the Lebanese Electricity Utility (EDL) to provide two Powerships totaling 270 MW of base load generation capacity. In 2016, EDL augmented the contract capacity to receive over 370 MW for two years.
Mecanique (BOT, 2016)	The contract was awarded to Autospect/SGS/Securitest/Autosécurité for 10 years consisting of updating the 47 centers for vehicle inspection and building, operating and maintaining10 new centers.
Jeita Grotto (BOT, 1994)	The contract was awarded for 21 years (renewable for four years "twice") to MAPAS to restore, expand, and operate the Jeita touristic complex. The revenue-sharing arrangement includes 35% for the Ministry's and 10% - 15% for the municipality.
Solid waste treatment plant in Saida (BOT, 2002)	The municipality of Saida signed a contract with IBC for a 20-year period.
Beirut Port container terminal (Management Contract, 2004)	The contract was awarded to Beirut Container Terminal Consortium (BCTC) for a period of 10 years. The management contract is based on a per container fee paid to the operator with a guarantee of handling 500,000 containers annually. The contract was renewed in 2014 for an additional 5 years. The new tender will be launched in 2020.
Gulftainer (Concession, 2013)	Gulftainer was awarded a 25-year concession to develop and operate a new container terminal at the Port of Tripoli in Northern Lebanon.

6.5 Current PPP Projects

In light of the enactment of the PPP Law in September 2017, potential PPP projects were presented by the high council and privatization and PPP. The main current projects are:

1- **The Expansion of Beirut Rafik Hariri International Airport** (HCP , 2018)

This project was proposed by the Minister of Public Works and Transportation and was approved as a PPP project in February 2018.

The project consists of:

- Development of a new terminal for 6,000,000 passengers
- Improvement and rehabilitation of the existing airport infrastructure
- Improvement of access roads.
- Development of non-aeronautical revenues for the financial sustainability of the project

The advisory team consists of a lead transaction advisor, a technical advisor, and legal advisors. The Steering Committee includes the HCP Secretary General, the representative of Minister of Works and Transportation and representative of Minister of Finance.

The next steps to be taken stated in HCP Report #2 from December 2018 state that the lead transaction advisor and consultants are now working on include:

- Preparing the first draft of the due diligence report for review by the Project Working Group and the Project Steering Committee
- Finalizing data collection
- Revising due diligence report according to the feedback of the Project Working Group and Steering Committee.

2- **The Khaldeh – Nahr Ibrahim Expressway** (HCP, 2018)

This project was proposed by the Minister of Public Works and Transportation and was approved as a PPP project in February 2018.

The project consists of:

- 38 km total length expressway divided into a tunnel section of 12 km and a dual 3-4 lane expressway of total length 20km, interchanges, service roads, and bridges

- The government might split the project into different standalone sections for ease of implementation and for securing the funds.

HCP signed with EBRD an agreement for the provision of consultancy services to the project. EBRD will then choose through a bidding process one financial, technical and legal consultant to deliver the necessary consultancy services to the Project.

The Steering Committee includes the HCP Secretary General, the representative of Minister of Works and Transportation and representative of Minister of Finance.

3- **Lebanon Cloud Data Center** (HCP, 2018)

This project was proposed by the Minister of Telecommunications and was approved as a PPP project in February 2018.

The project consists of:

- Promoting the ICT sector
- Improving business continuity and disaster recovery capabilities
- Encouraging foreign businesses to invest
- Creating employment
- Accelerating the overall economic development in Lebanon.

The advisory team consists of a lead transaction advisor, a technical and commercial advisor, and legal advisors. The Steering Committee includes the HCP Secretary General, the representative of Minister of Telecommunications, Chairman of Ogero and representative of Minister of Finance.

6. Current State of the Practice of LCCA in procurement

As planned in the thesis proposal and in order to focus on the current state of the practice of implementing LCCA in Lebanon and the present-day methods of procurement in the public sector in Lebanon, one-on-one interviews were conducted with key public sector personnel.

7.1 CDR perspective

There is different procurement method used all over the world such that open competitive bidding ("Public Tendering"), "Restricted Tender", "Request for Offers" or "Request for Proposals" or "Invitation to Bids", "Contracting by Mutual Consent or Direct Contracting", "Shopping" or "Invoice Purchasing" or "Single sourcing". In Lebanon, the most procurement method used is the open competitive bidding or "Public Tendering".

After choosing the procurement method, the type of contract is selected. CDR contracts follow FIDIC/ Red Book for detailed engineering whereas Inter-American Development Bank (IDB) and WB have their harmonized version for multilateral development banks. In general, all projects including contractors' projects are always evaluated and awarded according to the lowest price but for consultant's projects, they are awarded according to the Quality and Cost Based Selection (QCBS) method that takes into account the quality of the proposal and the cost. The weight distribution in QCBS varies from project to project; it could be 70% - 30% or 80% - 20% for the financial-technical distribution.

The consideration of the LCCA for the evaluation techniques in the CDR is limited so far, and in order to implement the LCCA with procurement in Lebanon a new strategy needs to be adopted. Only Waste Water Treatment Plants and Power Plants projects in the CDR

include the evaluation of chemical, electrical and operation, and maintenance costs. In fact, for Waste Water Treatment Plants CDR provides only the schematic plan and bidders have to do the detailed design and study the Chemical and Electricity consumptions for a period of 25 years. This part is added to the construction, supply and installation cost. Once the plant is operational for two years, the maintenance and operation costs should cover the evaluation proposed or else a penalty will be charged on the operator.

Whereas for Power plant projects, bids are awarded based on the lowest Levelized cost of energy that accounts for the construction, operation, maintenance, and fuel cost. After the operational stage, an efficiency test is conducted to check if what is declared in the offer is what is consumed. For any operational gaps, the operator incurs penalty charges (Haddad, 2018).

7.2 IoF perspective

IoF has invested significantly in fostering updated procurement practices at the national level since public procurement is a central component of budget execution. In addition, IoF maintains good communication networks with the WB MENA System of Public Procurement Experts and has joined the Francophone Sustainable Public Procurement Network.

In 2008, the Ministry of Finance with the aid of the WB gathered a National Procurement Manual based on the existing legal framework, and created a set of five SBDs demonstrating best practices and balanced conditions of contracting. The SBDs addressed the procurement of goods, works, and services in the public sector. Three documents addressed large contracts, two of which dealt with smaller contracts.

Practitioners at various ministries and public institutions revised those SBDs before they were distributed across the public sector during awareness-raising and benchmarking workshops carried out by the IoF. The use of these SBDs is not mandatory.

The legislative framework of public procurement in Lebanon is characterized by the absence of public procurement law and modern procurement procedures. In general, the Public Accounting Law of 1963 is followed; although this law is obsolete as it does not account for modern trends, it is a flexible law. There are no detailed award criteria mentioned in the SBDs which are specific to the procurement project itself. The simplest and most used approach used in Lebanon is the prerequisite with the lowest bid (Rizkallah, 2018).

7.3 HCP Perspective

With the new PPP Law No. 48 dated from September 7, 2017, LCCA will be incorporated in the procurement decision. For this, the current situation of infrastructures in Lebanon was discussed, solutions for improvement with PPP law were also examined and the results are summarized below.

7.3.1 Current situation of infrastructures in Lebanon

In general, the need for PPP is to build the infrastructure, operate and maintain it throughout its life cycle. PPP is being used for more than 20 years in developed countries. In Lebanon, PPP will be mainly used for major infrastructure projects that are poor and deteriorating over the years. This failure in quality and service is due to the fact that the government does not have solid plans to maintain this infrastructure and the means to finance it.

The problem in the traditional public procurement is the absence of a complete plan and strategy for the whole infrastructure system. For instance, a loan is provided only for the construction of a new water treatment plant. After building it, the plan and structure of the distribution system were not taken into account and the plant is not able to operate. The money invested in establishing the water treatment plant was wasted without getting any benefits (Chaar, 2018).

7.3.2 Solutions for improvement

With the expertise and competence of the private sector, it is assumed that they will do a better job than the public sector in maintaining and operating infrastructures, the latter must prepare a good contract.

When identifying the needs for a project, a good plan includes due diligence and reviews of the legal, technical and financial reports. The due diligence and consultancy offer transparency (by involving many stakeholders corruption is reduced), competitiveness (minimum three candidates), clarity (SPV foreign investor and international arbitration). The feasibility study and business plan must include a projection for the whole life cycle consisting of a forecast of revenues, incurred CAPEX (overhead, expenses, and taxes), operation & maintenance and replacement.

In the end, the final report will identify if the infrastructure needs to be optimized, maintained or expanded.

The pre-feasibility submitted to the Secretariat General of the HCP by the specialized ministry or public entity must follow the below outline:

I- Contact Information

II- Introduction

III- Identification of the need and benefits of the project

IV- Preliminary technical and operational analysis

V- Preliminary analysis of the financial feasibility

VI- Project readiness and Status

In the preliminary analysis of the financial feasibility part, LCCA is implemented consisting of estimation of Capex and Operation & Maintenance cost including life-cycle refurbishment costs during the expected duration of the project in addition to the forecast of revenues with their assumptions.

Moreover, and according to each type of project, the risks and mitigation measures should be listed and well defined as shown in table 10.

Table 10: Example of risks and mitigation measures matrix

Risk	Private	Public	Mitigation
Fuel			
Interest			
Technology			
Operation			
Replacement			

8. LCCA Application in Procurement of Marine Port

After studying the current state of the practice of LCCA in procurement and its existing laws, it was found that incorporating LCCA in the procurement process in PPP projects following the procedural framework of the HCP.

Accordingly, marine port infrastructure is chosen as an example to evaluate this type of infrastructure and analyze the feasibility of incorporating LCCA in its procurement projects.

8.1 Introduction

Marine port infrastructure is a harbor or a space that provides shelter to various boats and vessels, and allows constant or periodic transaction of shipment. There is two types of ports, a natural establishment and an artificial construction, which provides a place for the loading and unloading of cargo. Ports can be for large seagoing ships and also for inland waterways such as rivers and lakes.

In Lebanon, Maritime transport is the most important mode for external trade. The depth of the ports is a crucial factor to look at because it determines the types of ships that can enter the port (Dasgupta, 2016).

Ports receive ships and transfer their cargo containers between different transport methods. Generally, ports have special freight-handling equipment such as quay cranes and yard cranes to utilize in the loading and unloading of ships. The whole process from the arrival of the ship to its final stage is shown in figure 8.

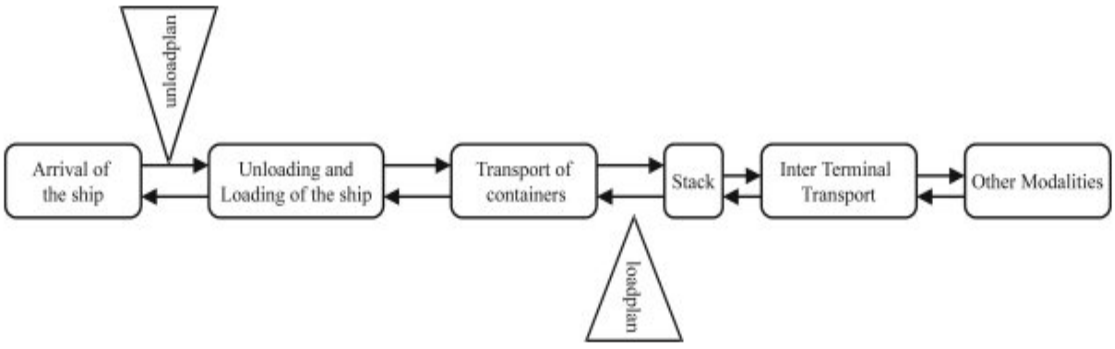


Figure 8: Process at a container terminal **(Vis , 2009)**

Due to the increase of ports movement and container ship capacity, ports need more cranes to load and unload vessels and move containers in terminal yards. For this, terminals and shipyards containers and all types of loads need to be transported using intermodal networks. Movement of these freights entails high-performance cranes that perform consistently and efficiently with high precision and safety.

Ports cranes types are divided as shown in Figures 9 and 10.

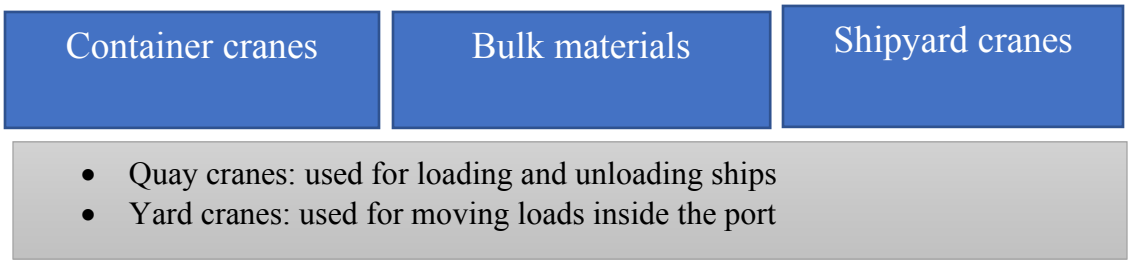


Figure 9: Cranes Types **(Nidec, 2009)**

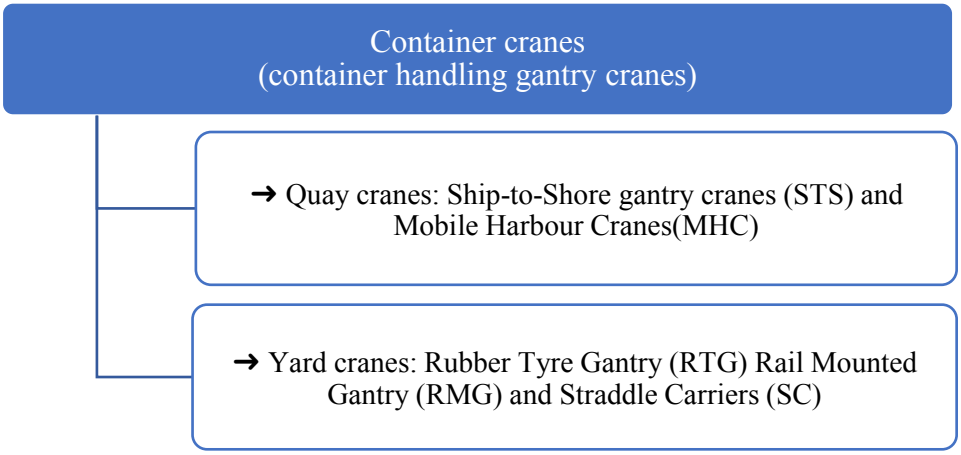


Figure 10: Container Cranes Types **(Nidec, 2009)**

8.2 Ship-to-shore gantry crane

Form the six operations stated in the previous section, the ship-to-shore gantry crane is used for the unloading and loading operations. This container quay crane is found at

container terminals and is used to reach out over berthed ships, pick up and move the containers to the wharf, where they are switched from one means of transport to another. STS cranes are also capable of pulling and moving specialized cargo like yachts, military equipment and non-containerized cargo.

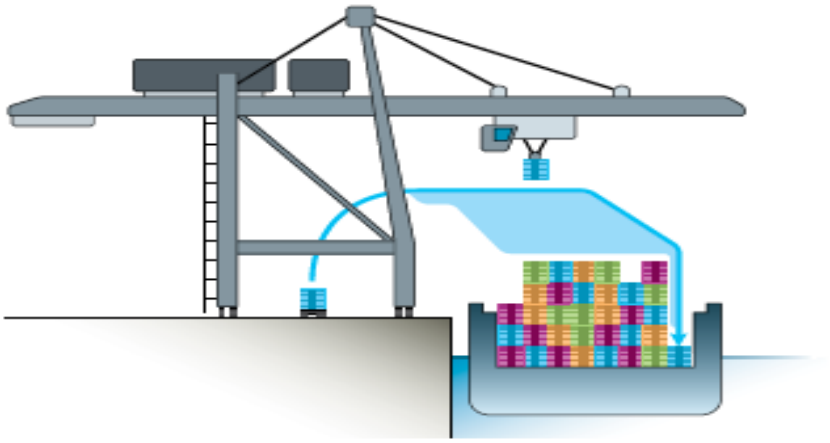


Figure 11: STS Crane **(Nidec, 2009)**

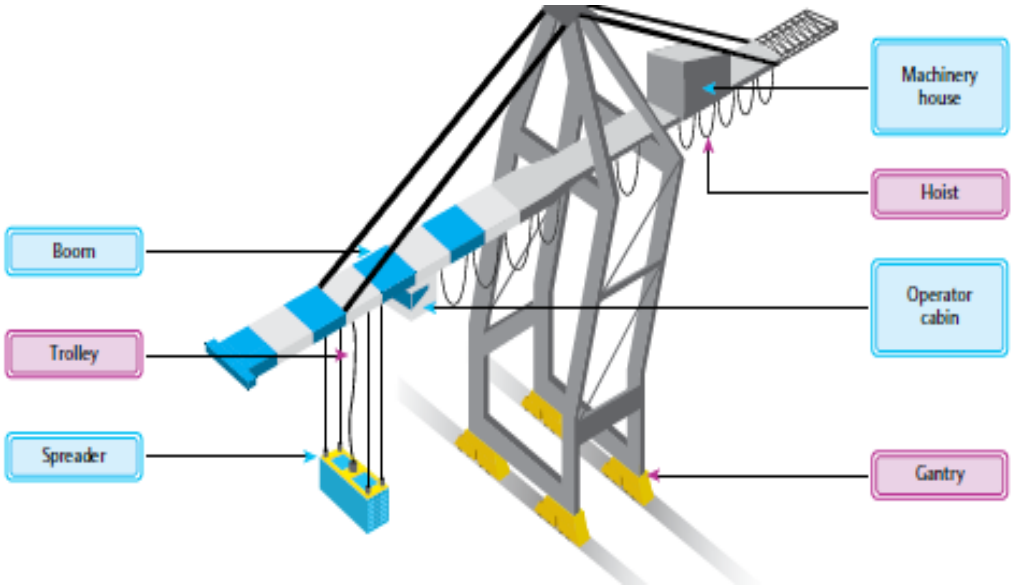


Figure 12: STS Crane features **(Nidec, 2009)**

STS cranes are composed of two main elements, a supporting frame of steel bars to cross

over something and a handling tool named spreader. This type of cranes has big dimensions to be able to transport containers across a quay. When connected to the container, the spreader is lowered down on top of the container, which locks on to its four corners using a “twist-lock” and picks it up, while using a mechanical and electrical system to monitor the process ensuring safe operation and indicating safe “landing”. Although the crane lifting capacity is normally limited to one container, new cranes nowadays have the capability of collecting up to two 20ft containers at once.

STS cranes are of two types, high and low profile. High profile cranes have hinged boom facing the waterside. The boom is lifted to clear the ships for navigation. Whereas low profile cranes have boom extended over the ship able to be pulled toward and over the ships and can perform more complex moves. This type is usually used in terminals near airports where they may be in the flight path (Nidec, 2009).

An operator sits in a cabin hanged from the trolley and drives the crane. In the operator cabin, the operator can monitor:

- Load weight
- Wind speed
- Spreader height
- Trolley position
- Boom angle
- Container’s number
- Date and hour
- Running mode
- Information pages for first-level troubleshooting

Each STS has the below safety features installed to avoid any deficiencies in the system:

Figure 13: STS Safety Systems **(Nidec, 2009)**

8.3 Rubber tyred gantry crane

Figure 14: RTG Crane **(Nidec, 2009)**

Figure 15: RTG Crane features **(Nidec, 2009)**

RTGs are the most common yard handling system and are used in the world's largest container terminals and container storage yards. This container yard crane is used to move unloaded shipping containers from the quay and stack them in the yard. Once the STS moves the container to the quay, two ways are identified to store them in ports. They can be stored on a chassis or stacked on the ground. By using the chassis system each container can be individually accessible, whereas by using the stacking method containers are piled up and containers cannot be directly accessible. Usually, containers are stacked on truck trailers (TTs) and the RTGs move them to the terminal yard.

RTGs are made of steel or aluminum, depending on their purpose. Their typical length is 23.47m which includes six containers plus one truck lane but RTGs with many spans can also be found. The height of the lift is defined as to permit a container to pass over a stack of containers four, five or six high. (Nidec, 2009). An RTG can have 4, 8 or 16 tubeless tires. The number of wheels is determined depending on the allowable load of the container

yard. The wheels of an RTG can turn for 90° so that it can move between different lanes. Underneath the trolley, an operator sits in the operator's cab where he drives the crane. The operator's job is to position the trolley over the container, lock the spreader on to the container, lift it and move it over the yard to discharge it on a trailer in order to be moved to wharf cranes or vice versa (Nidec, 2009).

Mostly, 85% of RTGs have a high cost of fuel and diesel maintenance since they are powered by diesel generators. For that, electric-powered RTGs are achieving more popularity. In fact, cranes performing on electricity lowers the energy and maintenance costs compared to diesel-powered cranes, but till now most of the cranes are running on fuel (Lane, 2019).

Each RTG has emergency push buttons and sensors installed to detect any deficiencies in the system:

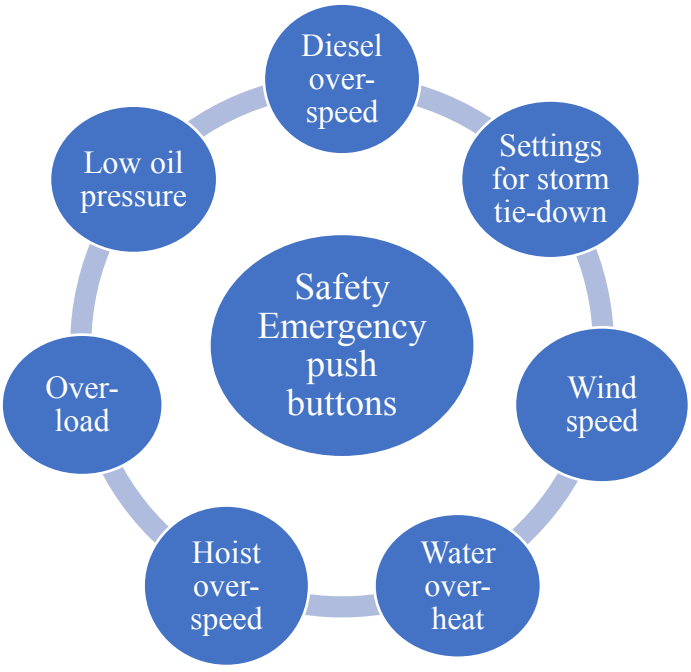


Figure 16: RTG Safety Systems **(Nidec, 2009)**

Although an RTG crane is essential and important to the terminal operation, it has a few disadvantages that can be minimized by switching to electric-powered RTGs. The advantages and disadvantages of a diesel-powered RTGs are listed in table 11.

Table 11: Advantages and disadvantages of diesel power RTG **(Naicker & Allopi, 2015)**

Advantages	**Disadvantages**
High efficiency: Ability to handle successive lifting, lowering, and stacking operations for a larger number of containers.	High mechanical breakdown rate and high maintenance costs. (Diesel Generator)
Optimization of space in terminals	Increase operating costs
Good mobility	Environmental pollution (Emissions and noise exhaustion)

8.4 PPP in Ports

Maritime transport is the backbone of globalization and international trade; in fact, over 80% of world merchandise is transported by sea. This infrastructure system is a key to other sectors and business activities like ship manufacturing, fisheries, banking, insurance, transport and tourism and the main element of economic growth for numerous developing countries.

Public sector participation in the shipping infrastructure is essential for ensuring safety, security, national planning and certain service operations (Panayides, Parola, & Lam, 2015). However, ports are projects that require large capital expenditures and better port management and performance; for this, public sector is often forced to search for sources of funding, managerial expertise, skills, and know-how while retaining control and

ownership of the asset (Panayides, Parola, & Lam, 2015) (Aerts, Grage, Dooms, & Haezendonck, 2014). Therefore, governments have started to look for private capital in order to execute infrastructure projects and to provide services that were previously the scope of the public sector (Aerts, Grage, Dooms, & Haezendonck, 2014).

To manage port operations more efficiently, PPP was introduced and used as a means for this process (World Bank , 2016). In fact, since late 1970s, port privatization became widespread, which presented opportunities for stevedoring companies and shipping lines to expand their market field in many methods (Panayides, Parola, & Lam, 2015).

According to (Cabrera, Aleman, & Trujillo, 2015), 381 PPP port projects worldwide have been developed in the last two decades. 47% of them focused on terminal concessions and 41% focused on Greenfield BOT concessions, accounting for more than US60 billion which represents 20% of private investment. The WB declared that concessions are the type of public-private investment with the largest share in port projects (47%) (World Bank data, 2014).

While some small ports, like Port Sultan Qaboos in Muscat, can be entirely privatized on a PPP basis, others are partially privatized. Specialization found in ports is not reproduced in other modes of transport, therefore ports tend to enter into PPPs agreement on a terminal only rather than a whole port. Ports are known to have different types of activities, thus a variation in profitability. Usually, the most cost-effective component of a port is its terminal. Consequently, seen as a strategic asset, governments are unwilling to let go of the ownership of ports, so when the private sector operates the terminal, PPPs allow private sector efficiency and investment to be merged with ongoing public sector control and recurrent income flow.

Terminals concessions differ greatly in terms of their forms, and inclusiveness. Some terminals have an integrated design and planning, shared or transferred construction-risk. Additionally, sometimes the maintenance and utilization of the infrastructure are also transferred to the private sector (Aerts, Grage, Dooms, & Haezendonck, 2014).

This PPP is evaluated based on its performance over time once it starts to face strong competition from neighboring facilities. The annual throughput (Total TEU) reflects the capacity of the PPP to attract new customers.

Generally, the public entity invites interested companies to submit a proposal in response to the invitation to submit proposals for the award of a container terminal concession contract. The duration of container terminal concessions is for 20-30 years, there are relatively few concessions of 31-49 years duration (Farrell, 2010).

The government's job is to pursue its role in setting standards and establishing systems to ensure that the partnership with the private sector operates efficiently and all resources are optimized. The public sector reveals the “rules of the game” in a society (Panayides, Parola, & Lam, 2015) .

8.5 Concession Period

The concession period is the time for which the rights of using a public asset are awarded to a private entity to avail their services. During this time, the private entity provides quality and level of service for the public and gains an acceptable profit margin. At the end of the concession period, the private company returns the property to the concerned public authority (Ullah & Thaheem, 2017).

The awarding process of terminals to a private operator creates several challenges to port authorities, one of them is the determination of the duration of the concession period. This

challenge is mostly due to the concession duration impact on the market structure in ports (Theys & Notteboom, 2010).

Usually, BOT-type projects need high project development costs, which are expected to be recovered through revenues in the future operation period. Generally, a longer concession period will allow the operator to collect more revenues with reduced interests to the public sector, and vice versa. Hence, the concession period divides the revenues in the project life cycle between the public and private sectors (Zhang & Abourizk, 2011).

One question arises is whether the concession period should be decided in advance by the port authority and input into the tendering process, or it should be proposed by the bidder as a variable parameter to be assessed along with other evaluation criteria declared in the tender document.

Using the public and private point of views and from the port authority position, the shorter the concession period is, the more frequent is the opportunity to re-launch the tender. Thus, reopen the competition for the market and therefore motivate the operator to maintain and increase its performance in order to defend obtaining a term extension.

From the operator position the longer the concession period is, the easier it is for them to plan for the development of the terminal and to secure long term financing by the projected revenues of the terminal operations (Juhel, 2017).

Recent cases confirmed the role of investment levels and return on investment (ROI) in the determination of the concession period (Theys & Notteboom, 2010), (Carbonara, Costantino, & Pellegrino, 2014). General methods for investment assessment constitute the backbone of almost all calculation techniques regarding the concession period.

For instance, the market consultation document on the Saeftinghe Development Area, a planned tidal dock in the Antwerp port, states that “The investments and return on

investment upon completion of these investments will be critical in determining the duration of the concession".

According to (Theys & Notteboom, 2010) most of the models proposed in the literature use the NPV and IRR for the determination of the terminal concession period. Whereas (Ma, Du, & Wang, 2018) state that nowadays the decision method of PPP project concession period is based on three methods; the NPV, the game theory, and the Monte Carlo simulation.

For NPV=0, the IRR is found as the return r and the return on any of the investments should exceed the corresponding hurdle rates. Thus, operators willing to invest in a terminal concession its minimally required operational concession period should be such that NPV ≥ 0 at the hurdle rate r min (Theys & Notteboom, 2010).

A long concession period will allow the concessionaire to recuperate its investment costs and obtain a reasonable return within that period. This is given that the scope and risks involved in the project and the opportunity costs in the current and future markets are taken into consideration and fairly allocated between parties (Zhang & Abourizk, 2011) (Carbonara, Costantino, & Pellegrino, 2014).

8.6 Financial Arrangements

In consideration of the payments to be made by the port to the operator of the terminal, the role and responsibility of the operator must be clearly defined. They can include tasks related to perform the operation services, provide the finance for design, manufacture, procure, supply, deliver, erect, test and commission the equipment depending on the contract made. When providing maintenance and operation and repair, the operator is responsible for all the losses or damages to the equipment and civil works.

A contract for the operation period is done between the port and the operator where the port shall retain a percentage of the tariff paid by the user and the remaining percentage is paid to the operator. In other words, the port will specify how much he will charge the user per TEU and the operator will get part of the tariff. This percentage is usually the winning criterion of the tender process. The operator proposing the lowest Container handling fee per TEU "Bid Price" will be the preferred bidder. Once the winning bidder is announced, the Port/Operator PPP contract is signed.

The operator is paid per full or empty container for six operations - three operations in the import and the same are repeated in the export - which consist of:

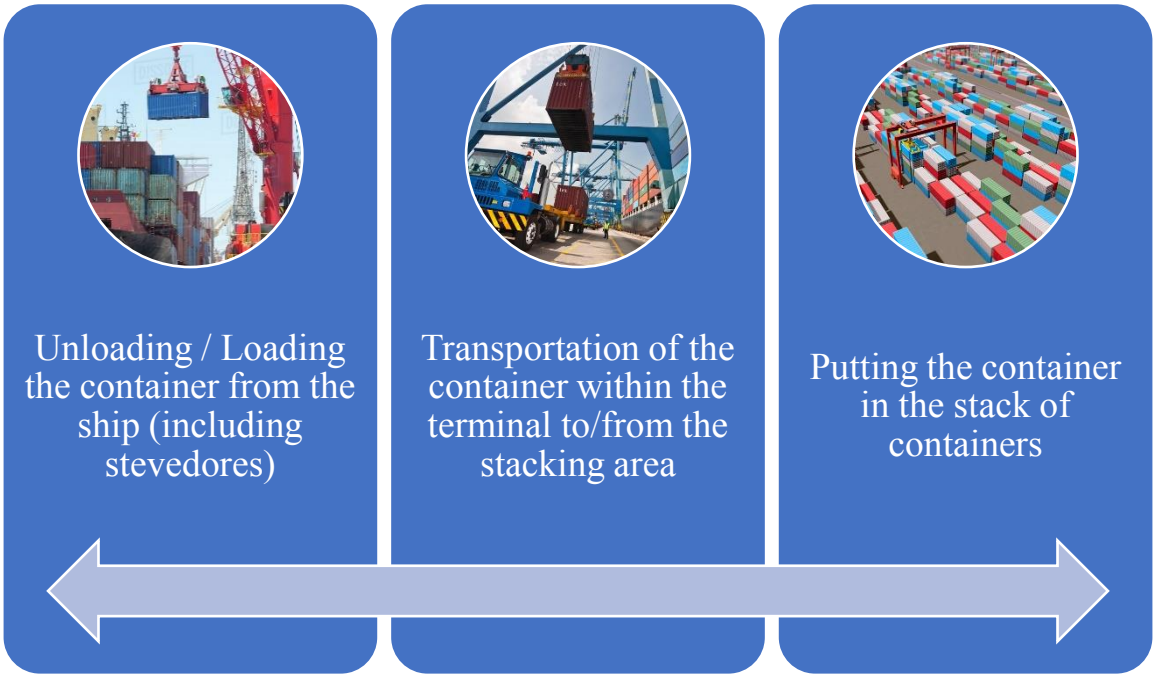


Figure 17: Import and Export Operations

Storage services at the port have also a payable fee where the port retains the biggest percentage of the tariff paid by the user and pay the remaining percentage to the operator.

8.7 LCCA Application

The purchase of an STS gantry crane and an RTG crane by the port or operator has a high cost. For this, the public entity – ports - invites interested bidders to submit a proposal in response to the invitation to submit proposals for the purchase of an STS and RTG cranes.

In this section, the LCC of the above-mentioned cranes over their life period will be computed, analyzed and evaluated.

With an assumed cost for the Local and Transhipment Throughput per TEU, the project business plan is prepared to demonstrate if the assumed costs can cover the initial cost of the equipment over their life period and if this investment is feasible.

The IRR and MIRR are computed and the required tariff to be paid by the user to the port is computed according to the Port/Operator PPP agreement.

Besides, the minimum duration of the concession period is analyzed and discussed according to the required IRR set.

Terms:

n	Number of years
i	Discount rate
STS	Ship to shore gantry crane
RTG	Rubber tyred gantry crane
TEU	Twenty-foot equivalent unit
OPEX	Operating expenses
EBITDA	Earnings before interest, tax, depreciation, and amortization
DCF	Discounted cash flow
PV	Present Value

NPV	Net Present Value
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return

Definitions:

- **Internal Rate of Return (IRR):** Discount rate that sets the NPV of all cash flows of a project to zero. It is the most common capital budgeting technique used to estimate the profitability of potential investments.
- **Modified Internal Rate of Return (MIRR):** MIRR computes a reinvestment rate by considering even or uneven cash flows. MIRR reflects more accurately than IRR the profitability of investments.

Procedure and Equations:

The procedure followed and the list of equations used in the computation of the LCCA are enumerated below:

1. **Total Revenue**
   - **Total Revenue** =

     Total Local Throughput Revenue + Total Transhipment Throughput Revenue

   Where:

   - Total Local Throughput Revenue = STS Local Revenue + RTG Local Revenue
   - Total Transhipment Throughput Revenue =

     STS Transhipment Revenue + RTG Transhipment Revenue

2. **Operating Expenses:**
   - **OPEX** = Maintenance and Repair + Insurance Expenses + Salaries

Where:

- Maintenance and Repair =

$$\text{Total Throughput} \times \left[OPEX\ rate \times [1 + (n-1) \times \text{Inflation Rate}]\right]$$

- Insurance Expenses = $(\text{STS} + \text{RTG Insurance}) \times [1 + (n-1) \times \text{Inflation Rate}]$
- Salaries =

  STS Drivers Salary + RTG Drivers Salary + Manager Salary + Accountant Salary

3. **Earnings before interest, taxes, depreciation, and amortization**

   ➢ **EBITDA** = $(\text{Total Revenue} + OPEX)$

4. **Net Income**

   ➢ **Net Income** = $(\text{EBITDA} + Total\ Depreciation)$

   Where:

   - Total Depreciation= $(\text{STS cost} \times \text{Depreciation rate}) + (\text{RTG cost} \times \text{Depreciation rate})$

5. **Present Value**

   ➢ **PV** = $\frac{Cash\ Flow}{(1+i)^n}$

6. **Net Present Value**

   ➢ **NPV** = $\sum_{t=0}^{n} \frac{\text{Net cash Inflow} - \text{Outflows}}{(1+i)^n}$

7. **Internal Rate of Return**

   ➢ Setting NPV = 0

   ➢ Find i = IRR

8. Modified Internal Rate of Return

- MIRR = $\sqrt[n]{\frac{Future\ value}{Present\ value}} - 1$

Where:

- Future value =
  Future value of the net cash inflows discounted at the reinvestment rate
- Present value =
  Present value of the net cash outflows discounted at the financing rate

8.8 Discussion and Analysis

1- Input Parameters

The list of data used for the calculation is shown in the input parameters table below.

Table 12: Input Parameters (Appendix A)

Business Plan 20 Years Input Parameters

I. Initial Investment :

Equipment Type	Short Name	Unit Cost	Qty	Total Cost
Ship to Shore	STS	$12,500,000	1	$12,500,000
Rubber Tyre Gantry	RTG	$2,000,000	1	$2,000,000
Total Initial Investment			**2**	**$14,500,000**

II. Operational Revenue:

Year	Local TEU Throughput	Transhipment TEU Throughput	Total TEU Throughput
1	14,249	14,249	28,498
2	60,000	90,000	150,000
3	90,000	110,000	200,000
4	120,000	120,000	240,000
5	150,000	150,000	300,000
6	170,000	150,000	320,000
7	182,000	155,000	337,000
8	195,000	160,000	355,000
9	209,000	165,000	374,000
10	224,000	170,000	394,000
711	240,000	175,000	415,000
12	257,000	180,000	437,000
13	275,000	185,000	460,000
14	294,000	191,000	485,000
15	315,000	197,000	512,000
16	337,000	203,000	540,000
17	361,000	209,000	570,000
18	386,000	215,000	601,000
19	413,000	221,000	634,000
20	442,000	228,000	670,000
Total	**4,734,249**	**3,288,249**	**8,022,498**

Revenue / TEU	**STS**	**RTG**
Local Throughput	**$21**	**$6**
Transhipment Throughput	**$10**	**$3**

III. Operational Cost :

OPEX / TEU	$2
Inflation Rate / Year	3%
STS Insurance / Year 1	$70,000
RTG Insurance / Year 1	$3,500
Insurance Inflation Rate / Year	2%

Monthly Salaries :	
STS Driver *2	$3,000
RTG Driver*2	$2,400
Manager *1	$3,000
Accountant*1	$1,200

IV. Depreciation:

STS Depreciation Rate	5%
RTG Depreciation Rate	5%

V. Discount Rate :

Discount Rate	10%
Risk-Free Rate	2%

- The lifetime period of both cranes is 20 years.
- It is assumed that the initial investment of $ 14,500,000 is issued by shareholders to cover the value of both cranes.
- Operational Costs are limited to the M&R (OPEX) and equipment insurance with their corresponding inflation rate, in addition to the monthly salaries of employees. Each crane needs two drivers, and the supervision of both cranes needs one manager and one accountant.
- With age and usage, the value of both cranes decreases over time, thus a depreciation rate of 5% is taken into account.
- A discount rate of 10% and a Risk-free Rate of 2% are used for the calculation.
- Assuming a PPP agreement of 60/40 for the Port/Operator Contract.

2- Income Statement

With the data in hand, the forecasted income statement is shown in Appendix B. The total Local Throughput Revenue and total Transhipment Throughput Revenue are calculated and summed up to find a total Revenue of $170,571,960 on a period of 20 years. The OPEX reached a total of $ 25,776,936. Then adding the depreciation rate to the EBITDA, a total net income of $ 130,295,024 which consists of 76% of the operations revenue will be earned in 20 years.

3- Cash Flow Statement

Furthermore, the forecasted cash flow statement is shown in Appendix C. The Net cash flow for the entire period is computed with the Present Value of each year yielding to a NPV equals to $ 155,050,045, an IRR of 25% and a MIRR of 16%.

The Net Income Evolution and Cash flow for the 20-year period are shown graphically in Appendix D and E respectively.

Starting with a negative Net income of $ 400,736 in year 1; the income increased reaching a value of $ 11,852,570 in year 20. For the cash flow, starting with a negative value of $14,500,000, it reached his peak of $130,295,024 in year 20.

4- Feasibility of the Project

An IRR of 25% greater than the discount rate of 10% means that the project is feasible and profitable. Furthermore, a MIRR equals to 16% confirm the profitability of purchasing both types of equipment.

5- Port and Operator Cost

In the contract between the port and the operator, the port shall retain a percentage of the Tariff paid by the user and the remaining percentage is paid to the operator. With an assumed PPP agreement of 60/40 for the port/operator, and for the operator to get his needed cost for the equipment, the port needs to charge the user per TEU as below:

Table 13: Port / Operator Cost

Cranes	**STS**		**RTG**	
Containers	**Local**	**Transhipment**	**Local**	**Transhipment**
Port Cost	$35	$17	$10	$5
Operator Cost	$21	$10	$6	$3

6- Concession Period

Table 14: Concession Period vs. IRR

Concession Period	**Net Cash Flow**	**IRR**
Year 0	(14,500,000)	
Year 1	(14,175,736)	
Year 2	(11,884,906)	
Year 3	(8,640,546)	
Year 4	(4,556,856)	
Year 5	576,564	
Year 6	6,184,514	
Year 7	12,120,674	**-19%**
Year 8	18,407,584	**-6%**
Year 9	25,067,604	**2%**
Year 10	32,122,914	**8%**
Year 11	39,595,514	**12%**
Year 12	47,507,224	**16%**
Year 13	55,879,684	**18%**
Year 14	64,744,574	**20%**
Year 15	74,147,214	**21%**
Year 16	84,108,464	**22%**
Year 17	94,673,044	**23%**
Year 18	105,861,334	**24%**
Year 19	117,717,454	**24%**
Year 20	130,295,024	**25%**

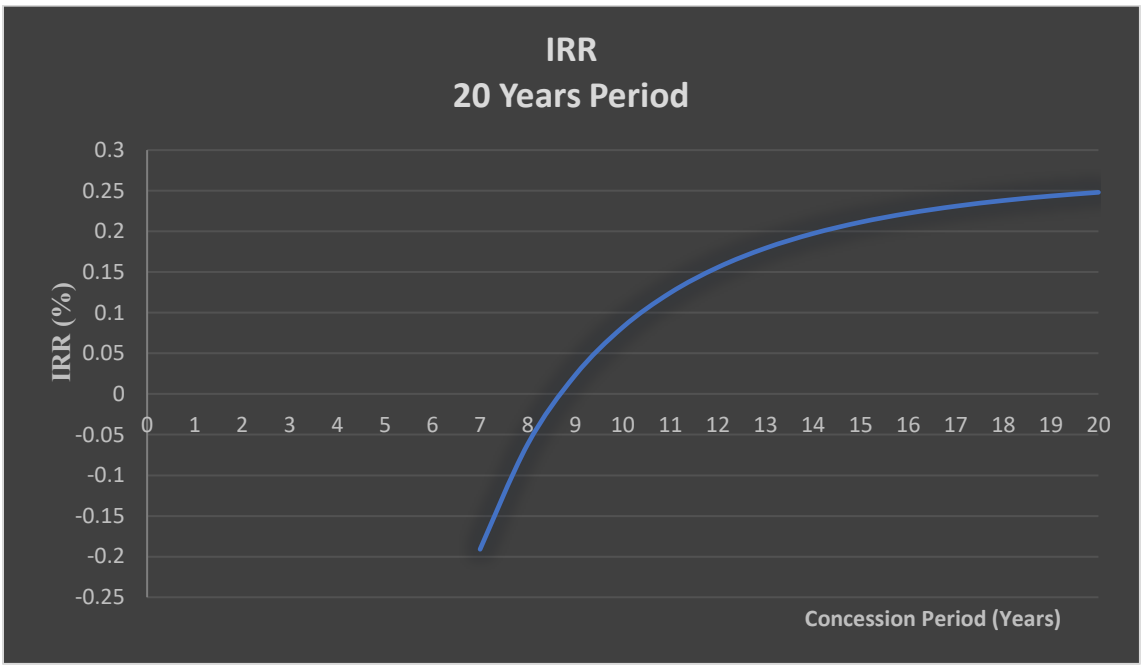


Figure 18: Concession Period vs. IRR for 20 years

As discussed above, that the duration of the concession period affects the operator's level of return on investment and the port's interests.

Figure 18 shows an increasing curve starting from year seven for an IRR equals to -19% and reaching an IRR of 25% in year 20.

Based on the cash flow evaluation, the return starts to be realized in year 9. In fact, only 2% are returned in years nine (Table 14). For the project to be profitable the minimum IRR must be above the discount rate, according to the table and graph above, the minimum concession period for the port operator should be 11 years.

These results suggest that concessionaire operates with long-term perspectives and rely on the entire concession period to build an adequate return.

9. Conclusion

The purpose of this master's thesis was to propose a general framework and guidelines of the LCCA method for diverse types of infrastructure facilities, and to investigate the status of incorporating LCCA results in the public procurement decisions. The proposed research reviewed the particular details of how this can be done in the context of Lebanon. The research started with a conceptual literature review on LCCA background as well as different types of contracts in procurement to reach a well-developed framework. Furthermore, an investigation on the state of the practice of LCCA in Lebanon was carried out through reviewing the published guidelines, policies. This was also done through conducting one-on-one interviews with key public sector personnel to gather their feedback, in order to build a concrete case study on the LCCA application and analyze the feasibility in the procurement field for Lebanon.

The developed and presented framework consists of five stages. The first stage is to establish the objective of conducting LCCA. Once the objective is chosen, the second stage would be to define the economic parameters which are the discount rate, the interest rate, and the inflation rate. After that, the third stage is the analysis period and the rehabilitation activities with specific time tables. Subsequently, the fourth stage presents the statement of three types of costs including agency costs, user costs and social costs and the last stage is the assessment and calculation of the NPV.

Based on the analysis of incorporating the LCCA feasibility within the current practices of procurement in the public sector in Lebanon, it was found that the only channel where LCCA is applied in the procurement decisions will be with the new PPP law through PPP project with HCP.

Following to the detailed analysis presented in this research, the following are the recommendations that should be adopted in order to improve the efficiency of the procurement system and set directives for civil servants and decision-makers. The first recommendation is to change the old and obsolete procurement laws in Lebanon and alternatively implement the PPP law and revise the current laws to take into consideration additional clauses that would ensure an efficient procurement system. The second recommendation is to issue directives for the specified civil servants and personnel to follow for guidance.

As an application on incorporating LCCA in the procurement system, a study was performed on the purchase of two components in the commercial sea port of Tripoli: an STS and an RTG crane. Actually, by fixing the local throughput and transshipment throughput tariff. The IRR and MIRR were calculated to be 25% and 16% respectively and the tariff to be set by the port is calculated based on the PPP contract agreement between the port and the operator. The investment resulted with a positive NPV of $ 155,050,045 and was found to be very profitable and feasible for a concession period of minimum 11 years.

Bibliography

El-Akruti, K., Dwight, R., Zhang, T., & Al-Marsumi, M. (2013). The role of life cycle cost in engineering asset management. *8th World Congress on Engineering Asset Management and Safety* (pp. 1-16). Australia: University of Wollongong - Faculty of Engineering and Information Sciences.

Estevan, H., & Schaefer, B. (2017). *Life Cycle Costing State of the art report.* ICLEI – Local Governments for Sustainability.

ACEC. (2009). *UNDERSTANDING PUBLIC PRIVATE PARTNERSHIPS IN CANADA.* Association of Consulting Engineering Companies - ACEC-Canada.

Aerts, G., Grage, T., Dooms, M., & Haezendonck, E. (2014). Public-Private Partnerships for the Provision of Port Infrastructure: An Explorative Multi-Actor Perspective on Critical Success Factors. *The Asian Journal of Shipping and Logistics, 30*, 273-298.

Babashamsi, P., Md Yusoff, N., Ceylan, H., Md Nor, N., & Jenatabadi, H. S. (2016, August). Evaluation of pavement life cycle cost analysis: Review and analysis. *International Journal of Pavement Research and Technology*, 241-254.

Blank, L., & Tarquin, A. (2012). *Engineering Economy.* New York: Mcgraw Hill.

Bowyer, J., Fernholz, K., Bratkovich, S., Howe, J., Stai, S., & Frank, M. (2013). *Life Cycle Cost Analysis of Non-Residential Buildings.* Minneapolis: Dovetail Partners.

Cabrera, M., Aleman, A. S., & Trujillo, L. (2015). Public-private partnerships in Spanish Ports: Current status and future prospects. *Utilities Policy*, 1-11.

Campisano, A., & Modica, C. (2012). Optimal sizing of storage tanks for domestic rainwater harvesting in Sicily. *Resources, Conservation and Recycling, 63*, 9-16.

Carbonara, N., Costantino, N., & Pellegrino, R. (2014). Concession period for PPPs: A win–win model for a fair risk sharing. *International Journal of Project Management*, 1223-1232.

CDR. (2008). *About CDR*. Retrieved from Council for Development and Reconstruction: http://www.cdr.gov.lb/eng/home.asp

Chaar, D. (2018, October 25). Personal Communication. (Y. Medawar , Interviewer)

Coony, R., Gould, S., Daly, A., & Davis, M. (2005, October). *GUIDELINES FOR LIFE CYCLE COST ANALYSIS.* Stanford University Land and Buildings.

CTC & Associates LLC. (2011). *Using Life Cycle Cost Analysis in Highway Project Development.* California: Caltrans Division of Research and Innovation.

Daouk, C. H., Hayeck, W., Hajjar, N., & Takieddine, M. (2017). *PUBLIC PRIVATE PARTNERSHIP - SAFEGUARDING LEBANON'S INTERESTS…AT FAST FORWARD DEVELOPMENT.* Beirut: Fransa Invest Bank.

Dasgupta, S. (2016, July 21). *What Are Different Types of Ports For Ships?* Retrieved from Marine insight.

Deloitte . (2006). *Closing the Infrastructure Gap: The Role of Public-Private Partnerships.* United States of America.

EBRD. (2019). *Public-private partnerships (PPPs).* Retrieved April 21, 2019, from European Bank for Reconstruction and Development: https://www.ebrd.com/infrastructure/infrastructurePPPs.com

Farrell, S. (2010). *Observations on PPP Models in the Ports Sector.* London: Imperial College London.

Ferreira, A., & Santos, J. (2012). LCCA system for pavement management: sensitivity analysis to the discount rate. *Procedia - Social and Behavioral Sciences*, 1174 – 1183.

FHWA. (2002, August). *Life-Cycle Cost Analysis Primer.* Washington, DC: U.S. Department of Transportation Federal Highway Administration Office of Asset Management.

FHWA. (2012). *Value for Money Assessment for Public-Private Partnerships: A Primer.* Federal Highway Administration- Innovative Program Delivery.

Goh , K. C., & Yang, J. (2009). Extending life-cycle costing (LCC) analysis for sustainability considerations in Australian road infrastructure projects. *Proceedings of 3rd CIB International Conference on Smart and Sustainable Built Environment.* Delft, Amsterdam.

Goh , K. C., & Yang, J. (2009). Extending life-cycle costing (LCC) analysis for sustainability considerations in road infrastructure projects. *Proceedings of 3rd CIB International Conference on Smart and Sustainable Built Environment.* Delft, Amsterdam.

Goh, K. C., & Yang, J. (2009). Extending Life-Cycle Costing Analysis For Sustainability Considerations In Australian Road Infrastructure Projects. *Proceedings of 3rd CIB International Conference on Smart and Sustainable Built Environment,.* Amsterdam.

Greeno, R. (1995). An Overview of the building Delivery Process. In *Principle of Construction.*

Haddad, G. (2018, May 22). Personal Communication. (Y. Medawar, Interviewer)

HAGLUND, H., & YMAN, O. (2016). *Adoption of Life Cycle Cost Analysis in Early Design Phases of Road Bridges.* Gothenburg, Sweden : CHALMERS UNIVERSITY OF TECHNOLOGY.

Hawk, H. (2003). Bridge Life-Cycle Cost Analysis. *Report 483*.

HCP . (2018). *Expansion of Beirut Rafic Hariri International (BEY) Airport - Progress Report #2* . Beirut : High Council for Privatization and PPP .

HCP. (2018). *Invest in Lebanon - THE PPP GUIDE FOR PRIVATE COMPANIES.* Beirut: High Council for Privatization and PPP.

HCP. (2018). *Khaldeh - Okaibeh Expressway - Progress Report #1.* Beirut: High Council for Privatization and PPP .

HCP. (2018). *Lebanon Cloud Data Center Project - Progress Report #1.* Beirut: High Council for Privatization and PPP .

Helmersen, E., & Pedersen, H. A. (2014). *Public Private Partnerships, an investigation and comparison with traditional procurement contracts in Norwegian Road projects.* Norwegian University of Science and Technology.

Heuvinck, T. (2015). *Life Cycle Cost Analysis: Application to an airport pavement*. Retrieved August 10, 2017, from https://fenix.tecnico.ulisboa.pt/downloadFile/281870113702632/Extended%20abstract.pdf

Highton, J. (2012). Life-cycle costing and the procurement of new buildings: The future direction of the construction industry. *Public Infrastructure Bulletin, 1*(8).

Hunt, D., Nash, D., & Rogers, C. (2014). Sustainable utility placement via Multi-Utility Tunnels. *Tunnelling and Underground Space Technology*, 15-26.

IoF . (2013). *Professionalizing Public Procurement in Lebanon: Diagnostic Review and a vision forward.* Republic of Lebanon - Ministry of Finance.

IoF . (2014). *Professionalizing Public Procurement in Lebanon: Diagnostic Review and a vision forward.* Republic of Lebanon - Ministry of Finance.

IoF. (2018). *Learning* . Retrieved from Institut des Finances Basil Fuleihan: http://www.institutdesfinances.gov.lb/

IRS. (2012, November 19). *CHAPTER 6.6 - CONSTRUCTION PROCESS.* Retrieved from Construction Process - Cost Segregation Study: http://www.csp-360.com/about-us/resources/irs-cost-segregation-audit-techniques-guide/construction-process-cost-segregation-study

ITU , infoDev, & The World Bank . (n.d.). *Models of Public-Private Partnerships*. Retrieved from ICT regulation toolkit.

Jawad, D. (2017). *CEN594 Infrastructure Management.* NDU .

Jawad, D., & Ozbay, K. (2006). THE DISCOUNT RATE IN LIFE CYCLE COST ANALYSIS OF TRANSPORTATION PROJECTS. *85th Annual Meeting of the Transportation Research Board.* Washington.

Jawad, D., Ozbay, K., & Nassif, H. (2007). Lifecycle Cost Optimization of Infrastructures Using Genetic Algorithms and Monte Carlo Simulations.

Juhel, M. (2017). *Container Terminal Concession Guidelines.* SSATP.

Kibert, C. J., Olbina, S., Oppenheim, P., Ries, R., & Walters, R. (2010). *Life Cycle Cost Guidelines for Materials and Building Systems for Florida's Public Educational Facilities.* Florida: University of Florida - Department of Education.

KPMG . (2017). *Public Private Partnershipsin Real Estate.* KPMG Al Fozan & Partners.

Lane, S. (2019). *Types of Port Cranes.* Retrieved June 5, 2019, from KoneCranes: https://www.konecranesusa.com/resources/lifting-viewpoints/types-of-port-cranes

Langdon, D. (2007, May). *Guidance on the use of the LCC Methodology and its application in public procurement.*

Langdon, D. (2007, May). *Life cycle costing (LCC) as a contribution to sustainable construction : Guidance on the use of the LCC Methodology and its application in public procurement.* Davis Langdon Management Consulting.

Liu, H. J., Davis, P., Love, P. E., Smith, J., & Regan, M. (2014). Life-Cycle Critical Success Factors for Public-Private Partnership Infrastructure. *Journal of Management in Engineering*.

Liu, R., Smartz , B., & Descheneaux, B. (2015). LCCA and environmental LCA for highway pavement selection in Colorado. *International Journal of Sustainable Engineering*, 102-110.

Ma, G., Du, Q., & Wang, K. (2018). A Concession Period and Price Determination Model for PPP Projects: Based on Real Options and Risk Allocation. *Sustainability*.

Meng, X., & Harshaw, F. (2013). The application of whole life costing in PFI/PPP projects. *Procs 29th Annual ARCOM Conference* (pp. 769-778). UK: School of Planning, Architecture and Civil Engineering, Queen's University Belfast.

MoF . (2019). *Reforming Public Procurement in Lebanon.* Beirut: Lebanese Ministry of Finance.

Naicker, R., & Allopi, D. (2015, June). Analysis of Electric-Rubber Tyred Gantries for a more green Durban Container Terminal. *IOSR Journal of Engineering (IOSRJEN), 05*(06), 24-28.

Nidec. (2009). *An Introductory Guide to Port Cranes and the Application of Variable Speed Drives.* Control Techniques.

Ozbay, K., Jawad, D., Parker, N., & Hussain, S. (2004, January). Life Cycle Cost Analysis: State-of-the-Practice vs. State-of-the Art. *83rd Annual Meeting of the Transportation Research Board, 1864*, pp. 62-70.

Panayides, P. M., Parola, F., & Lam, J. (2015). The effect of institutional factors on public–private partnership success in ports. *Transportation Research Part A*, 110-127.

Riddell, T. (2017 , January 27). *The 5 Stages of Project Management – Understanding a Construction Project's Life Cycle.* Retrieved from e SUB Construction software :

https://esub.com/5-stages-project-management-understanding-construction-projects-life-cycle/

Rizkallah, R. (2018, August 25). Personal Communication. (Y. Medawar, Interviewer)

Safi, M., Sundquist, H., & Karoumi, R. (2015). Cost-Efficient Procurement of Bridge Infrastructures by Incorporating Life-Cycle Cost Analysis with Bridge Management Systems. *Journal of Bridge Engineering, 20*(6).

SIGMA. (2016). *Public Procurement Brief 34.* France: Organisation for Economic Co-operation and Development.

Sinha, K., & Labi, S. (2007). *Transportation Decision Making: Principles of Project Evaluation and Programming.* Hoboken: Wiley.

Stiegler, S., & Vinson & Elkins. (n.d.). *Parties to a Construction Contract.* Retrieved from Global Arbitration Review - The Guide to Construction Arbitration: https://globalarbitrationreview.com/chapter/1145207/parties-to-a-construction-contract

Ta, N., Orcesi, A., & Cremona, C. (2013). A comparative life-cycle cost analysis of steel-concrete composite bridges. *Life-Cycle and Sustaianbility of Civil Infarstructure Systems*, 169.

The World Bank. (2016). *Value for Money - Achieving VfM in Investment Projects Financed.* Washington DC: The World Bank.

The World Bank. (2017). *PUBLIC- PRIVATE PARTNERSHIPS: Reference Guide Version 3* . Washington DC: PPP Knowledge Lab library.

Theys, C., & Notteboom, T. (2010). *Determining terminal concession durations in seaports: theoretical considerations, applicable techniques and current practices.* Belgium: University of Antwerp.

Tysseland, B. (2008). Life cycle cost based procurement decisions A case study of Norwegian Defence Procurement projects. *International Journal of Project Management*, 366-375.

Uddin , W., Haas , R., & Hudson , W. (1997). *Public Infrastructure Asset Management.* United Sates : Mc-Graw Hill .

Uddin, W., Hudson, W., & Haas, R. (2013). *Public Infrastructure Asset Management.* New York: Mcgraw Hill .

Ullah, F., & Thaheem, M. (2017). Concession period of public private partnership projects: industry–academia gap analysis. *International Journal of Construction Management*.

UNDP. (2004). *Public Sector Transparency and Accountability in Selected Arab Countries: Policies and Practices.* New York: United Nations Development Programme - Department of Economic and Social Affairs.

Vaissier, F.-G., Le Bars, O., & Houriez, D. (2018, April). *The Public-Private Partnership Law Review - Edition 4.* France: The Law Reviews. Retrieved from The Law Reviews: https://thelawreviews.co.uk/edition/the-public-private-partnership-law-review-edition-4/1168042/france

Vis , I. F. (2009, March). *Processes at a container terminal.* Retrieved from Iris F.A. Vis: http://www.irisvis.nl/container/processes.html

Wang, J., Koizumi , A., & Tanaka, H. (2017). Framework for maintenance management of shield tunnel using structural performance and life cycle cost as indicators. *Structure and Infrastructure Engineering*, 44-54.

WATT, B., & WATT, A. (2012). *The Project Life Cycle (Phases).* Retrieved from BC Open Textbooks - Open Textbooks Adapted and Created by BC Faculty: https://opentextbc.ca/projectmanagement/chapter/chapter-3-the-project-life-cycle-phases-project-management/

Wennstrom, J., & Karlsson, R. (2016). Possibilities to reduce pavement rehabilitation cost of a collision-free road investment using an LCCA design procedure. *International Journal of Pavement Engineering, 17*, 331-342.

Woetzel, J., Garemo, N., & Mischke, J. (2016). *Bridging global infrastructure gaps.* Mckinsey Global Institute.

World Bank . (2016, November 28). *Public Private Partnerships in Ports / Port Reform*. Retrieved from World Bank Group: https://ppp.worldbank.org/public-private-partnership/sector/transportation/ports

World Bank. (2016, July). *Use of evaluation criteria for procurement of Goods, Works, and Non-consulting Services using RFB and RF.* Retrieved July 1, 2017, from The World Bank Group: www.worldbank.org

World Bank. (2018). *STRATEGIC ASSESSMENT: A Capital Investment Plan For Lebanon* . WORLD BANK GROUP .

World Bank data. (2014). *THE WORLD BANK* . Retrieved from Private Participation in Infrastructure Database .

World Bank Group . (2016). *WORLD BANK NEW PROCUREMENT FRAMEWORK.* Tokyo: World Bank Group .

World Bank Group. (2001). *Bank-Financed Procurement Manual.* World Bank Group.

Zhang, D., Ye, F., & Yuan, J. (2013). Life-cycle Cost Analysis (LCCA) on Steel Bridge Pavement Structural Composition. *Procedia - Social and Behavioral Sciences, 96*, 785-789.

Zhang, X., & Abourizk, S. M. (2011). Determining a reasonable concession period for private sector provision of public works and service. *Canadian Journal of Civil Engineering*, 622-631.

Zoeteman, A. (2001). Life cycle cost analysis for managing rail infrastructure. *European Journal of Transport and Infrastructure Research*, 391-413.

Zurbrügg, C., Caniato , M., & Vaccari, M. (2014). How Assessment Methods Can Support Solid Waste Management in Developing Countries—A Critical Review. *Sustainability, 6*, 545-570.

Appendices

Appendix A	Input Parameters
Appendix B	Forecasted Income Statement
Appendix C	Forecasted Cash Flow Statement
Appendix D	Net Income Evolution
Appendix E	Cash Flow

Appendix A: Input Parameters

Business Plan
20 Years
Input Parameters

I- Initial Investment:

Equipment Type	Short Name	Unit Cost	Qty	Total Cost
Ship to Shore	STS	$12,500,000	1	$12,500,000
Rubber Tyre Gantry	RTG	$2,000,000	1	$2,000,000
Total Initial Investment			**2**	**$14,500,000**

II - Operational Revenue:

Year	Local TEU Throughput	Transhipment TEU Throughput	Total TEU Throughput
1	14,249	14,249	28,498
2	60,000	90,000	150,000
3	90,000	110,000	200,000
4	120,000	120,000	240,000
5	150,000	150,000	300,000
6	170,000	150,000	320,000
7	182,000	155,000	337,000
8	195,000	160,000	355,000
9	209,000	165,000	374,000
10	224,000	170,000	394,000
11	240,000	175,000	415,000
12	257,000	180,000	437,000
13	275,000	185,000	460,000
14	294,000	191,000	485,000
15	315,000	197,000	512,000
16	337,000	203,000	540,000
17	361,000	209,000	570,000
18	386,000	215,000	601,000
19	413,000	221,000	634,000
20	442,000	228,000	670,000
Total	**4,734,249**	**3,288,249**	**8,022,498**

Revenue / TEU	STS	RTG
Local Throughput	**$21**	**$6**
Transhipment Throughput	**$10**	**$3**

III- Operational Cost:

OPEX / TEU	$2
Inflation Rate / Year	3%
STS Insurance / Year 1	$70,000
RTG Insurance / Year 1	$3,500
Insurance Inflation Rate / Year	2%
Monthly Salaries:	
STS Driver *2	$3,000
RTG Driver*2	$2,400
Manager *1	$3,000
Accountant*1	$1,200

IV. Depreciation:

STS Depreciation Rate	5%
RTG Depreciation Rate	5%

V. Discount Rate:

Discount Rate	10%
Risk Free Rate	2%

Appendix B: Forecasted Income Statement

Business Plan
20 Years
Forecasted Income Statement

I.REVENUE:

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Total
Local Throughput	14,249	60,000	90,000	120,000	150,000	170,000	182,000	195,000	209,000	224,000	240,000	257,000	275,000	294,000	315,000	337,000	361,000	386,000	413,000	442,000	4,734,249
Transhipment Throughput	14,249	90,000	110,000	120,000	150,000	150,000	155,000	160,000	165,000	170,000	175,000	180,000	185,000	191,000	197,000	203,000	209,000	215,000	221,000	228,000	3,288,249
Total Throughput	**28,498**	**150,000**	**200,000**	**240,000**	**300,000**	**320,000**	**337,000**	**355,000**	**374,000**	**394,000**	**415,000**	**437,000**	**460,000**	**485,000**	**512,000**	**540,000**	**570,000**	**601,000**	**634,000**	**670,000**	**8,022,498**
Growth %		***81%***	***25%***	***17%***	***20%***	***6%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	***5%***	
STS Local Throughput Revenue	299,229	1,260,000	1,890,000	2,520,000	3,150,000	3,570,000	3,822,000	4,095,000	4,389,000	4,704,000	5,040,000	5,397,000	5,775,000	6,174,000	6,615,000	7,077,000	7,581,000	8,106,000	8,673,000	9,282,000	99,419,229
RTG Local Throughput Revenue	85,494	360,000	540,000	720,000	900,000	1,020,000	1,092,000	1,170,000	1,254,000	1,344,000	1,440,000	1,542,000	1,650,000	1,764,000	1,890,000	2,022,000	2,166,000	2,316,000	2,478,000	2,652,000	28,405,494
Total Local Throughput Revenue	**384,723**	**1,620,000**	**2,430,000**	**3,240,000**	**4,050,000**	**4,590,000**	**4,914,000**	**5,265,000**	**5,643,000**	**6,048,000**	**6,480,000**	**6,939,000**	**7,425,000**	**7,938,000**	**8,505,000**	**9,099,000**	**9,747,000**	**10,422,000**	**11,151,000**	**11,934,000**	**127,824,723**
Growth %		***76%***	***33%***	***25%***	***20%***	***12%***	***7%***	***7%***	***7%***	***7%***	***7%***	***7%***	***7%***	***6%***	***7%***	***7%***	***7%***	***6%***	***7%***	***7%***	
STS Transhipment Throughput Revenue	142,490	900,000	1,100,000	1,200,000	1,500,000	1,500,000	1,550,000	1,600,000	1,650,000	1,700,000	1,750,000	1,800,000	1,850,000	1,910,000	1,970,000	2,030,000	2,090,000	2,150,000	2,210,000	2,280,000	32,882,490
RTG Transhipment Throughput Revenue	42,747	270,000	330,000	360,000	450,000	450,000	465,000	480,000	495,000	510,000	525,000	540,000	555,000	573,000	591,000	609,000	627,000	645,000	663,000	684,000	9,864,747
Total Transhipment Throughput Revenue	**185,237**	**1,170,000**	**1,430,000**	**1,560,000**	**1,950,000**	**1,950,000**	**2,015,000**	**2,080,000**	**2,145,000**	**2,210,000**	**2,275,000**	**2,340,000**	**2,405,000**	**2,483,000**	**2,561,000**	**2,639,000**	**2,717,000**	**2,795,000**	**2,873,000**	**2,964,000**	**42,747,237**
Growth %		***84%***	***18%***	***8%***	***20%***	***0%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	***3%***	
Total Revenue	**569,960**	**2,790,000**	**3,860,000**	**4,800,000**	**6,000,000**	**6,540,000**	**6,929,000**	**7,345,000**	**7,788,000**	**8,258,000**	**8,755,000**	**9,279,000**	**9,830,000**	**10,421,000**	**11,066,000**	**11,738,000**	**12,464,000**	**13,217,000**	**14,024,000**	**14,898,000**	**170,571,960**
Growth %		***80%***	***28%***	***20%***	***20%***	***8%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	***6%***	

II. OPEX:

Maintenance and Repair	(56,996)	(309,000)	(424,000)	(523,200)	(672,000)	(736,000)	(795,320)	(859,100)	(927,520)	(1,000,760)	(1,079,000)	(1,162,420)	(1,251,200)	(1,348,300)	(1,454,080)	(1,566,000)	(1,687,200)	(1,815,020)	(1,952,720)	(2,103,800)	(21,723,636)
Insurance Expenses	(73,500)	(74,970)	(76,440)	(77,910)	(79,380)	(80,850)	(82,320)	(83,790)	(85,260)	(86,730)	(88,200)	(89,670)	(91,140)	(92,610)	(94,080)	(95,550)	(97,020)	(98,490)	(99,960)	(101,430)	(1,749,300)
Salaries for STS and RTG Drivers	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(64,800)	(1,296,000)
Salaries for Manager and Accountant	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(50,400)	(1,008,000)
OPEX	**(245,696)**	**(499,170)**	**(615,640)**	**(716,310)**	**(866,580)**	**(932,050)**	**(992,840)**	**(1,058,090)**	**(1,127,980)**	**(1,202,690)**	**(1,282,400)**	**(1,367,290)**	**(1,457,540)**	**(1,556,110)**	**(1,663,360)**	**(1,776,750)**	**(1,899,420)**	**(2,028,710)**	**(2,167,880)**	**(2,320,430)**	**(25,776,936)**
% of Revenue	**43%**	**18%**	**16%**	**15%**	**14%**	**14%**	**14%**	**14%**	**14%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**16%**	**15%**
EBITDA	**324,264**	**2,290,830**	**3,244,360**	**4,083,690**	**5,133,420**	**5,607,950**	**5,936,160**	**6,286,910**	**6,660,020**	**7,055,310**	**7,472,600**	**7,911,710**	**8,372,460**	**8,864,890**	**9,402,640**	**9,961,250**	**10,564,580**	**11,188,290**	**11,856,120**	**12,577,570**	**144,795,024**
% of Revenue	**57%**	**82%**	**84%**	**85%**	**86%**	**86%**	**86%**	**86%**	**86%**	**85%**	**85%**	**85%**	**85%**	**85%**	**85%**	**85%**	**85%**	**85%**	**85%**	**84%**	**85%**

III- Depreciation:

STS Depreciation	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(625,000)	(12,500,000)
RTG Depreciation	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(100,000)	(2,000,000)
Total Depreciation	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(725,000)**	**(14,500,000)**
% of Revenue	**127%**	**26%**	**19%**	**15%**	**12%**	**11%**	**10%**	**10%**	**9%**	**9%**	**8%**	**8%**	**7%**	**7%**	**7%**	**6%**	**6%**	**5%**	**5%**	**5%**	**9%**
Net Income	**(400,736)**	**1,565,830**	**2,519,360**	**3,358,690**	**4,408,420**	**4,882,950**	**5,211,160**	**5,561,910**	**5,935,020**	**6,330,310**	**6,747,600**	**7,186,710**	**7,647,460**	**8,139,890**	**8,677,640**	**9,236,250**	**9,839,580**	**10,463,290**	**11,131,120**	**11,852,570**	**130,295,024**
% of Revenue	**-70%**	**56%**	**65%**	**70%**	**73%**	**75%**	**75%**	**76%**	**76%**	**77%**	**77%**	**77%**	**78%**	**78%**	**78%**	**79%**	**79%**	**79%**	**79%**	**80%**	**76%**

Appendix C: Forecasted Cash Flow Statement

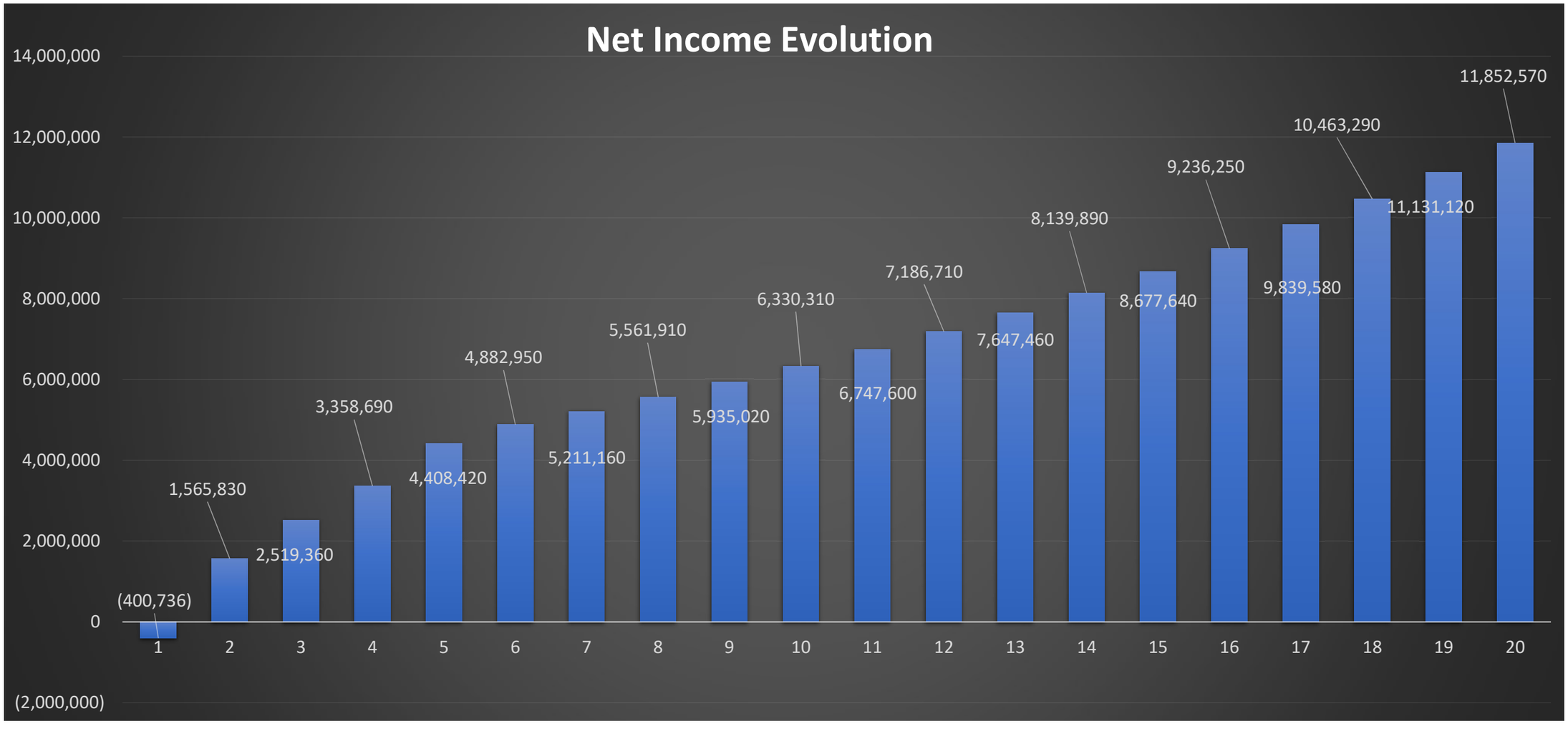
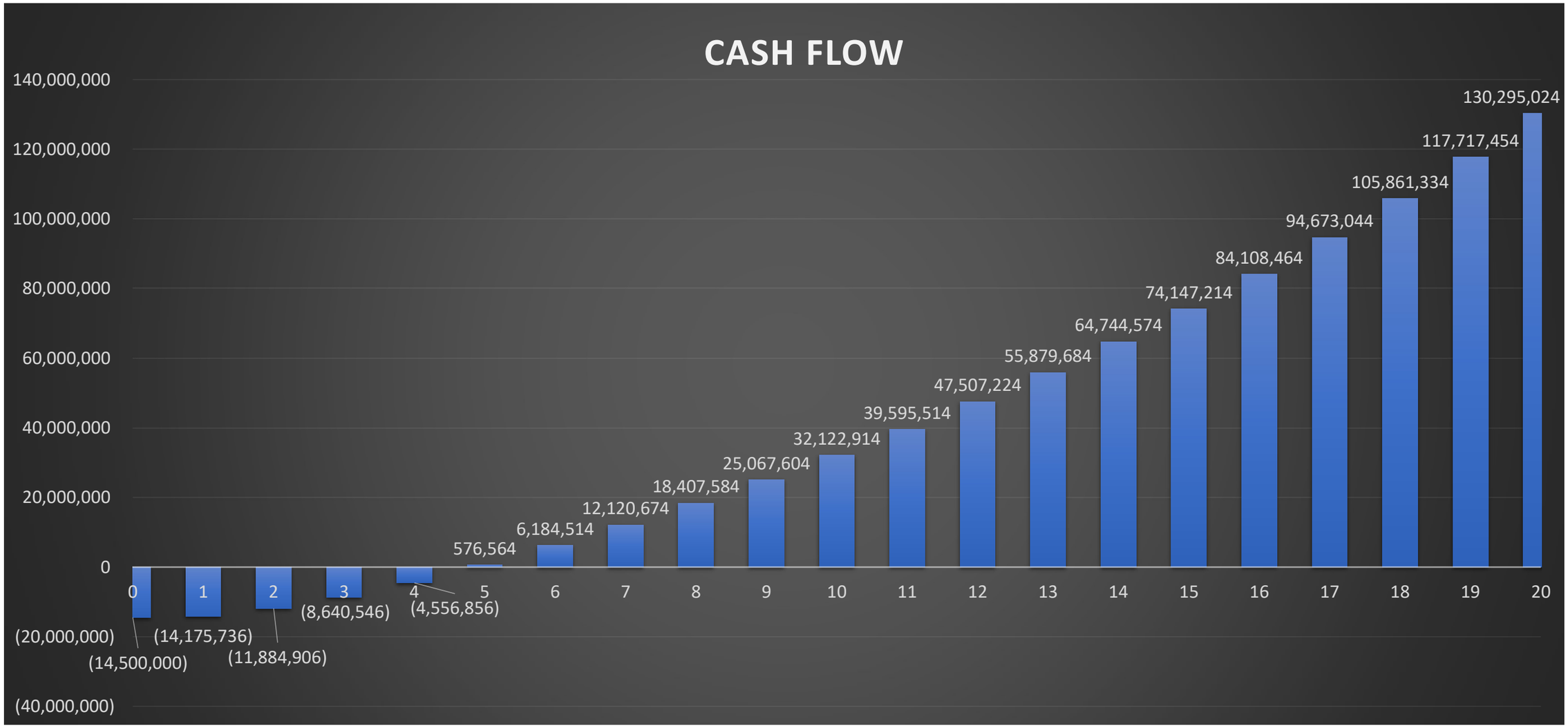
Business Plan
20 Years
Forecasted Cash Flow Statement

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total Cash in from Operations		**569,960**	**2,790,000**	**3,860,000**	**4,800,000**	**6,000,000**	**6,540,000**	**6,929,000**	**7,345,000**	**7,788,000**	**8,258,000**	**8,755,000**	**9,279,000**	**9,830,000**	**10,421,000**	**11,066,000**	**11,738,000**	**12,464,000**	**13,217,000**	**14,024,000**	**14,898,000**
Operational Cash-Out																					
Maintenance and Repair		*(56,996)*	*(309,000)*	*(424,000)*	*(523,200)*	*(672,000)*	*(736,000)*	*(795,320)*	*(859,100)*	*(927,520)*	*(1,000,760)*	*(1,079,000)*	*(1,162,420)*	*(1,251,200)*	*(1,348,300)*	*(1,454,080)*	*(1,566,000)*	*(1,687,200)*	*(1,815,020)*	*(1,952,720)*	*(2,103,800)*
Insurance Expenses		*(73,500)*	*(74,970)*	*(76,440)*	*(77,910)*	*(79,380)*	*(80,850)*	*(82,320)*	*(83,790)*	*(85,260)*	*(86,730)*	*(88,200)*	*(89,670)*	*(91,140)*	*(92,610)*	*(94,080)*	*(95,550)*	*(97,020)*	*(98,490)*	*(99,960)*	*(101,430)*
Salaries for STS and RTG Drivers		*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*	*(64,800)*
Salaries for Manager and Accountant		*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*	*(50,400)*
Total Cash Out from Operations		**(245,696)**	**(499,170)**	**(615,640)**	**(716,310)**	**(866,580)**	**(932,050)**	**(992,840)**	**(1,058,090)**	**(1,127,980)**	**(1,202,690)**	**(1,282,400)**	**(1,367,290)**	**(1,457,540)**	**(1,556,110)**	**(1,663,360)**	**(1,776,750)**	**(1,899,420)**	**(2,028,710)**	**(2,167,880)**	**(2,320,430)**
Net Cash Flow from Operations		**324,264**	**2,290,830**	**3,244,360**	**4,083,690**	**5,133,420**	**5,607,950**	**5,936,160**	**6,286,910**	**6,660,020**	**7,055,310**	**7,472,600**	**7,911,710**	**8,372,460**	**8,864,890**	**9,402,640**	**9,961,250**	**10,564,580**	**11,188,290**	**11,856,120**	**12,577,570**
Cash Out for Investing Activities	**(14,500,000)**																				
Net Cash Flow for The Period	**(14,500,000)**	**324,264**	**2,290,830**	**3,244,360**	**4,083,690**	**5,133,420**	**5,607,950**	**5,936,160**	**6,286,910**	**6,660,020**	**7,055,310**	**7,472,600**	**7,911,710**	**8,372,460**	**8,864,890**	**9,402,640**	**9,961,250**	**10,564,580**	**11,188,290**	**11,856,120**	**12,577,570**
Cash Begininng Balance	**0**	**(14,500,000)**	**(14,175,736)**	**(11,884,906)**	**(8,640,546)**	**(4,556,856)**	**576,564**	**6,184,514**	**12,120,674**	**18,407,584**	**25,067,604**	**32,122,914**	**39,595,514**	**47,507,224**	**55,879,684**	**64,744,574**	**74,147,214**	**84,108,464**	**94,673,044**	**105,861,334**	**117,717,454**
Net Cash Flow Period End	**(14,500,000)**	**(14,175,736)**	**(11,884,906)**	**(8,640,546)**	**(4,556,856)**	**576,564**	**6,184,514**	**12,120,674**	**18,407,584**	**25,067,604**	**32,122,914**	**39,595,514**	**47,507,224**	**55,879,684**	**64,744,574**	**74,147,214**	**84,108,464**	**94,673,044**	**105,861,334**	**117,717,454**	**130,295,024**
PV of Cash Flow	**(14,500,000)**	**(12,887,033)**	**(9,822,236)**	**(6,491,770)**	**(3,112,394)**	**358,001**	**3,490,997**	**6,219,822**	**8,587,274**	**10,631,111**	**12,384,774**	**13,877,986**	**15,137,266**	**16,186,354**	**17,049,270**	**17,750,254**	**18,304,452**	**18,730,557**	**19,040,091**	**19,247,744**	**19,367,525**

Sum of DCF	**169,550,045**
Initial Outlay	**(14,500,000)**
NPV	**155,050,045**

IRR	**25%**
MIRR	**16%**

Appendix D: Net Income Evolution



Appendix E: Cash Flow