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WORLD MARITIME UNIVERSITY
Malmö, Sweden

COST AND BENEFIT ANALYSIS OF PORT PROJECTS INVESTMENT

A case study of Rades Container Terminal (Tunisia)

By

HOUCEM EDDINE CHERNI
Tunisia

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the reward of the degree of

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature):

(Date): 22 September 2020

Supervised by: Professor Shuo Ma

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Abstract

Title of Dissertation: **Cost and Benefit Analysis of Port Investment Projects: A case study of Rades Container Terminal (Tunisia)**

Degree: **Master of Science**

During the last decade Tunisia has made much political progress in the way towards democracy and significant steps forward in new open system of governance. However, the economic situation has not followed the positive political changes.
In fact, it has deteriorated since the revolution in 2011.

Ports are gates to international trade and the catalyst for national economic growth however, Tunisia has suffered in this area due to continued poor quality of services.
In this respect, Rades Container Terminal is the major asset for Tunisia's general cargo trade and through which more than 60% of the country's traffic passes. However, it losses 271,9 M€ annually to the national economy (OBG, 2016) because of its time and costs inefficiencies.

The study of different Port Performance Indicators has revealed that the losses are attributable to low cargo handling operations performance rates compared to regional and international standards mainly as a result of outdated equipment, inadequate port infrastructure for containerized traffic and the lack of storage areas due to long average dwell time of containers. Consequently, congestions, high turnaround time of container vessels, berth unavailability and frequent interruptions of the port logistics and supply chain have been observed. The attractiveness of the port has suffered due to the poor liner shipping connectivity and the introduction of congestion surcharges to containers shipped to or from Rades Terminal.

It is clear that urgent and adequate investment in infrastructure the terminal equipment was needed to allow for this important asset to reach its economic potential and to mitigate the mentioned losses to the national economy. This research looks into possible alternative investment projects to address the issue and has investigated their financial feasibility by applying a Cost and Benefit Analysis (CBA) that will allow for the choice of a suitable operating system for the terminal, enable the wise allocation of limited resources for the maximum long term profits and highlight the importance of port investments to avoid interruptions of the port logistics chain.

KEYWORDS: Container Terminal Efficiency, Port Logistics, Tunisia, National Economy, Port logistics, KPI, CBA, Port Investment Projects

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List of Abbreviations

BOT	Build, Operate and Transfer
CAPEX	Capital Expenses
CBA	Cost-Benefit Analysis
CBM	Condition Based Maintenance
CMMS	Computerized Maintenance Management System
DEA	Data Envelopment Analysis
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
IoT	Internet of Things
IRR	Internal Rate of Return
KPI	Key Performance Indicators
LPI	Logistics Performance Indicators
LSC	Liner Shipping Connectivity
MIRR	Modified Internal Rate of Return
NPV	Net Present Value
OBG	Oxford Business Group
OECD	Organization for Economic Co-operation and Development
OMMP	Office of Merchant Marine and Ports
OPEX	Operational Expenses
PSC	Port Community System
PPP	Public-Private Partnership
PV	Present Value
QPI	Quality Port Infrastructure
RCT	Rades Container Terminal
RMG	Rail Mounted Gantry cranes
ROI	Return On Investment
RoRo	Roll-on/Roll-off
RTG	Rubber Tyred Gantry cranes
STAM	Tunisian Stevedoring Company (Societe Tunisienne d'Acconage et de Manutention)
STS	Ship to Shore cranes
TEU	Twenty Equivalent Unit
TOS	Terminal Operating System
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital

Chapter 1. Introduction

1.1. Background and context

Trade has always been considered an important factor in the economic growth of nations. In observing the historical evolutionary trend between the world Gross Domestic Product (GDP) and global trade it was found that both variables were connected (WTO, 2018). Scholars have also come to the conclusion that trade is one of the drivers of economic growth, through analyzing the long term macroeconomic data of many countries, and they found that economic growth was the reason for an increase in growth in their trade during the same period (Frankel & Romer, 1999; Alcalá & Ciccone, 2004; Ortiz-Ospina, 2018).

Nowadays, seaborne trade accounts for a significant share of world trade with more than four fifth in volume and over 70% of value (United Nations Conference on Trade and Development [UNCTAD], 2018, 2019). Therefore, it is considered to be the biggest contributor to many countries' economies. Consequently, this huge cargo volume is handled by ports all over the world serving the global economy and the world supply chain.

In this context, ports are the backbone of this trade and represents the first interface for cargo exchange between sea and shore on one hand, and on the other hand, they are the gateways to securing such growth.

Despite all the uncertainty in the current global trade environment, statistics provided by UNCTAD (2019) show that seaborne trade keeps growing at a pace of 2.7% in volume during 2018 and it is predicted to continuously grow by 3.4% on average between 2019 and 2024, however, due to the unpredicted Covid-19 pandemic, seaborne trade growth will certainly be affected and forecasts may no longer be accurate.

In this respect, containerized general cargo is also gradually increasing its share of the world's cargo volume with a steady growth of at least 4% during the last 4 years (Statista, 2020a). As a consequence, 793.26 million Twenty Equivalent Units (TEUs) were handled in worldwide ports in 2018 with an increased rate of 4.7% (UNCTAD, 2019). Thanks to its modularity and flexibility, containers not only become the first choice for carrying goods by sea (Fenton et al., 2018) but also facilitate door to door services that increasingly are demanded by customers (Frankel, 1999).

Taking into account this fast growth rate in container traffic and the rise of new service demands and pressure, port terminals have to cope with the emerging challenges imposed by its stakeholders and the economic needs of the country.

On one hand, containers are carried by liner shipping companies that operate on defined routes with fixed schedules and with a certain number of port calls and rotations (WSC, n.d.). In this respect, liner shipping services are more time-sensitive while they must maintain low transit times, frequent services, remaining punctual and reliable (Notteboom, 2004). It has always been seen that ports are the black box to where most of the delays occur and high costs are embedded which are mainly caused by poor port performance that greatly affects shipping line schedules. As a consequence, in order to reduce losses, shipping companies increase their freight rate. Therefore, higher transport costs discourage foreign investment, limits the export of services, decreases employment opportunities and leads to a lower savings ratio. It has been estimated that doubling transport costs, decrease the rate of economic growth by more than 0.5%, it might be negligible but considering the long term effects it has a negative impact (Dwarakish & Salim, 2015, p. 297).

On the other hand, port as nodes of the entire logistics chain have to avoid a disruption to the supply chain and ensure the continuity of the firm's production. Avis et al. (2007) argues that poor logistics facilitation heavily impacts the country's competitive advantage in a way that the high logistics costs will be transferred to the final product price which might be higher than its competitors. The same perspective, Tovar et al. (2007) confirms that port operations have a direct impact on some economic factors such as export competitiveness and final import price which ultimately affect economic development.

Beside the importance of cost and time, today's just-in-time production process requires the need for a reliable and predictable shipping delivery (Munim & Schramm, 2018), and poor logistical performance generates higher inventory maintenance requirements for firms (Avis et al., 2010).
Bearing the above in mind the primary component of maritime transport logistics as a link to the global economy, port performances are crucial to reducing the total transport costs and promote the national economy.

Nowadays, there are more container terminals than piers, due to the time sensitivity of containerized general cargo, ports are evolving over time to provide efficient operational services and better logistical solutions in a cost effective way. In this context, port operational performances are paramount to port infrastructure as well as its superstructure which are the principle tools to providing high performance levels. Actually, what differentiate the countries' logistics performances and seaborne trade is the quality of the port's infrastructure (Munim & Schramm, 2018)
Investing in port infrastructure will foster economic development, since quality infrastructure permits handling more cargo in a shorter time period with the same amount of resources but at a lower unit cost (Chang & Talley, 2019). Unfortunately, the rapid growth of seaborne trade, the evolution of globalization, alliances, big shipping companies merging and the scale of ship enlargement makes port adaptation to this fast change a very challenging task especially in terms of the development of infrastructure and investments. (Xiao et al., 2016)

Nevertheless, an estimation shows that there was a 10% increase in the overall quality of infrastructure measured by Logistics Performance Index (LPI) would increase seaborne trade by 50% (ITF, 2016, P. 77).
However, ports are capital driven and investments in infrastructure are very expensive. To allocate public resources, which are naturally limited, governments have to firstly justify the need for the development of a larger infrastructure facility and calculate the precise economic impact that the country may assume or earn respectively in the case of making non-investment or investment decisions. Thereafter, they have to meticulously prioritize the investment of a specific project over others in the selection process by adopting a scientific approach ranking the different projects on a feasibility basis, including costs and their return on investment (ROI).
In this setting, Cost Benefit Analysis (CBA) is a widely utilized methodology by governments to deal with such tasks and helps to better allocate public funds to ensure that public investment will be used in an effective way.

1.2. Problem statement

UNCTAD (2019) has classified countries based on the time spent in ports for container ships. As shown in Figure 1, Tunisia was ranked as one of the top 10 slowest economies for container handling in 2018. In addition, the largest ship in terms of Gross tonnage doesn't exceed 18,000 which means that Tunisian ports can only handle Feeders of less than 1500 TEU of capacity.
Also, the average time spent in ports (4 days for relatively small ships) is considered very high, compared with the top ranking countries that deal with bigger ships in capacity, which can explain the uncompetitive nature of Tunisian ports.

Table 3.4 Ten highest- and lowest-ranking economies: Median time spent in port by container ships, 2018

Economy	Ranking, from fastest to slowest	Median time in port (days)	Average size of vessels (gross tons)	Size of largest vessel (gross tons)	Average age of vessels (years)	Total number of port calls in 2018
Faroe Islands	1	0.23	11 635	17 368	14	276
Saint Vincent and the Grenadines	2	0.28	13 325	18 358	11	114
Grenada	3	0.30	13 899	16 162	10	86
Gibraltar	4	0.31	11 187	35 878	14	40
Norway	5	0.33	8 377	21 586	15	3 536
Japan	6	0.35	17 334	217 617	12	38 238
Saint Lucia	7	0.40	12 620	16 162	11	137
Taiwan Province of China	8	0.46	29 444	217 617	14	15 616
Honduras	9	0.46	17 887	32 901	14	1 297
Denmark	10	0.49	21 242	214 286	13	1 171
Myanmar	147	2.77	14 676	25 165	19	355
Guinea-Bissau	148	2.86	13 278	25 294	17	59
Algeria	149	2.96	12 145	28 397	16	926
Bangladesh	150	2.97	18 306	94 511	12	1 338
Gambia	151	3.39	18 174	32 903	17	144
Guyana	152	3.53	22 575	27 279	8	65
Yemen	153	3.62	20 603	34 610	16	187
Tunisia	154	3.80	9 356	18 327	18	344
Sudan	155	4.31	26 581	73 899	16	182
Maldives	156	6.48	17 075	39 753	15	87
World		**0.70**	**38 520**	**217 673**	**13**	**454 016**

Figure 1. Median time spent in port by container ships in 2018 (UNCTAD, 2019)

Besides dealing with feeders it means that the country is not availing the benefits of the economies of scale, but it also means that the freight rate will be higher due to the accumulation of transshipments and poor port performances costs.

On the other hand, ports are looking to be more profitable in addition to only serving national economies in this competitive market in which they operate, and it is essential to increase performance in order to attract more customers. However, upgrading port performance is mostly related to investment either in infrastructure or superstructure. Sorgenfrei (2018, p. 44) confirmed that "*investments in port and terminal infra- and superstructure are often very high, with costs for a new terminal easily reaching one billion USD*". In this respect, to provide the appropriate equipment and tools, ports have to bear huge expenses.

Moreover, port authorities as both a public asset and business entity have to allocate limited public funds to well targeted investments in projects that have the highest profit return, and generating economic growth and social wealth to ensure port sustainability. Unfortunately, this task is quite difficult and a tricky for decision makers.

1.3. Research aim and objectives

The aim of this research is to firstly, provide an insight into the Rades Container Terminal (RCT) which is the main terminal in Tunisia in terms of annual container throughput, then to investigate and identify the causes behind the high median time spent by container ships and find the answer to the question to the ranking that Tunisia is one of top 10 weakest economies handling container ships. Thereafter, the second aim is to identify solutions to the above problems.

To reach these goals, the study will have the following objectives:

1. Identify the root causes of deficiencies that might occur on berth, yard and gate operations affecting their overall performances.

2. To recognize the bottleneck where Rades port is not performing using comparative analysis of Key Performance Indicators (KPIs) with other regional and international standards and benchmarks.

3. Propose solutions to the identified problems and compare those alternatives using CBA

4. Select the best alternative method to address the problem and recommend it to decision makers.

1.4. Research questions

This paper aims to address the following questions:

Research Question 1: What are the root causes that hinder Rades Container Terminal from fostering the national economy?

Research Question 2: What is needed to resolve the problems to get the port back on the right developmental track and have it play its role in driving economic growth?

Research Question 3: How to classify and adopt the selected projects that might address port performance problems on the basis of ROI?

Research Question 4: What are the necessary measures that need to be taken in order to overcome the issues of implementing a solution and the feasibility of the selected project in the field?

1.5. Research methodology and methods

This research is founded on a quantitative methodology that describes the first stage of the status quo in the case study focusing on calculating the actual KPIs, then to compare it with standard benchmarks and world container terminals in the same region to find how much of the port is the norm and to identify the bottleneck.
A deductive reasoning will be conducted in a logical manner to investigate the causality relationship, between the port deficiencies and a potential infra- and superstructure quality and if necessary the needs for port investment. In light of this approach, the proposed solutions will be compared using CBA and the best solution will be recommended to decision makers.

In the process of elaborating on this research, secondary data and statistics has been collected from official sources of the port authority, the port operator and the ministry of transport. To a lesser extent, some other data will be gathered from existing databases such as AXS Marine and UNCTAD.

In addition, a literature review of relevant articles, World Bank, Tunisian Central Bank of Tunisia and the Organization for Economic Co-operation and Development's (OECD) data will be used to make appropriate assumptions in the course of setting a CBA analysis.

To analyze the gathered data, excel spreadsheets will be used as a tool for categorizing different information, to visually present the findings and to process different calculations of the CBA methodology.

1.6. Scope and limitations

The scope of this dissertation will study the enhancement of the RCT performance through assessing Port Performance Indicators (PPIs). This paper is limited also to the study of liner shipping services in Tunisia and the implications of port logistics in national economy.
In addition, the CBA methodology will consider the projects that are not yet finished (*ex ante*) or the ongoing ones in the course of analyzing and ranking different solutions.

1.7. Structure of the dissertation

The next chapter will look at the literature review highlighting the role of ports in the national economy, the importance of using PPIs as a tool for assessing port efficiency and as a method for port development decisions, the impact of port infrastructure and the investment and use of the CBA in public asset investment assessment and as a decision making tool.

Chapter Three includes the general description of the case study, also present the different KPIs, identify the bottleneck of the port performance and highlight some of the impacts of this on the national economy.

Thereafter, the CBA will be applied to compare and identify solutions and to help in the adoption of the best alternative based on profitability criteria which will take place in Chapter Four.

Chapter Five discuss the findings, also touches the challenges for implementation and providing recommendations to decision makers.

Finally, Chapter Six will conclude the research and highlight its limitations.

Chapter 2. Literature review

2.1 Role of ports in national economy

Ports as nodes in the maritime logistics and transport chain and play an important role as a platform for trade exchange, they foster the growth in the service sector and provide jobs directly and indirectly to people in the surrounding areas (Santos et al., 2018).
For instance, they are a catalyst for different economic activities to be agglomerated in its vicinity for the facilitation that can provide in terms of added value logistics services, intermodal transport integration and overall costs minimization which had a multiplier effect on local, regional and national economy (Deng, Lu, & Xiao, 2013)

Notteboom, Pallis and Rodrigue (2020) have described ports as "Funnels" to economic development as the following figure shows.

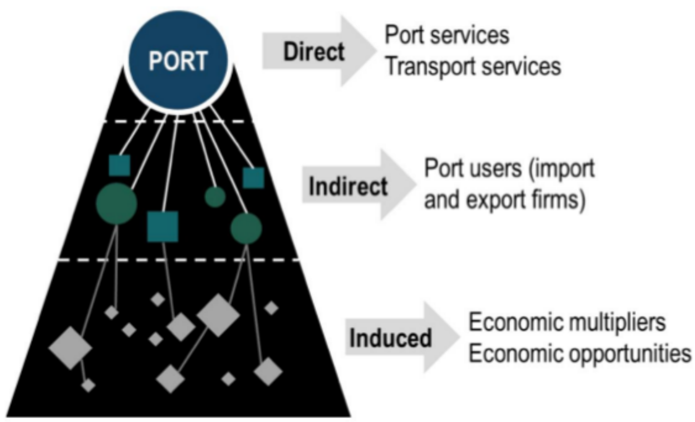


Figure 2. Ports as a funnel to economic development (Notteboom et al., 2020)

The authors have classified the effects of ports into three different categories:

- Direct benefits derived from port activity which generate revenue from ships and cargo dues as well as incomes from concession and land rental agreements.

- Indirect benefits involving cost cutting that the port provide to its users and customers raised from the reduction of operating, transport and interest cost related to the firm's inventory, all gained from efficient port operations, time saving measures and logistical integration solutions.

- Induced benefits which are reflected in job creation in port related activities, incomes earned by industries providing supplies and services to the port and which indirectly also creates jobs.

Integration into the global supply chain in the last decades has resulted in higher inter and intra port competition and the growing demand for integrated logistics services, ports become more than just piers that focus only in cargo handling. Therefore, such integration allows collaboration between port operators and different stakeholders in the supply chain to improve reliability, predictability of shipping delivery, on time performance and minimizing the overall transport costs (Han, 2018).

Increasing port competition has also pressed ports to extend their hinterland coverage to areas ignored before (Marcadon, 1999) and implementing dry ports (Jeevan et al., 2019) which improved inland connectivity, encouraged firms to be more productive and eased the import and export of goods in previously isolated zones (Paardenkooper, 2019). On the shipping side, Marcadon (1999) has also confirmed that such wide coverage motivates shippers and carriers to call into such ports where there is an opportunity for higher cargo volumes and to establish economies of scale. In this regard, important shippers and shipping lines mainly choose to call into a specific port for the logistic chain solution that it can provide (Notteboom & Yap, 2012).

As a result of having good hinterland and maritime connectivity this avails the national economy with the benefits of economies of scale and supports the competitiveness of exported product in the international markets by reducing its final prices. Jouili (2019) has comes to a conclusion that seaport infrastructure, logistical performance and shipping connectivity has had a positive impact on export and national economy in general.

Furthermore, most of the industrial zones are mainly located on port borders or in its immediate hinterland driven by the fact that today's port centric logistics and port free trade zones are more cost efficient locations and providing more added value services and logistic solutions (Santos et al., 2018; Alavi et al., 2018). This has created a competitive advantage that attract industries and direct foreign investments (FDI).

The impact of port logistics on economic growth has been studied by many scholars who found a positive relationship between the two variables in the scope of specific ports and regions such as Shanghai, The Pearl river delta, Rotterdam and so many others Asian and European areas (Shen & Yang, 2010; Zhang & Ning, 2012; Bottasso et al., 2014; Artal-Tur et al., 2016; Yudhistira & Sofiyandi, 2018; Sun & Yu, 2019).

In contrast, Notteboom, Pallis, and Rodrigue (2020) have criticized the economic impact of ports arguing that existing literature is restricted to only the scope of studying single ports in a predefined and limited range which complicates the deduction of a general assessment. Thus, the authors claimed that port are becoming more capital driven, consuming more land and relying less on labor forces due to automation and digitization. Therefore, they admit that ports still have benefits in employment, however, the growth in the amount of cargo that goes through ports are competing for an insignificant increase in employment with less than 0.05 job per 100 tons, which is the weakest rate in the transport sector. Santos, Salvador and Soares (2018) also supported the idea that socioeconomic significance of ports could not be well assessed if taking the trend of port automation into consideration.

Narrowing the scope to ports is part and parcel of the holistic maritime logistics chain, ports have to ensure their central function is to efficiently transfer cargo between shore and sea in a cost efficient way and that reduces transport costs, and promotes the competitiveness of exported products and reducing final price of the imported ones.

In this context, port efficiency and performance are negatively linked to transport costs (Suárez-Alemán et al., 2016). Evidence from Latin America shows that doubling efficiency in two ports, reduces transport costs by halving the distance between them (Wilmsmeier, Hoffmann, & Sanchez, 2006). Similarly, increasing port efficiency from 25% to 75% decreases shipping costs by 12% in the same region (Dollar et al., 2002). Furthermore, the maritime transport costs could be reduced by 0.9 to 3.8% when there is only an 0.1% increase in port efficiency (Dollar et al., 2002; Clark et al., 2004; Blonigen & Wilson, 2008).

In addition, studies conducted on the countries located in the Indian and western Pacific Ocean have shown that increased efficiency in container port facilities gain significant benefits to their trade and economy. It concluded that if a given country becomes as efficient as the country with the most efficient port sectors in the mentioned area, it can reduce its average maritime transport costs by up to 14% and increase its exports by almost 2.2% (Herrera Dappe et al., 2017).

As conclusion, based on the previous research work and studies reviewed, this dissertation takes the view that the first contribution of ports to the national economy is to secure its core function of efficiently transferring cargoes from sea to land side to reduce the maritime transport and port logistics costs as Suárez-Alemán et al. (2016) suggest. Then, this study differs from previously mentioned studies who treated the subject from job creation point of view or developing additional logistics services such as Santos et al. (2018), Deng, Lu, & Xiao (2013) or Han (2018) suggest. This approach is taken because in Tunisia, ports still negatively impact the national economy by adding more costs to the maritime transport due to poor efficiency and cargo handling performance as Dollar et al (2002); Clark et al. (2004) and Blonigen & Wilson (2008) have previously addressed.

2.2 Port performance and indicators

Port performance is determined by how efficiently the port handles ships and cargo. There are a panoply of indicators that could be categorized in various ways and its

assessment could be viewed from different angles depending on the interest of the port's stakeholder.
Port performance stands for setting a course of KPIs that serve as a benchmark measure the quality of service levels and monitor the performance with the intended objectives and modern port management tends to line up with the port strategy planning (UNCTAD, 2016).

In focusing on performance management, the purposes of port manager is to improve efficiency and effectiveness in order to reduce costs and increase incomes (Woxenius, 2012) and to allocate the appropriate resources and respond quickly to the international market demand (Brooks & Pallis, 2013). Starting from the fact declared by Peter Drucker that "*you can't manage what you can't measure*", thus, measuring port performance could be made via indicators to be used by port organizations or companies to assess and measure their overall performance has on a particular activity which they are engaged in (Turi, Goncalves, & Mocan, 2014).

Sorgenfrei (2018, p. 40) stated that "*Port performance can be measured with a set of indicators, often referred to as Key Performance Indicators…they should provide insight for the port management into operational details of the key areas of port business. They can be used, first, to compare performance levels with targets and second, to observe industry trends in performance levels.*"
In this aim, researchers have been engaged in measuring port performances using various methodologies such as DEA (Díaz-Hernández et al., 2014; Talley et al., 2014; Wan et al., 2014), Stochastic Frontier Analysis (SFA) (Cullinane & Song, 2003; Ju & Liu, 2015; Suárez-Alemán et al., 2016), Free Disposal Hull (FDH) (Cullinane et al., 2005; Lu, 2014).

Although, what and how to measure and which criteria to adopt in evaluating port performance still depends on the perspective of different port stakeholders who naturally have different interests. In fact, ports are complex entities where a lot of activities have to be conducted from the arrival of the ship to the cargo left on the port premises. This process makes the study of ports difficult as a homogeneous unit as different tasks are conducted by various interveners (Lei & Bachmann, 2019). Dappe et al. (2017) highlighted that, due to this complexity, identifying consistent measures for port efficiency is a tricky job where literature on maritime logistics have struggled to clarify it. Furthermore, considering only the sheer size of traffic flow in ports, this does not reflect productivity, efficiency or responsiveness to customers. It could serve only as a criterion among others that shippers might consider in evaluating performance (American Association of Port Authorities [AAPA], n.d.)

However, the increased cargo volume handled in ports especially for containerized cargo and the furious competition between ports have stressed the need for establishing PPIs. In this context, Burns (2015, p.39) said "*As transportation nodes are handling increasingly larger cargo volumes, port authorities have been asked to measure and maximize their performances in terms of ships' turnaround time,* *efficiency, cargo operations, congestion and market concentration through their regional clients."*

Moreover, internal and external demands of measuring port performance by policymakers, port users and other stockholders in environmental and safety issues for example, have increased in the last year, leading port manager to deliver those indicators to a critical level (UNCTAD, 2016).

However, port cooperation in this process is still stagnant. Brooks and Pallis (2013) state that "*If ports do not proactively participate in efforts to bench their performance, we expect that a number of stakeholders will do it for them*". UNCTAD (2016) also estimated that in the next five-years performance benchmarking will take place in the areas of efficiency and effectiveness with or without participation from the ports while in the aim of measuring end to end supply chain management and improving their own competitiveness, port users will be more engaged in this process.

Actually, port performance is not a new topic, it has been addressed by UNCTAD in 1976 and 1987 where it established a set of indicators which ports have to follow and the rationale behind its settings.

Reviewing the Port Performance Indicator report issued by UNCTAD (1976), the following objectives from establishing PPIs were detected:

1. Collecting data to calculate PPIs can be used by port authorities in two ways, firstly to improve port operations and secondly to build up plans for future port development.

2. PPIs serve as indicators for key areas of operation with the aim to compare performance with targets and monitor the trend in performance levels, for example how the cranes move per hour could vary from month to month, so if a decline in performance is observed, actions have to be taken in order to recognize the deficiencies factors leading to this and proactively mitigate it. Thus, it is used as a feedback system for port operation performance (Figure 3).
3. PPIs are also used as factors for negotiating port congestion surcharges, port development, port tariff adjustment and investments decisions.

4. PPIs serve also as a reason to justify the necessity for strategic investment in ports and to prioritize the allocation of limited resources.

5. PPIs allow port managers as well to improve asset utilization by highlighting problems, then upgrading port services and reducing unit costs through appropriate interventions.

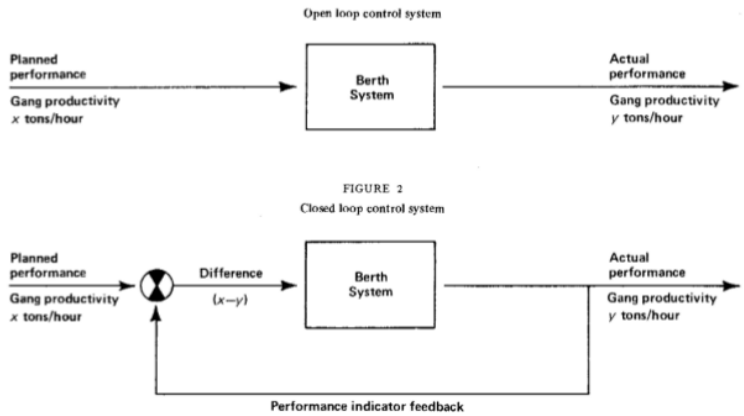


Figure 3. PPIs' port operations performance monitoring (UNCTAD, 1976)

In addition, the report is defining and delimit operations and financial indicators which are still relevant today in assessing port performance, as illustrated in the following figures.

Indicators	*Units*
Tonnage worked	Tons
Berth occupancy revenue per ton of cargo	Monetary units/ton
Cargo-handling revenue per ton of cargo	Monetary units/ton
Labour expenditure per ton of cargo	Monetary units/ton
Capital equipment expenditure per ton of cargo	Monetary units/ton
Contribution per ton of cargo	Monetary units/ton
Total contribution	Monetary units

Figure 4. Summary of financial indicators (UNCTAD, 1976)

Indicator	*Units*
Arrival late	Ships/day
Waiting time	Hours/ship
Service time	Hours/ship
Turn-round time	Hours/ship
Tonnage per ship	Tons/ship
Fraction of time berthed ships worked	–
Number of gangs employed per ship per shift	Gangs
Tons per ship-hour in port	Tons/hour
Tons per ship hour at berth	Tons/hour
Tons per gang-hour	Tons/gang-hour
Fraction of time gangs idle	–

Figure 5. Summary of operation indicators (UNCTAD, 1976)

More recently, UNCTAD (2016) provided more comprehensive approach in defining areas for port performance assessment by proposing a scorecard that introduce more issues that have to be considered as PPIs such as environmental and market indicators as shown in Figure 6.

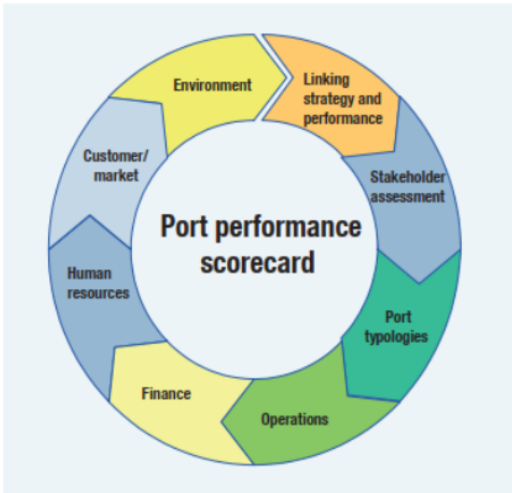


Figure 6. Port Performance scorecard components (UNCTAD, 2016)

Nowadays, the shift towards landlord of port governance and new models of organizational structure and ownership (Verhoeven, 2009; Brooks et al., 2017), mean port authorities lose the holistic and integrated role within port activity (Brooks et al., 2017), therefore, the establishment of PPIs becomes not only a duty of the port authority but also the responsibility of port operators and the other stakeholders directly involved in daily port operations. In this context, port performance is still a field of interest for researchers and scholars. Considering the fact that every port has its own characteristics therefore need to adopt different kinds of indicators, Morales-Fusca et al. (2016) have conducted research in 61 Mediterranean ports to find 77 where different KPIs have been used. After analysis, the authors classified 27 of them into six categories: Traffic, Financial, Operational, Customs procedures, Sustainability and Security.
Similarly, Ha. et al. (2017) have reviewed literature from 1970 to 2016 to find the analysis of the 16 principal KPIs and 60 other indices categorized also into six categories: Core activity, Supporting activity, Financial strength, Users satisfaction, Terminal supply chain integration and Sustainable growth.
Furthermore, Hinkka et al. (2018) listed indicators for evaluating terminal performance into five categories, all differentiating between KPIs which are written in normal text and performance indicators written in italic (Figure 7). The authors have also highlighted the degree of difficulty to obtain such indicators through simulation

or calculation models starting from the color green for the easier ones to the color red for the most difficult ones as shown in figure 7.

Operational	**Financial**	**Quality**	**Environmental**	**Safety**
Intermodal terminal throughput (volume)	Return on investment (ROI)	Turnaround time	Energy consumption per handled unit	Number of road accidents
Equipment utilization	Terminal's profitability	Waiting time	Carbon footprint per unit	Number of railway accidents
Gate utilization	Operating efficiency	Easiness of entry and exit from highways	CO, NOX, SOC, PM emissions	
Labour utilization rate	Operating revenues per unit	Easiness of entry and exit from rail network	Population exposed to high level traffic noise	
Storage area utilization	Operating benefits per unit	Delays produced (reliability) - road		
Rail track utilization	Direct jobs sustained from terminal activities	Delays produced (reliability) - railway		
Berth utilization	Indirect jobs sustained from terminal activities			
	Road and rail track maintenance cost			
Manoeuvring time	*Capital expenditures (CAPEX)*	*Unproductive time*	*Use of alternative fuels from total consumption*	*Accidents related to hazard cargo*
Service time	*Operational expenditures (OPEX)*			
Berthing time	*Corrective maintenance cost (equipment)*			
Idle time (equipment)	*Preventive maintenance cost (equipment)*			
	Corrective concrete structures maintenance cost			
	Preventive concrete structures maintenance cost			

Figure 7. List of indicators for evaluating terminal performance (Hinkka et al., 2018)

To summarize, the calculation of different PPIs depends on the nature of each port and the type of activities. In particular, considering the classification provided by (Hinkka et al., 2018), this study will consider some of the already mentioned operational, financial and quality performances. The case study is based on the available data and statistics with the aim of monitoring and detecting deficiencies therefore recognizing areas that need immediate interventions based on the feedback obtained from the performance indicators as UNCTAD (1976) described.

2.3 Impact of port infrastructure and investment

One of the most important factors that determine port performance is the Quality of Ports Infrastructure (QPI). An effective investment in port infrastructure or

superstructure could have a great impact on cargo throughput and efficiency of cargo handling operations in particular on trade and country economy on general.
Munim and Schramm (2018) investigates the impact of QPI by establishing the following framework (Figure 8).

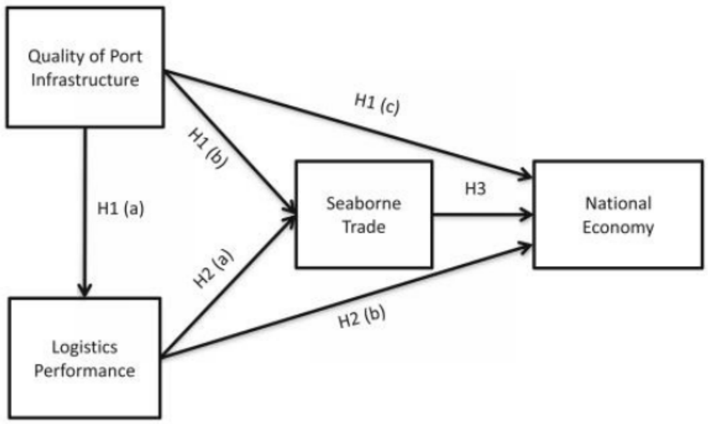


Figure 8. Impact of QPI on logistics performance, seaborne trade and national economy (Munim & Schramm, 2018)

The authors have found three positive impacts of QPI on logistics performance H1(a), seaborne trade H1(b) and national economy H1(c), and they come to a conclusion that:

- Better QPI such as having new equipment and technologies to improve the logistical performances of the country in the way of reducing the delivery of variability to the supply chain, reliability and delivery timeliness.

- Better QPI such as appropriate navigational channels depth, quay wall length and sufficient storage areas increases Liner Shipping Connectivity (LSC). In this respect, Wilmsmeier and Hoffmann (2008) have estimated that one standard deviation increase in LSC reduces the freight rate by 287 US$ in the Caribbean region. Similarly, one standard deviation in port infrastructure for an importing country reduces the freight rate by 225 US$.

- Observations also led to a conclusion that ports having better quality infrastructure are more efficient and have better logistics performances, thus, attract more FDIs to the country (Panayides et al., 2015).

Consequently, if the QPI is not continuously improved or maintained, it might have a substantial impact on the economy of the country. For this reason, investment in port infrastructure is required.

De Langen et al. (2018, p. 17) stated that investment in port infrastructure is needed to enhance performance, remove bottlenecks and ensure the sustainable function of ports as an efficient gateway to manufacturing and logistics clusters.
The authors (p. 23) have distinguished twelve types of infrastructure investments that could take place either in upgrading existing facilities or constructing new ones, they also saw the potential value created by investing in each category as the next figure highlights.

Type of port infrastructure	Potential economic value creation [31]	Potential societal value creation
Maritime access	Reduced unit shipping costs in case of improved maritime access (for larger ships). Reduced risk of catastrophes and port blockages if the works improve resilience	Increased trade as a result of reduced import/export costs; increased safety. Reduced environmental footprint and better air quality if investments enable deployment of more efficient and state-of the art ships and/or a shift of cargo flows to the port closest to the cargo destination. In case of locks and breakwaters: flood protection
Basic port infrastructure	Reduced costs for present (and future) port users (shipping lines, tenants and shippers) in the port	Reduced environmental footprint if investments enable deployment of more fuel-efficient ships and/or a shift of cargo flows to the port closest to the cargo destination
Equipment and superstructure [32]	Value for port users through more capacity and/or higher productivity	Reduced environmental footprint if investments enable deployment of more fuel-efficient ships and/or a shift of cargo flows to the port closest to the cargo destination
Infrastructure for smooth transport flows in the port	Value for port users through lower generalised transport costs and efficiency	Reduced pollution through more efficient operations and/or more use of environmentally friendly transport modes
Energy-related infrastructure	Value for port users through lower production costs	Reduced emissions. Increased energy efficiency and energy independence
Rail transport connection	Value for port users through lower generalised transport costs	Increase of trade due to the extension of hinterland. Increased use of environmentally friendly transport modes and decreased carbon footprint
Road transport connection	Value for port users through lower generalised transport costs	Increased trade. Reduced emissions (e.g. due to reduced congestion) or local pollution (through removing traffic from urban areas)
Inland waterway transport connection	Value for port users through lower generalised transport costs	Increase of trade due to the extension of hinterland; reduction of the carbon footprint and road congestion
ICT/digital infrastructure	Value for port users through lower generalised transport costs	Reduction of emissions due to better utilization of assets (e.g. less empty trucking)
Intermodal/ multimodal terminals	Value for port users through lower generalised transport costs	Increase of trade due to the extension of hinterland. Increased use of environmentally friendly transport modes
Infrastructure for reducing environmental footprint	No direct economic value creation for port users, unless such infrastructure reduces costs of users to meet their environmental requirements (SECA, LNG, etc)	Reduced (local) pollution and CO_2 emissions
Sites for logistics & manufacturing activities	Value for (future) port tenants that benefit from a location in a port cluster	Support regional development through facilitation of investments in manufacturing and logistics

Table 1. Relevant types of ports infrastructure investments and its potential value creation (De Langen et al., 2018)

However, the selection of investment on one or more of these twelve categories has to be argued based on a pragmatic approach and the actual needs of that particular port.

Finally, as Munim and Schramm (2018) have highlighted the importance of QPI, this research is addressing the impact of low quality of port super-infrastructure of the case study in affecting port logistics performance and retaining the national economy growth. Nevertheless, as De Langen et al. (2018) have identified different types of port investment which are capital intensive by nature, this work will provide an accurate assessment on which infrastructure have to be upgraded basing on performance indicators and CBA in order to better allocate the limited resources and achieve the intended outcomes.

2.4. Cost Benefit Analysis

Cost benefit analysis was firstly used as a concept to evaluate the public utility of a project by assessing its costs and benefits (Mills, 2018) and served also to compare the net benefits between different projects (Ekelund et al., 1999) in order to give a sufficient justification to prioritize them among others (Fuguitt et al., 1999). It has been used by governments and international organizations to minimize the uncertainty of the evaluation of the potential benefit of public investment (Nas, 2016; Sarkar et al., 2017; Mishan & Quah, 2007).

According to Nas (2016), CBA is an "*evaluation procedure that provide a systematic and careful assessment of all costs and benefits relevant to projects under consideration… it's a method specifically developed for evaluation of public project… to ensure efficiency in resource allocation and to achieve maximum gains in social welfare*", which means that the CBA values the respective costs and benefits of a specific project mainly in the public sector taking into consideration the society pros and cons from developing such projects and all in safeguarding the available resources.
Mendez (1992) highlighted also that "*Cost-benefit analysis estimates and aggregates the monetary equivalent of the present and future social costs and benefits, from the citizens' point of view, for the public investment projects, in order to decide if these are in the public interest*". In this context, CBA allows public authorities to allocate resources for a project where the marginal social benefit is greater than the marginal social cost during its life cycle (MOŞTEANU & Iacob, 2007).
However, focusing on social benefit does not mean that government investments cannot achieve what private sector does. It can provide at the time a clearly monetary value profit as well as public prosperity.

To summarize all the above, CBA it is about listing all the costs on one side and the benefits on the other side, determining the future net benefit of similar projects then to classify them based on that value in the aim to certainly select the highest one in term of ROI.

In this case study that focus on public investment in a public infrastructure operated by a public entity, it is essential for the government to argue the selection criteria of a specific investment. In a world of uncertainty, high risk and limited resources, CBA can provide a clear vision about choosing between an alternative course that have the highest financial and social benefit even in short, medium or long term by allocating minimum resources.

From this perspective Boardman et al. (2001), distinguish between two main types of CBA. The ex-ante, that will be adopted in this paper, which is the standard CBA that is performed before the project process being and the ex post analysis that is conducted after the project has been completed. Between these two stages, a CBA analysis could be performed also for ongoing projects. The principle value of the ex-ante analysis is to help governments to select the best project, making “go” versus “no-go” decisions and which resources should be allocated to that specific project during the consideration stage.

At the end, the steps and methods of performing CBA in the case study will in due course be described in Chapter 4 of this research.

2.5 Conclusion

Most of the studies of port performances have been conducted in major container terminal around the world that handle millions of TEUs annually focusing on their contribution evolved from their development over years, but only few researches have looked into feeder ports in the Mediterranean and the North African region where most of them, contrary to developed countries ports, negatively impact economic growth due to their low performance.
In this paper, the implication of port performance and the quality of its infrastructure on the nation’s economy will be addressed, through the study of the principle container terminal in Tunisia and it will look at how the detected deficiencies could be mitigated by an efficient and effective investment in port infrastructure to foster their role as gates for international trade.

CHAPTER 3. Rades container terminal: The case study

3.1 General description

Rades Container Terminal (RCT) is considered as the principal asset for containerized cargo transit while in 2013, 76% of the total country container TEUs and 80% of rolling units were handled in this terminal (OMMP, n.d.). The port is governed under the Landlord model where the port authority belongs to the Office of Merchant Marine and Ports (OMMP) and operated by a state owned company (STAM). Further details regarding the port governance and structure are provided in Appendix A.

As the following table and figure detail, the terminal has as infrastructure of 3 berths with total quay wall lengths of 480 meters dedicated to container ships and 4 berths for Roll-on/Roll-off (RoRo) ships.

Figure 9. RCT Map (Alphaliner.com)

Navigational Approach							
Canal				Length		3.5 NM	
				Width		100 M	
				Depth		12 M	
Basin				Surface		80 Ha	
				Depth		10.5 M	
				Turning circle		430 M	
Berths							
Berth Number	1	2	3	4	5	6	7
Type	Container	RoRo	RoRo	RoRo	RoRo	Container	Container
Length (m)	150	150	150	150	150	180	150
Depth (m)	9	9	9	9	8	9	9.2
Storage Area							
Hangars of 2 Ha				Yard 48 Ha			

Table 2. RCT main infrastructure (ommp.nat.tn)

As shown in the above table, most of the berths are dredged to 9 meters which is sufficient for all RoRo but only adequate for small container ships. In addition, the quay lengths are not appropriate to accommodate larger container vessels.

3.2 RCT Performance Indicators

3.2.1 Container throughput

Based on statistics provided by the port authority starting from 2010 till 2019, the container volume that RCT handled during the last decade has been progressively decreased as the following figures shows.

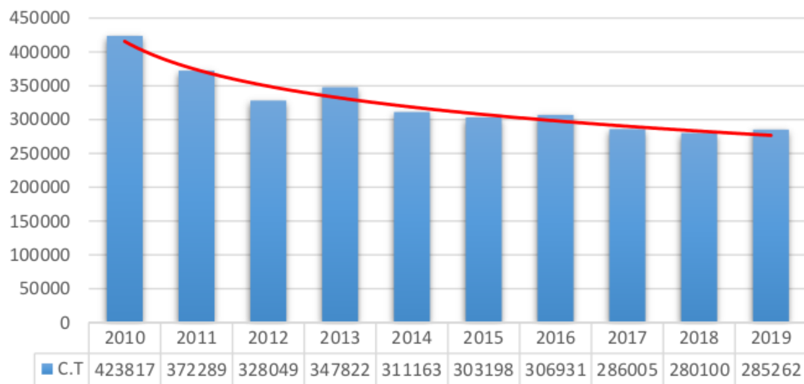


Figure 10. RCT Container throughputs (Source: Author)

The terminal has lost almost 33% of the TEUs recorded in 2010 compared with 2019. Considering that the total country containers TEUs were always around half-million, leads to the conclusion that RCT is losing its market share for other ports.

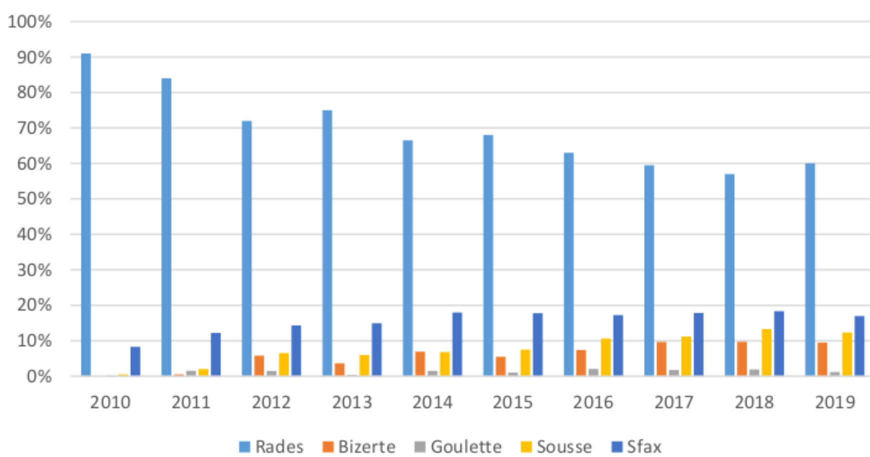


Figure 11. Tunisian container ports volume share evolution (2010-2019)

(Source: Author)

Observing the container traffic for the rest of the Tunisian container terminal, it shows in the above figure that the container volumes previously handled in Rades were redirected towards other terminals where in comparison with 2010, in 2019 the number of TEUs handled in Sfax and Bizerte ports increased by 10%, 12% in port of Sousse and some container traffic (between 1 to 2%) was handled in the passenger port of La Goulette. One of the relevant reasons for ships to call in other ports is the unavailability of berths in RCT, therefore the examination of other PPIs such as waiting time, berth occupancy, loading and unloading operation rates, are able to explain the root causes that may lead to the decrease in RCT's activity.

3.2.2 Other RCT's PPI and Impacts

- Data collection:

In the aim of calculating the performance indicators, data was collected from AXS Marine databases for the year 2019 on a monthly basis. It provides the number of calls per ship per operator, vessel time in berth and number of TEUs per ship. As well, other data is provided from the OMMP and the Ministry of Transport such as the average waiting time, crane productivity, and container dwell time.

- Methodology:

In order to make an appropriate assessment, the container traffic in RCT must be distinguished between the volume carried by Roro and container ships. In this process, eight main liner shipping operators have been identified. Thereafter, having the number of calls of each ship type per operator, the number of TEUs that were carried and the time spent at berth (Table 3), different KPIs are established to compare performances between container handling operations for Roro and container ships and to calculate and compare the obtained results with benchmarks to detect deficiencies (Table 4). Calculation and data details are provided in Appendix B.

<table>
<tr><th>Liner shipping operator</th><th>Service Type</th><th colspan="2">% of containers carried from total throughput</th><th>Number of calls</th><th>Mean Turnaround time (h)</th><th>Average TEUs per ship call</th></tr>
<tr><td>CTN</td><td>RORO</td><td colspan="2">21%</td><td>132</td><td>31</td><td>752</td></tr>
<tr><td rowspan="2">CMA-CGM</td><td rowspan="2">Combined</td><td>Cont. Ships</td><td>7%</td><td>44</td><td>175</td><td>794</td></tr>
<tr><td>Roro</td><td>19%</td><td>158</td><td>19</td><td>585</td></tr>
<tr><td rowspan="2">MSC</td><td rowspan="2">Combined</td><td>Cont. Ships</td><td>1%</td><td>3</td><td>248</td><td>1118</td></tr>
<tr><td>Roro</td><td>13%</td><td>95</td><td>38</td><td>683</td></tr>
<tr><td>GRIMALDI</td><td>RORO</td><td colspan="2">10%</td><td>138</td><td>6.5</td><td>342</td></tr>
<tr><td>LINEA MESSINA</td><td>RORO</td><td colspan="2">4%</td><td>38</td><td>39</td><td>520</td></tr>
</table>

ARKAS	CONTAINER SHIPS	11%	51	89	1020
EXPRESS FEEDER GROUP	CONTAINER SHIPS	12%	64	151	876
SEALAND EU & MED	CONTAINER SHIPS	2%	13	170	877
Average Total	Roro	67%	561	27	576
	Cont. Ships	33%	175	166	937

Table 3. Liner shipping operator's performances

KPIs	Roro	Container Ships	Benchmarks	Remarks
TEUs per ship hour at berth	28	6 [1]	Lowest rate which make Tunisia ranked as one of top 10 slowest economies in container handling (Figure 1)	Considering only container ships
Crane gross productivity* (moves)	-	7	15-17 for mobile cranes 20-25 for Ship to Shore cranes (STS)	Hamburg Port Consulting (HPC), 2017
TEUs per quay crane	-	31.666 [2]	Drewry: 116.130 in Africa and 105.615 in South Europe 69.993 minimum in Africa	International Association of Ports and Harbors (IAPH), 2016
Average waiting time* (h)	6	219	-	More than 9 days
Berth occupancy rate [3]	-	95%	Drewry 65% Unctad 55%	

* Data provided by port authority

[1] Average container ships Turnaround time divided by average TEUs carried per ship

[2] 1/3 of container throughput in 2019 divided by 3 cranes, one crane per container berth

[3] Container ships total time spent at berth divided by total hour container berth available (362 working day/year x 24h x 3)

TEU per meter of quay	-	198 [4]	Drewry: 776 in Africa and 774 in South Europe. 380 as minimum rate in Africa, 526 in South Europe	International Association of Ports and Harbors (IAPH), 2016

Table 4. RCT's KPIs and Benchmarks

3.2.2.1 Roro shipping versus Container shipping lines performances

Results of the analysis of containers throughput and liner shipping operator's volume share show that two thirds of the total of TEUs handled in RCT in 2019 were carried by Roro ships. Therefore, it is unusually that containers are carried by Roro while the horizontal handling costs are usual higher than vertical operations. For instance, to accommodate a container onboard a roro vessel, it has to be loaded on a roll trailer which have to be rented for the whole voyage causing extra unit costs.

Beside the fact that the port is more efficient in handling roro ships (28 TEUs per hour and a waiting time of no more than 6 hours), however, it is not efficient from an economic perspective to use roro ships as container feeders while they have lower carrying capacity (576 for roro vs. 937 for container ships). For this reason, and in normal cases, liner shipping operators have to deploy more ships to maintain its schedule reliability. However, comparing turnaround time and waiting time for both services, it is more efficient for shipping companies to use Roro ships instead of container ships, even if it is costlier in normal circumstances but still more profitable in this case while to ensure one round for a short intra Mediterranean trip a container ship has to spend almost one month, therefore, shipping companies needs 3 to 4 ships to ensure weekly calls.
In this respect, MSC and CMA-CGM have changed their operations toward Roro service to call RCT, while only 3 and 44 calls have been provided respectively by their container ships in 2019 (Appendix A). According to Alphaliner (2018), MSC has also deployed in 2018 a Roro ship to connect RCT and Gioia Tauro port in Italy instead of its three container ships.

To conclude, it seems that some shipping companies have found solutions to avoid losses from operating container ships by deploying Roro ships instead but it still causes losses to the Tunisian economy making the unit costs higher and eradicate the advantages of economies of scale.

[4] 1/3 of container throughput in 2019 divided by 480 m length of container ship berths

3.2.2.2 High Turnaround and waiting time and low berth productivity

Summarizing Table 3, all obtained KPIs are below Benchmarks in Africa and southern European ports reflecting low performance and container handling operation inefficiency. In addition, the average turnaround time is about 7 days which is higher than recorded in the southern European ports which is around 0.5 to 1.5 days and from 2.5 to 5 days in the north of Africa as shown in the figure below.

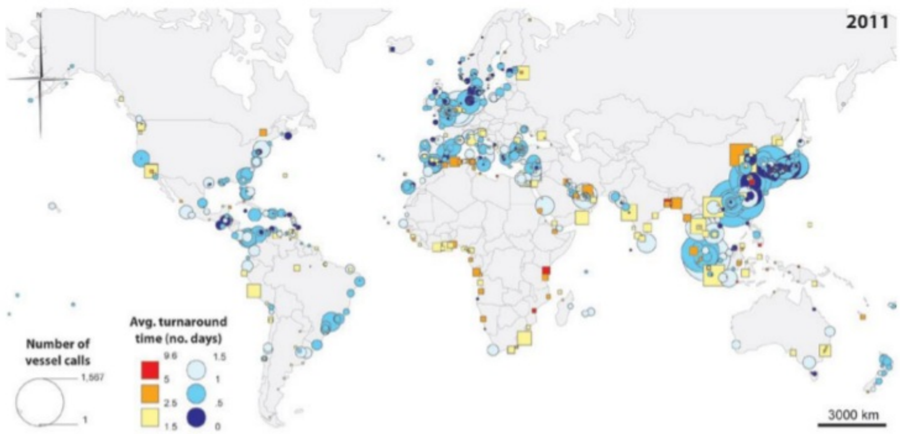


Figure 12. Average Turnaround time in ports (Ducruet & Merk, 2013)

In Appendix B it has been observed that SEALAND EU&MED stopped its service in March after 13 calls. Thus, handle an average of 937 TEUs container ships that have to stay 7 days in berth with an additional 9 days spent at anchorage caused by the low handling rate of 6 containers per hour. In this respect, Tunisia has lost over the last years in its LSC due to such port performances where index provided by UNCTAD has fallen from 11.46 in 2014 to 7.59 in 2019 (UNCTAD, 2020).

Clearly, the berth unavailability generates long waiting periods which is a result of congestion in the terminal despite the moderate volume that it handles. The main causes are related to three legs of cargo handling operations as described in Figure 13 that could be behind low performances:

1. Berth operation: Crane productivity, equipment utilization, equipment downtime,
2. Yard operation: Yard equipment, storage capacity, and terminal planning,
3. Gate operation: Container numbers leaving and entering the terminal

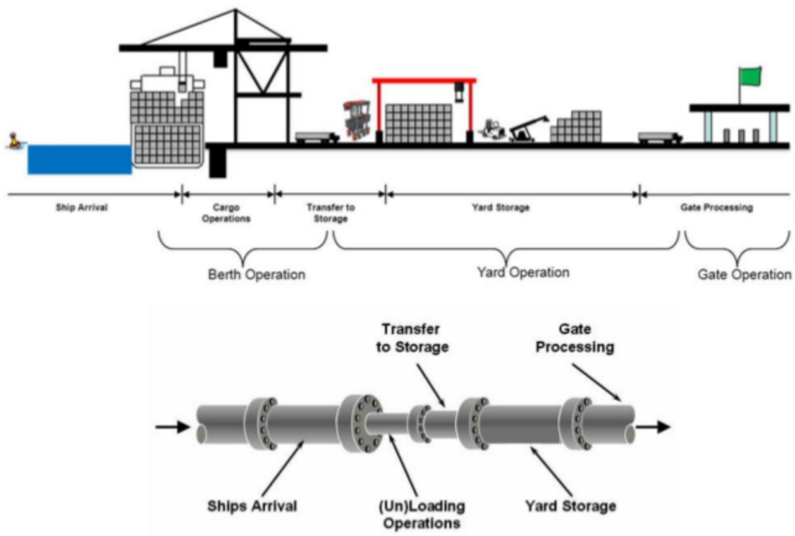


Figure 13. Typical container terminal operations (Steenken, Vob, & Stahlbock, 2004)

3.2.2.3 Cargo handling Performances

A container terminal is as strong as the weakest link in its logistics chain, then determining the drop in performance and an assessment of each operational stage must take place.

To operate the port, the STAM has 3 shifts of 6 hours each, working 362 days annually. The following table provided by the technical department of STAM indicates the different equipment utilized and the working statue of each type dated May 2019.

Equipment type	Number	Out of order	Availability rate
Mobile crane	8	4	50%
Roro truck	31	18	42%
Straddle carrier	21	8	38%
Reach stacker	9	4	56%
Forklift	6	3	50%
RTG[5]	6	1	83%

Table 5. Equipment and availability rate (STAM, 2019)

[5] Purchased in 2017 and starts operation in the end of 2019

The above table reveal that more than 50% of equipment were out of order when this information was collected. The situation might change overtime but it will not change the fact that shortage in equipment has affect the terminal performance. Furthermore, because of the uncertainty of which type of equipment is being utilized to berth-yard or yard-gate transfer, the terminal operating system could change overtime from reach stacker with chassis system to straddle carrier system or even RTG system, making it impossible to assess yard capacity, equipment productivity or other KPIs.

- Crane downtime and container transfer interruptions:

Therefore, the OMMP has monitored the cranes downtime and period where operations were stopped due to containers berth-yard transfer. Taking the month of January 2019 as a sample, the following table was established in light of container operation statistics provided by the OMMP. Calculation details are presented in Appendix B.

Total working hours	Suspended operation time (h)			Total
2232[6]	Crane breakdown	Berth to yard transfer	Yard to berth transfer	
	481	183	143.5	807.5
Daily operation suspension average/crane (h)	4	1.5	1	6.5
Percentage of suspension per category	59.5%	22.7%	17.8%	100%
Crane utilization	64%			
Berth utilization rate	75% [7]			

Table 6. Cranes working time statistics (Appendix B)

Analyzing results from the above table, the breakdown of cranes is often the major cause of cargo operation interruptions, to a lesser extent transfer from and to yard

[6] Number of available cranes (4) x Working hours per day (3 shifts x 6h) x working days in January (31)

[7] Considering 18 hours working time per day (18/24)

activities also contributes to the drop in performance clearly due to unavailability of equipment and difficulties to track containers in the yard while the terminal is not using any digitized Terminal Operating System (TOS) that helps to synchronize cargo flow and track containers in the terminal.
In addition, without taking into account interruptions due to other circumstances such as bad weather and Idle time[8], the crane utilization will be lower than 64% while the optimal rate have to be around 85 to 90%.

- Long container dwell time

On the other side, delays have also occurred due to yard congestion as result of long dwell time that reached 17 days in 2018, historically, container dwell times have never been below 14 days as the following table shows.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
	14	15	16	17	18	17	16	n/a	17

Table 7. Container dwell time (Source: Ministry of Transport (2015, 2016, 2018))

Long dwell time tremendously affect the capacity of the port yard which creates congestions and delivery delays as well as stack shifting that will inevitably increase affecting the entire logistics chain and handling costs.
A sensitivity analysis has been conducted by WSP a consultant company to assess the impact of dwell time on the yard capacity of RCT as the following figure shows.

Dwell time (Day)	Yard capacity (TEU)
8	768,382
9	683,006
10	614,706
11	558,823
12	512,255
13	472,850
14	439,075
15	409,804
16	384,191
17	361,592
18	341,503

Figure 14. Dwell time and yard capacity (WPS, 2020)

Comparing with Sub-Saharan Africa countries, Tunisia has a much higher dwell time than for example Kenya, 8.7 days or 3.9 days in South Africa (Beuran et al., 2012).

[8] Time from berthing time to cargo handling start and from cargo handling finish to the departure of the ship.

Limited productivity of handling operations and the ineffective management of the port land interface is one of the reasons for long dwell time, however, some others are the most influential factors which are beyond the control of the port management. For instance, customs formalities which is a significant pillar to assess the gate performance, seem to be the major cause for containers to be stuck in the port while according to a declaration by the head officer of the customs office in Rades port, Dean Gharbi Idriss said in a local channel interview, 13.000 customs infractions have been recorded only in the beginning of 2016 mainly due to incorrect declarations (Gharbi, 2016). Besides, clearance procedures take a longer time compared with countries in the region while Tunisia scored 2.38 in custom's LPI in 2018 against 2.54 for the Middle East and the North African region (World Bank, 2018a).
Furthermore, some shippers are using the port yard as a storage area due to low user costs and high level of security.

3.3 RCT identified bottleneck and implications on the economy

The limited performance and productivity at the port can be explained by the following factors identified from the above analysis of different PPIs:

- Non availability of berth for container vessels due to limited number of dedicated berth and long container ships lead time,
- Limited port infrastructure (draught and quay length) which limit the size of container vessels that can be accepted into the port,
- Low productivity of mobile cranes,
- Low utilization rate of equipment due to breakdowns,
- The terminal operating system depend on the availability of equipment which makes it difficult to establish a KPI feedback control system,
- Lack of 24/7 operations and digitization for daily terminal operations,
- Non linearity of quays which narrow the maneuvering space,
- The port authority has no financial autonomy to conduct investment in port infrastructure,
- Poor storage tariff strategies that contributed to the extension of container dwell time, and
- Absence of inter-port competition.

Given that 98% of Tunisia's foreign trade is conducted by sea making ports the principle nodes in the country's trade network (Oxford Business Group [OBG], 2018), however, unlike playing its role as a forester of economic growth, the poor RCT logistics negatively impacted the Tunisian economy.
For instance, due to its bad performance, shipping companies have introduced a port congestion surcharge applied to all containers heading and coming from RCT. For example, CMA-CGM has implemented an additional fee of 120US$/TEU since 2018 because of their high operating costs and the severe disruption to their services (CMA-CGM, 2018). Similarly, OOCL has increased their tariffs by 92 and 110 US$ applicable respectively to exported 20 and 40 feet containers and 120 to 141 US$ applicable to the imported ones (OOCL, n.d.). Hapag-Lloyd has also adopted the same approach by implementing a dynamic surcharges fee depending on the port performance where the amount fluctuated between 125 US$ in 2016 and 98 US$/ Imported TEU in 2018 with the highest recorded rate of 225 US$ applied in the month of May 2018 (Hapag-Lloyd, 2016; 2017a; 2017b; 2017c; 2018a; 2018b).

According to government figures, congestion at RCT has incurred added costs of 650 M€ in 2016, about 1.8% of the country's GDP for that year (OBG, 2018).
Moreover, the time and cost bottlenecks have made logistics expensive for firms operating in Tunisia which represent 20% of their operating costs and shippers have to pay an average of 469 US$ to export a container in terms of border compliance, much higher than Morocco which is estimated at only 156 US$ (World bank ,2018b).

In general, the whole logistics costs in Tunisia have risen from 12% of GDP in 2010 to 20% in 2016, higher than most emerging economies which is accounts for 15% and 10% in industrialized countries (OBG, 2017).

3.4 Needs for investment in RCT super and infrastructure

In order to reduce the impact of RCT on the logistics chain and to minimize its impact on the national economy and to avoid losses in foreign currency, port authorities and operators have to invest in both infrastructure and superstructure. However, the options on the kind of equipment to be utilized and port development projects have to be studied further before making any decisions. In that respect, allocating funds will be processed based on a CBA in the next chapter.

- Port operator options:

  Adopting a clear TOS is crucial to upgrade performance and monitor different KPIs. To do so, the port operator has options and can choose between different configurations as shown in the figure below.

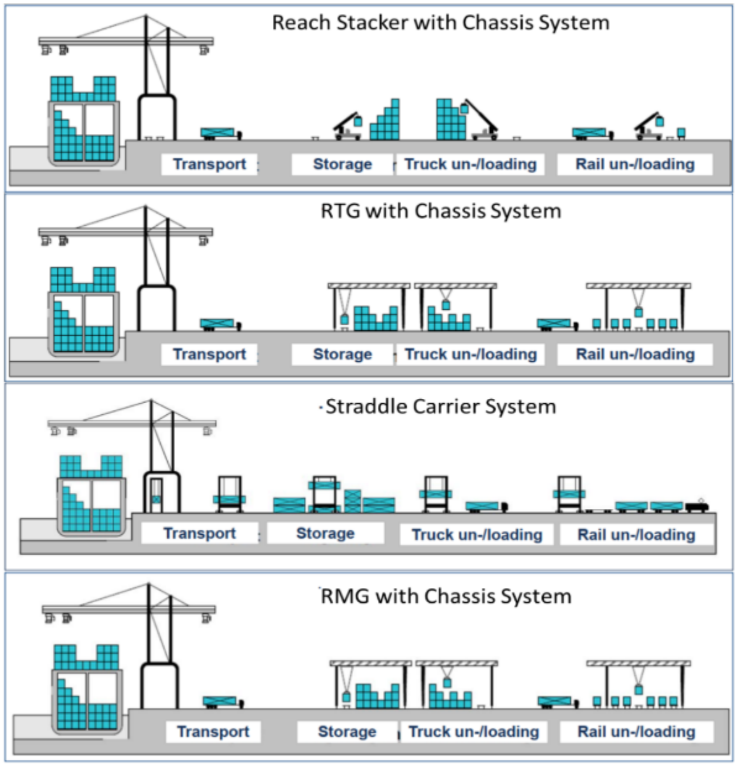


Figure 15. Different Terminal operating system options (Kraemer, 2020).

Considering the Terminal size and the annual container volume that handles, the Rail Mounted Gantry cranes (RMG) system could not be an appropriate option for the case study, for this reasons, it will not be considered in the upcoming analysis. Similarly, the reach stacker system is not an option either due to its low storage capacity of 500 TEU per hectare (Kalmar, n.d.).

- Port authority options:

Separating the traffic of trailers and containers on berth and yard operations should result on better management of the terminal. Also, extending berth length and providing sufficient depth will allow the terminal to accommodate bigger ships and realize to some extend the economy of scale. The project has to develop as well sufficient berth linearity for better cargo handling efficiency.

Chapter 4: Cost-Benefit Analysis of the different investment projects

In this case study, the analysis started in the previous chapter reveals the need for increase investment in port efficiency. The upcoming research aims to assess whether the intended project will be economically and financially beneficial, to help to adopt the best approach in terms of ROI and to estimate savings to the national economy after enhancing the port performances.

4.1 Data and Methodology

4.1.1 Data

In due course of this research data was collected from various sources and literature, therefore it could be categorized as follows:

- Financial data: Projects with different magnitude will be assumed to be financed through both debt and equity with respectively 67% and 33% ratio, 5.43% and 8% of the total interest rate (Libor + Spread) and a Front-end fee of 1% of the loan amount. Amortization is considered for 8 years on a semiannual repayment basis.

- Equipment performances, costs, life cycle and operational expenses (OPEX) data: Information is gathered from port equipment manufacturers, Global terminal operators and a study provided by the OMMP proposed by WPS in 2020, a consultant company that recently conducted research on ameliorating and developing RCT infrastructure and container handling operations. As well as reports from UNCTAD and the World Bank that are used as guidelines to assess maintenance and operational costs.

- Port and cargo dues: Port fees and charges are the main income for port authorities and the terminal operator which represent the main benefits. Tunisian seaport fees are determined by law Number 2017-915 dated August 16th, 2017. Also the maximum port operator charges are fixed by order of the Minister of Transport in January 16th, 2014 (The official Gazette of Republic of Tunisia [JORT], 2014; 2017). While the STAM is the only operator, the charges are counted to the maximum of what the law permits.

Further information and details on data sources and assumptions are provided in Appendix C for each proposed project.

4.1.2 Methodology

Stages to undertake CBA are almost standard. Based on the steps cited by Newcomer, Hatry, and Wholey (2015) and Boardman et al. (2001), the CBA proceedings will be as follow:

Step 1: Select the investment needed to increase the terminal performance. The projects have already been discussed in chapter 3 addressing identified deficiencies.

Step 2: Identify whose costs and benefits should be recognized

Recognize the particular group of people who will be impacted by the establishment of the project. In this case study, the port authority and operator will underpin the costs, however benefits, in general, will be reflected in the country's economy and specifically spread out to all port stakeholders.

Step 3: Distinguish and categorize costs and benefits

Consist of setting out the costs on one side and the benefits on the other side. It is about identifying as many as known impacts and the most significant ones. Costs and benefits could be tangible and intangible, financial and social, direct and indirect, real versus transfer (Musgrave & Musgrave, 1973). However, the disadvantage of CBA here is that, for certain, costs and benefits may not be all known. This research is considering the capital and operational expenses (CAPEX + OPEX) as the main costs of the project during its life cycle and the benefits are the financial income generated directly by the project activity.

Step 4: Project costs and the benefit over time

Is to predict the quantitatively impacts over the life of the project and thinking how costs and benefits could be changed over the time. These include different cash flows of profits generated during that period, maintenance costs, loans or any other financial support and payback period.

Step 5: Discount costs and benefits to obtain Present Value (PV)

In this stage, costs and benefits that will occur in longer life years of the project have to be discounted to its real value of today. This means that the value of an amount of money is much higher for a person or organization to get now rather than one, five or ten years later. The idea is that money has an opportunity cost for the public or investors, most people prefer to get the benefits now and if it will be received in the future, they will prefer to invest in other projects. For that reason, analysis has introduced a discount rate. It is a percentage that has to be deducted from benefits and costs which occurs in the future. In this case the financial discount rate will be considered as the Weighted Average Capital Cost (WACC) while projects are suggested to be financed by both debt and equity, it could be calculated using the following formula:

$$WACC = \frac{D}{D+E} Rd + \frac{E}{D+E} Re * (1 - \text{Tc})$$

D: Debt value
E: Equity value
Rd: Cost of debt
Re: Cost of equity
Tc: Corporate tax rate

The calculation of PV for costs and benefit is as follow:

$$PV\ (C,B) = \sum_{t=0}^{n} \frac{(B,C)_t}{(1+s)^t}$$

The costs (C) or Benefits (B) that occur in year t is converted to its present value by dividing it by $(1+s)^t$, where "s" is the discount rate and "n" is the number of years of the project life.

<u>Step 6:</u> Compute the Net Present Value (NPV) of each alternative

It is simply the difference between the PV of Benefits and the PV of Costs. In CBA the most important calculation is NPV. For a single alternative, it is obtained as follow:

$$NPV = PV(B) - PV(C)$$

When NPV value is greater than 0, then it is safe to say that particular project is profitable. If it is not, then it is better not to invest in it.
In the alternative where many projects are proposed, the selection criteria is based on choosing the project with the largest NPV. In fact, to supplement the calculation of NPV, the following formula helps decision makers to choose between potential projects.

- <u>Internal Rate of Return (IRR)</u>

As it name tells, IRR determine the rate of return of an investment of a particular project.

$$0 = NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t}$$

where:

CF= Net cash inflow during the period t
IRR=The internal rate of return
t=The number of time periods

IRR is generally used by organization to rank between competing investment projects. It aims to define the discount rate where NPV is zero. If IRR is greater than the discount rate, then the project is worth investing in, otherwise it is not profitable.

However, IRR assumes that the cash inflows are re-invested at IRR rate which overstate the expected return. Using Modified Internal Rate of Return (MIRR) allows avoiding this issue and permits to correctly assume the reinvestment at opportunity cost in a project. It could be calculated as follow:

$$MIRR = \sqrt[n]{\frac{FV\ (positive\ cash\ flows * Cost\ of\ capital)}{PV\ (initial\ outlays * financial\ cost)}} - 1$$

FV: The future value of positive cash flows at the cost of capital of the project
PV: The present value of negative cash flows at the financing cost of the project
n: Number of periods

Actually, IRR and MIRR are a financial indicator from a private investor point of view while NPV is an economic indicator of capital investment from the society point of view (Tang & John Tang, 2003). Ports combine the two perspective. It can generate financial incomes and social welfare at the same time. That is why in ranking potential project both of approaches will be considered.

<u>Step9:</u> Suggest recommendations where appropriate

The final stage in developing a CBA is to make a recommendation to decision makers to adopt projects that have the highest NPV, IRR and MIRR and to help them choose between the alternatives. At the end of the day, CBA tends to push toward efficient resource allocation to get the highest benefit from it. The decision making is still down to the politicians and bureaucratic lense. This research will try to be one input into the equation of decision making in the Rades port development plan.

4.2 Port operator investments

Different equipment investments are evaluated in the following section form berth side to yard and gate operations.

- Costs depend on the type of equipment and its specific operational expenses that is suggested to be escalated by 2% per 2 years.

Costs = CAPEX + OPEX

- However, benefits are calculated based on the specific handling tariff of each operation and the expected increasing cargo volume due to the amelioration of the terminal efficiency. According to WPS (2020), the expected container throughput in Rades would be around 650,000 TEU by 2040 for the base case (Figure 16) which could be accepted while in 2010 the terminal handled almost 424,000 TEUs with older types of equipment.

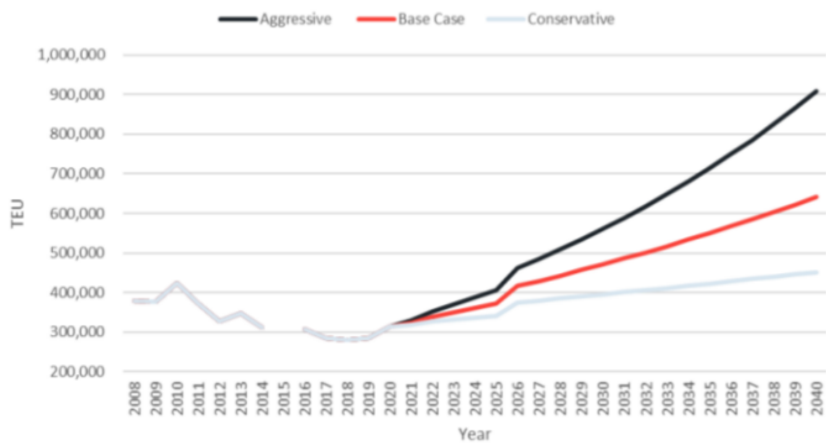


Figure 16. Annual container throughput projection in Rades from 2017-2040 (WPS, 2020)

Therefore, benefits will be calculated based on the yearly cargo volume increasing and the tariff escalation of 5% per 5 years that reflects the willingness of customers to pay for the quality of service during the period of each equipment type life cycle.

- Calculations are also conducted on a 24h operation basis divided into 3 shifts and 3 gangs (gang per container berth) for 362 p.a. working day. All types of equipment are estimated to operate at 80% of utilization rate and 10% in seasonal peaks.
- All calculation details are provided in Appendix C.

4.2.1 Ship-Shore interface

One of the major deficiencies in the terminal operations is the low performance of mobile cranes as well its high downtime rate. Investment in modern STS will increase the un/loading operation rate. The project consists of the investment in 3 new Panamax gantry cranes with estimated productivity of 22 moves/h and an expected 25-year life cycle based on the industry standard for STS cranes. The following table summarizes the obtained results.

Costs		
CAPEX	Cranes purchase cost	$ 30,000,000
	Rail installation	$ 2,000,000
	Total interest (Debt + Equity)	$ 8,538,216
	Front-end fees	$ 320,000
	Total	$ 40,858,216
OPEX	Manning	$ 3,360,000
	Energy	$ 12,796,652
	Maintenance	$ 28,587,549
	Inventory	$ 2,684,835
	Employee training	$ 42,444
	Total	$ 47,471,480
Benefits		
Cumulative Net incomes (25 years)		$ 439,504,029
Net before Tax		$ 345,080,693
Net after Tax		$ 258,810,0520
Results		
WACC		5,62%
NPV		$ 115,118,737
IRR		26%
MIRR		12%
Payback period (years)		4,09

Table 8. CBA for Panamax STS Gantry cranes

The project has a positive NPV, its IRR and MIRR are greater than the WACC leading to the conclusion that the project is profitable for the next 25 years and it could be paid within around 4 years after starting operations.

4.2.2 Berth-Yard transfer

The transfer rate of containers from and to the yard has to be synchronized with the ship-shore interface performance, thus, the amount of equipment is calculated on this basis. Also, yard capacity varies as well depending on the equipment type and their maneuvering capacity. With this in mind these conditions to transfer systems was adopted. A supplement investment in TOS is also considered to ensure better yard management and to avoid cargo flow interruptions.

A- Straddle carrier system

Based on calculations provided in Appendix C-II, 9 straddles are needed for container transfer in accordance with STS cranes peak performance and 8 moves/h straddle productivity. The expected life cycle was fixed as 12 years. The following table presents the results of the analysis.

Costs		
CAPEX	Straddles purchase cost	$ 9,000,000
	TOS purchase cost	$ 2,350,000
	TOS implementation	$ 3,500,000
	Total interest (Debt + Equity)	$ 3,962,266
	Front-end fees	$ 149,985
	Total	$ 18,962,251
OPEX	Manning	$ 4,032,000
	Energy	$ 9,792,373
	Maintenance	$ 12,960,000
	Inventory	$ 1,243,118
	Total	$ 28,027,491
Benefits		
Cumulative Net incomes (12 years)		$ 170,983,276
Net before Tax		$ 122,555,710
Net after Tax		$ 91,916,783
Results		
WACC		5,62%
NPV		$ 59,657,459
IRR		40%
MIRR		20%
Payback period (years)		2,86

Table 9. CBA for Straddles carrier system

Results show a positive NPV with IRR and MIRR higher than the WACC, therefore, the project could be accepted while it is profitable during its life cycle and its payback period is less than 3 years.

B- Tractor-trailer with Rubber Tyred Gantry cranes (RTG) system

The same approach in calculating the number of straddles is adopted in calculating the needed number of equipment (Appendix C-II). In the same context, Tractors and RTGs are estimated to have respectively a productivity rate of 8 and 20 moves/h, 15 and 20-year life cycle as well. The overall project life will be considered as 15 years only.

- Number of Tractors: 9
- Number of RTGs: 4
- Number of Trailers: 18

Considering the existed 5 RTGs purchased in 2017, thus there is no need to purchase additional ones. The results of the analysis are shown in the table below.

Costs		
CAPEX	Tractors purchase cost	$ 900,000
	Trailers purchase cost	$ 360,000
	TOS purchase cost	$ 2,350,000
	TOS implementation	$ 3,500,000
	Total interest (Debt + Equity)	$ 1,897,085
	Front-end fees	$ 71,100
	Total	$ 9,078,185
OPEX	Manning	$ 3,024,000
	Energy	$ 5,997,803
	Maintenance	$ 17,130,000
	Inventory	$ 1,565,300
	Total	$ 32,757,103
Benefits		
Cumulative Net incomes (15 years)		$ 235,459,888
Net before Tax		$ 191,403,117
Net after Tax		$ 143,552,337
Results		
WACC		5,62%
NPV		$ 86,509,547
IRR		76%
MIRR		25%
Payback period (years)		1,27

Table 10. CBA for Tractor-trailers with RTGs system

The obtained results lead to accepting this alternative as well while it also has a positive NPV and its IRR and MIRR are superior to the WACC with a short payback period of less than one year and a half.

On the whole, the CBA permit also, in this case, choose between the two systems by comparing different indicators such as in the following table.

System Type	Straddles	Tractor-trailers with RTGs
NPV	$ 59,657,459	$ 86,509,547
IRR	40%	76%
MIRR	20%	25%

Table 11. Straddle carriers Vs. Tractor-trailers with RTGs systems

The Tractor-trailers with RTGs systems have a higher ROI while all its indicators are greater than the straddle carrier system, thus, it is better to adopt it to ensure transfer between berths and the container yard. In addition, RTGs have a better utilization rate of the storage area with around 700-1000 TEU/ha against 400 TEU/ha for straddle carriers (HPC, 2017).

4.2.3 Yard-Gate interchange

Container delivery could also be ensured with even RTGs or Straddle carriers. Numbers of the required equipment is calculated based on the evolution of annual container moves and every equipment type productivity during the life cycle, taking into consideration the equipment utilization rate, peak time factor and extra moves for housekeeping.

A- Straddle carrier system:

Calculations to determine the required number of straddles are provided in Appendix C-III where 8 straddles have been determined. The STAM has already 8 available straddles purchased in 2016. Taking into consideration their remaining 8 years of service, the investment will occur in 2028 for new straddles. Therefore, the total life cycle of this project is extended to 20 years.

Costs		
CAPEX	Straddles purchase cost	$ 10,000,000
	Total interest (Debt + Equity)	$ 2,668,193
	Front-end fees	$ 100,000
	Total	$ 12,768,193
OPEX	Manning	$ 5,040,000
	Energy	$ 9,625,761
	Maintenance	$ 24,000,000
	Inventory	$ 2,117,470
	Total	$ 40,783,231
Benefits		
Cumulative Net incomes (20 years)		$ 214,852,032
Net before Tax		$ 241,811,987

Net after Tax	$ 181,358,990
Results	
WACC	5,62%
NPV	$ 96,408,397
IRR	55%
MIRR	19%
Payback period (years)	0,89

Table 12. CBA for Straddle-Truck interchange

The above table indicates favorable indicators to accept the project while it has a positive NPV for the next 20 years, IRR and MIRR greater than the WACC and less than 1-year payback period.

B- RTG system

Similarly, to the previous analysis, the terminal needs 3 RTGs for container delivery. Therefore, the terminal operator has to invest in two additional RTGs considering the remaining existing one. The CBA is highlighted in the next table.

Costs		
CAPEX	eRTG purchase cost	$ 5,000,000
	Total interest (Debt + Equity)	$ 1,334,096
	Front-end fees	$ 50,000
	Total	$ 6,384,096
OPEX	Manning	$ 2,016,000
	Energy	$ 1,411,775
	Maintenance	$ 8,000,000
	Inventory	$ 2,117,470
	Total	$ 13,545245
Benefits		
Cumulative Net incomes (20 years)		$ 361,844,063
Net before Tax		$ 340,482,573
Net after Tax		$ 255,361,930
Results		
WACC		5,62%
NPV		$ 134,305,363
IRR		124%
MIRR		29%
Payback period (years)		0,64

Table 13. CBA for RTG-Truck interchange

The above results indicate the profitability of the project similarly to the straddle system, however, both projects analysis favor the adoption of the RTG system as the following table shows.

System Type	Straddles	RTGs
NPV	$ 96,408,397	$ 134,305,363
IRR	55%	124%
MIRR	19%	29%

Table 14. Straddle carriers Vs. RTGs systems

In summary, combining all the above CBA results, the terminal operating system that RCT have to adopt is STS gantry cranes for the Ship-Shore interface for the three container berths and RTG with Tractor-trailers system for yard operations and different transfer activities.

4.2.4 Impact of superstructure investment on the national economy

Effective implementation of the suggested project would extend benefits to the overall supply chain intervenient, and secure savings to the national economy. Therefore, the reduction of unit costs will not only be realized by savings in port logistics but also in maritime transport while reducing ship's turnaround time, shipping lines will eliminate the port congestion surcharges. In the previous analysis, ships have to spend 15 days to handle an average of 937 TEUs. After the implementation of the project, typical feeder ships would only spend 1.5 days at berth.

$$Vessel\ time\ in\ berth = \frac{Ship\ carring\ capacity\ (TEUs)}{Crane\ No. * (Crane\ moves\ per\ h * Teu\ factor) * (daily\ working\ hours * equipment\ Utilization\ rate)} + \text{Idle time}$$

Idle time[9] is estimated to be around 2h, then the resulting time in berth equal to:

$$\frac{937}{1 * (22 * 1{,}5) * (24 * 80\%)} + 2 = 1.5\ day\ (37{,}5\ h)$$

As consequence, the berth would be available for the next ship within 1.5 day maximum. Thus, Ship's turnaround time will be reduced from 15 days to 3 days (1.5 days for cargo operation plus 1.5 days waiting time) saving 12 days of ship OPEX.

According to Drewry (2012), a feeder container ships carrying a capacity between 1000 and 2000 TEUs would have the following daily fix costs.

[9] Time between the ship arrival at berth and cargo operations commence and period between cargo operations ends and the ship sailing time.

Manning	$ 2,128
Insurance	$ 388
Stores	$ 269
Spares	$ 353
Lubricating oils	$ 650
Repair & Maintenance	$ 388
Management & Administration	$ 436
Total	$ 4,613
Total for 12 days	$ 55,356

Table 15. Container feeder daily OPEX (Drewry, 2012)

Hence, considering the 175 container ships calls in 2019, the national economy could save $ 9,687,300 p.a. It could save even more considering the demurrages applicable to late delivery of boxes.

Furthermore, the maximum annual throughput that berths could handle with new cranes could be calculated as follow:

$$Maximum\ berth's\ annual\ throughput\ (TEU) = No.of\ cranes\ x\ (Productivity\ rate\ x\ TEU\ factor)\ x\ (Daily\ working\ hours\ x\ Utilization\ rate)\ x\ Working\ days\ p.a.x\ berth\ occupancy\ rate$$

Then, the annual throughput would be equal to 412.853[10] TEU greater than 285,000 TEUs recorded in 2019 but still below 650,000 TEUs that the RCT is expected to reach by 2040. Therefore, it is necessary to expand the terminal while it is expected to reach its maximum capacity by 2026 (Figure 16).

4.3 Port Authority infrastructure investment

The port authority investment project aims to separate the container ship traffic from Roro traffic to ensure better port operation efficiency and reduce congestion. WPS (2020) has proposed the following project that consists of three main pillars in order to address the issue.

- Divide the terminal into two sub-terminals one for Roro and the other for container ships by transforming berth No. 1 into two Roro berths and to keep the peer No. 5 empty in order to allow more operational length to peer 6, then to accommodate bigger container ships. Peer No. 5 could be used as well when peer No. 6 is not expected to be used. Therefore, all Roro ships will be served in Terminal 1 starting from former peer 1 to peer 4 and container ships to be served in peer No. 6 to 9 where building two new berths (No. 8 and 9) have to

[10] Productivity rate = 22 moves/h; TEU factor = 1,5; Daily working hours = 24; Utilization rate = 80%; Working days p.a. = 362; Berth occupancy rate = 60%

take place with 530m quay wall length. Thus, all container ships will be accommodated in Terminal 2. Then, the linearity problem will be solved while continuous quay wall will be around 680 m long from berth 7 to berth 9.

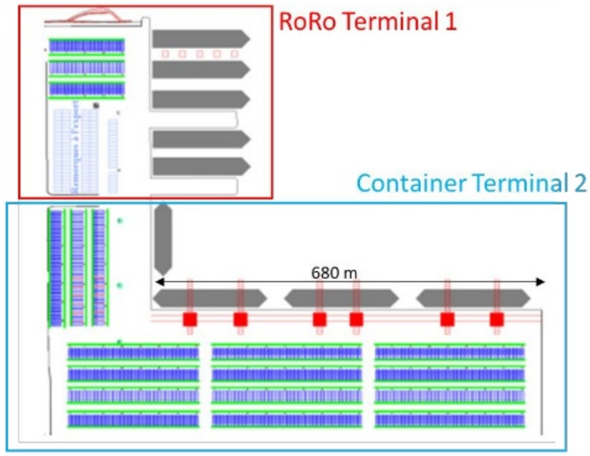


Figure 17. Proposed berth option

- The creation of new Gates which consist of building a new one for Terminal 1 and to supplement the existing gate of Terminal 2 with an additional one to split the incoming trucks from the leaving ones. All gates investment has considered to digitize all operations by the implementation of a smart gate system. This will reduce the gate congestion and reduce the gate-yard interchange time. The following figure illustrate the proposal.

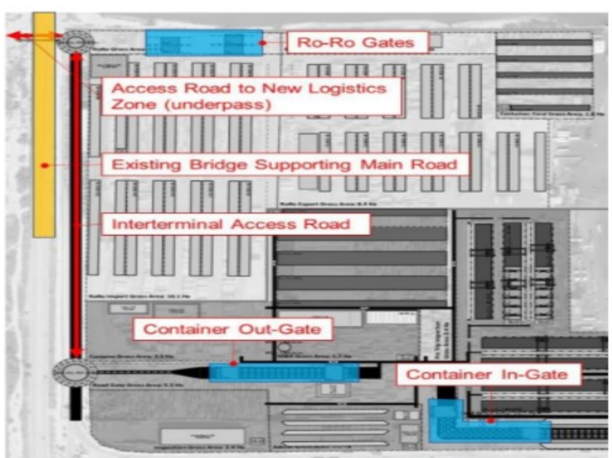


Figure 18. Proposed gate configuration

➢ Demolition of existing warehouse which will provide the terminal with additional 2 Ha and permitting to lay container stacks much closer to berths, reducing equipment travelling time, as a consequence increasing berth-yard transfer productivity.

Figure 19. Warehouses demolition

The upcoming CBA was conducted to assess whether the project will be financially viable and if it is profitable to the port authority or not during its expected life cycle. In this case, the project costs were identified by the consultant company WPS (2020) where it is expected to have a life cycle of 50 years before a major overhaul has to take place. On the other hand, benefits were calculated based on the generated incomes from vessel dues calling the container terminal and the expected container volume to be handled during that period while the port authority secure incomes of $1/TEU. JORT (2017) provides all the port tariffs that have been used in this analysis. In addition, the project assume that yard paving costs will be assumed by the port operator therefore, costs consider only the previously mentioned pillars. The following table summarizes results of the analysis, further details on data and calculations are provided in Appendix C-IV.

Costs		
Construction cost	New Wharf	$31,150,000
	Crane beam on piles	$7,840,000
	Earth work & basin dredging (-12m)	$16,130,000
	Terminal works-civil & yards	$5,550,000
	Execution engineering	$1,520,000
	construction contingencies	$12,750,000
	Total construction cost	$74,940,000
Design & supervision	Design fees	$2,500,000
	Construction supervision	$1,790,000

	Design & supervision contingencies	$880,000
	Total Design & Supervision costs	$5,170,000
T2 gate cost	Weighbridges	$1,000,000
	Scanners	$500,000
	OCR	$500,000
	Canopies	$700,000
	T2 total Gate cost	$2,700,000
T1 gate cost	Weighbridges	$600,000
	Scanners	$300,000
	OCR	$300,000
	T1 total Gate cost	$1,200,000
Demolition cost	Demolition T1	$310,000
	Demolition T2	$2,660,000
	Total demolition cost	$2,970,000
Total interest		$83,275,544
Total costs		$ 171,125,344
Benefits		
Cumulative incomes over 50 years		$ 248,304,509
Results		
WACC		6,28%
NPV		$ -13,673,933
IRR		2%
MIRR		4%
Payback period (years)		35.02

Table 16. CBA of port infrastructure development project

As a result, the project is not financially profitable to the port authority while its NPV is negative. As well, its IRR and MIRR are below the WACC. Nevertheless, it has long payback period of around 35 years. Thus, the port authority might not adopt the project with the present conditions while it cannot pay the cost of capital during the first 10 years (Appendix C-IV), however, considering its return to the national economy in establishing some extent economies of scale and its positive impact in reducing logistics costs, other benefits could be generated that might not be directly gained by the port authority but perceived by other stockholders.

Chapter 5: Research Findings, discussions and recommendations

5.1 Findings

- RCT superstructure investment

In assessing different KPIs obtained from the available data, it has been observed that RCT is far below performance benchmarks of similar container ports in the region. It has been found that low container handling operation efficiency in RCT is one of the major deficiencies that has led to long container ships turnaround time. The main causes are the shortage and non-availability of equipment, where one shift of 6 hours is wasted daily due to equipment breakdowns (Table 5&6).

As result, to ensure the continuity of the service, the port operator uses a combined operating system based on the availability of equipment which makes it difficult to monitor operational efficiency and equipment productivity. As a consequence, it has been identified that operations were interrupted at many legs of the port logistics chain causing congestion at berth and yard.

As a solution, investing in new equipment with new technologies will help to decongest the port and ensure smooth container flow from the ship side to gate delivery. Investing in new cranes is an urgent measure that the port operator has to take because of the frequent breakdowns of the existing cranes.
Replacing mobile cranes with STS gantry cranes will positively impact berths productivity by increasing hourly moves from 7 to 22 then increases the number of TEUs per crane from 31,666 to 130,333[11] annually even higher than benchmarks in Africa and South Europe (Table 4), an expected utilization rates up to 80% instead of 64% if proper maintenance is applied, rising annual throughput to 391.000 TEUs and berth productivity to 815[12] TEU/meter instead of 198 TEUs (Table 4).

However, other equipment that ensure different port logistics chain legs have to keep up with the STS productivity. For Berth-Yard transfer two system options were identified based on equipment storage capacity, the terminal size and the expected annual container throughput criteria. Similarly, for the Yard-Gate interface, two possible options were adopted.

The adoption of one of the preselected projects is based on results obtained by the CBA. Analysis conducted in chapter 4 helps decision makers to assess the discounted future incomes, thus, to decide whether to invest in such project or not. Furthermore,

[11] 391,000/3
[12] 391,000/480 (container berths length)

the CBA also helps to choose between the available equipment to be utilized that have similar productivity and expected return. Therefore, the choice of the RCT operating system was based on the ROI of projects that address the weakest chain of the terminal logistics performances taking into account various factors (Appendix C).

Table 17 below summarizes the results of all potential equipment investment projects that have been treated by the CBA. Hence, RCT operators have to opt for the RTG system for yard and container delivery operations along with Tractor trailer system for transfer operations and STS gantry cranes for Loading/Unloading activities. The straddle carrier system project is also profitable but RTG system has a higher return. Investment, has also considered implementing TOS software and its appropriate equipment in order to synchronize the terminal logistics chain and enhance tracking and traceability.

The expected results of implementing this project are mainly to reduce cargo handling operation from 7 days to 1.5, ship's waiting times will be reduced as well to 1,5 days instead of 9 days while the berth is expected to be occupied during that time and increasing berth availability to accommodate 417[13] container ship at 60% of the recommended berth occupancy rate instead of 175 calls p.a. with 95% of the actual occupancy rate.
Increasing numbers of calls will also permit increasing the annual container throughput up to 391,000[14] TEU instead of approximately 285,000 TEU in 2019. However, the terminal is expected to reach this capacity within the next 7 years as forecasted (Figure 17), thus, the investment project will mitigate actual deficiencies in the short term without any further investment in infrastructure but in the medium to long term the port authority has to consider expanding the terminal accordingly with the projected increasing cargo volume.

[13] [362 (working days p.a.) * 3 (berth no.) * 24 (berth availability p.d.) / 37,5 (ship time at berth)] * 60% (berth occupancy rate)
[14] 417 (expected no. of calls) * 937 (Average TEU/ship [Table 3])

Terminal Logistics Chain Leg	Suggested projects	Existing No. of equipment	Needed No. of equipment	CBA results				Ranking
				NPV	IRR	MIRR	Payback Period (years)	
Ship-Shore Interface	STS gantry cranes	-	3	$ 115,118,737	26%	12%	4,09	5
Berth-Yard Transfer	Straddle carrier system	8	9	$ 59,657,459	40%	20%	2,86	3
	RTG with chassis system	5	4	$ 86,509,547	76%	25%	1,27	2
Yard-Gate Interchange	Straddle carrier system	-	10	$ 96,408,397	55%	19%	0,89	4
	RTG system	1	3	$ 134,305,363	124%	29%	0,64	1

Table 17. CBA results summary of equipment investment

- RCT infrastructure investment

The investment project in Terminal infrastructure has considered three main aspects, firstly, to adapt the terminal capacity to the future demand and upgrade its capability to accommodate bigger ships, secondly, to separate Roro and container ships traffic and cargo flow by creating two terminals with separate digitized gates and finally, to provide more storage capacity by demolishing the existing warehouses which will also approximate container stacks to wharf. The CBA results indicate that the suggested project is not financially viable. The project is highly expensive and needs to generate income to the port authority within the next 50 years, even when considering that the yard and storage areas will be developed by the port operator and the project will be exonerated from Taxes and VAT (Value Added Tax), it is still unworthy from the port authority perspective.

Even though, the project is expected to generate indirect benefits to the port users and stakeholders and induces the development of additional services, create more economic opportunities and multiply chances for better shipping lines connectivity. Furthermore, more container berths should be constructed accordingly with the projected increasing cargo volumes otherwise the terminal will suffer again from congestion in the next few years despite the increasing operational efficiency after the terminal operator's investments. For instance, the total capacity of the terminal after enhancing the overall performance is expected to increase to 391.000 TEUs sufficient for the projected cargo volume until 2026, thereafter, terminal expansion is needed to be able to handle up to 650.000 TEUs by 2040. Building the additional 530 m linear quay walls and freeing berth No. 6 from Roro activities in berth No. 5 is expected to increase RCT capacity to 632.200[15] TEUs annually. This increases the need for this project otherwise RCT will suffer again from congestion by 2026 if container volume increased as predicted.
Thus, while construction takes around 5 years to complete, the port authority has to proactively consider expand the terminal for the benefit of the national economy and society.

5.2 Discussion and recommendations

Upgrading port infra-superstructure quality will positively impact terminal efficiency and performance, however, it has to be supplemented by other measures to realize the desirable outcomes.

- Importance of efficient management and planning

Efficient planning will ensure that all equipment performs at the intended productivity. On one side, good berth planning will avoid vessels from being crowded in the anchorage area and consequently reduce ship waiting time. The above analysis

[15] See Appendix C-IV

assumes that all vessels are expected to wait 37 hours which is the maximum time needed for the berth to be clear but with good berth scheduling the waiting time could be reduced if not eliminated and equipment will work properly as expected. To realize such synchronization, mainly the port authority, operator and shipping companies have to establish a weekly or monthly plan in a way that all vessels will be served at the time of their arrival or to inevitably wait for a certain short period. The Terminal KPIs always have to be monitored to proactively take measures when necessary in the aim to not affect the agreed planning. Meanwhile, information exchange between stakeholders is crucial, updates in cargo operations progress and ship's estimated time of arrival will provide a clear vision on the expected berth availability while either the port operator could adjust the cargo operation rate if possible or the ship may adjust its speed accordingly. From this perspective, developing a Port Community System (PCS) will facilitate real-time information exchange between the ship through its agent, the port authority and the terminal operator.

In addition, berth planning is closely related to vessel planning where for an efficient container loading and unloading operation, vessel stowage plans have to be priorly communicated to the operator to avoid delays relating to tracking and containers plotting.

On the other hand, ineffective management of the port land interface has also contributed to the degradation of services and delays while there is no clear delimitation between the container yard and trailers, in addition due to the bad management of truck delivery time where trucks are mostly contributing to congestions. Therefore, good planning is also about yard management and container delivery operations. The terminal operator must easily identify containers in the yard either for export or for gate delivery to avoid interruptions and effectively ensure the intended equipment utilization rate. Technology plays an important role in such cases, while the utilization of TOS software is broadly utilized in all container terminals in the world, it proves that investment in technology is also crucial for a well-functioning of the terminal. Furthermore, container delivery has to be scheduled out of peak times, thus, to cope with unexpected and increasing container volume, equipment reserved for delivery operations might be used for berth-yard interchange and vice versa. Again, well informed customers and port users through PSC will permit avoiding gate congestion and better yard management.

To conclude, proper planning, appropriate management and the use of technology are the keys for a successful investment.

- Terminal layout

An appropriate terminal layout will enhance equipment productivity by reducing travelling time, and energy cost and provide better yard storage capacity.

In this context, dedicating linear quay walls in the new terminal 2 and approximate storage yards by demolishing unnecessary warehouses will eliminate obstacles to the flow of cargo which will ameliorate handling operations.

Using the RTG system will also allow the establishment of a bloc layout rather than a linear layout which has a lower storage capacity due to the extended need of aisles for equipment maneuverability and safety.
Moreover, taking into account that the terminal handles only transit containers, perpendicular stacks would facilitate yard interchange operations by separating delivery trucks from the tractor trailer traffic and provide better storage area utilization compared to parallel configurations as shown in the Table below.

Stack configuration	Parallel to the berth	Perpendicular to the berth
Row	7	8
Bay	40	38
Tiers	4	4
Capacity (TEUs)	1120	1216

Table 18. Container stacks configuration capacity

Stacks were assumed to be 260 m in length equivalent to 40 TEUs using 7 wide plus truck lane RTG. As shown in the above table, the perpendicular configuration has a better ground utilization rate while it has a greater capacity of around 100 TEUs per stack. Hence, losing 2 bays for interchange interfaces is better than keeping an entire truck lane in comparison to a parallel configuration.

As a result, it is strongly recommended that the terminal transform from the conventional to an emerging terminal layout configuration (Figure 20) after the new equipment and infrastructure investments have been done.

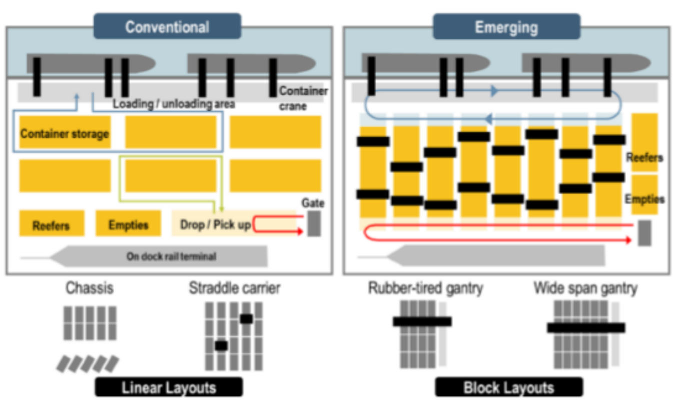


Figure 20. Conventional Vs. Emerging container terminal configuration (Rodrigue, 2020)

➢ Equipment maintenance and working hours

Investing in equipment without proper maintenance and refurbishment scheduling will rewind the terminal to its first situation and all deficiencies will appear again. It has been observed that less than half of the existing equipment is available (Table 5). Beside that the STAM does not accurately give the number and type of equipment that could be recovered, the aging factor could explain the reason for this low availability rate. However, bearing in mind that straddle carriers were purchased in 2016 and RTGs since 2017, already 62% and 17% respectively are out of order, which reveals a failure to properly maintain equipment.

Therefore, proper maintenance will extend the economic life of equipment and will prevent unexpected breakdowns and additional investment costs.
It is recommended in this case to monitor the working hours of each piece of equipment, perform preventive and routine maintenance on time, use new technologies such as sensors to detect mechanical performances and implement a Computerized Maintenance Management System (CMMS) to collect data, ensure maintenance intervention happens on time, keep records on spare parts and purchase costs and comply with recommended maintenance plans.

In this context, an efficient inventory will permit to avoid waiting time for importing spare parts, skillful employees are needed as well to make repairs rapidly therefore training is crucial from this perspective and conduct daily routine checks which is necessary to avoid unexpected breakdowns.
Furthermore, the new trend of equipment maintenance is heading toward Condition-Based Maintenance (CBM) rather than preventive maintenance which are scheduled in intervals or working hour basis. In this respect, CBM aims to extend the machine life, increase productivity and lower OPEX by relying on the actual equipment condition to dictate exactly when and what maintenance is required. For this purpose, substantial amounts of data are collected from different equipment through detectors, cameras and sensors, and transmitted to a data center via a high speed wireless network (5G) and then the data is analyzed to create patterns in real time to monitor how the equipment behaves. This system also known also as Internet of Things (IOT) permits detection and alerts when there is a drop of the equipments performance by surveilling time series data patterns then enabling timely decision making. Hence, it will avoid breakdowns, reduce downtime and decrease maintenance costs. The system could gradually be implemented in each of the RCT's logistics segments until the terminal has become fully digitized.

On the other side, working hours have to be extended to cover 24 hour operations daily which will increase the overall productivity. The case study has assumed that cargo handling operations to be secured in three 8 hours shifts instead of 6 hours and at an 80% equipment utilization rate that gives almost 5 hours daily for routine maintenance, breaks and shift changes.

- Dwell time problem

One of the biggest problems of RCT is the long dwell time of containers in the terminal yard that reaching 17 days reducing the annual terminal throughput capacity to 361,592 TEU (Figure 14). Some of the reasons causing these issues are beyond the control of the OMMP or the STAM because of customs clearances, administrative formality procedures and technical control on cargo are currently performed within the terminal causing excessive delays, are time consuming and do not generate any commercial revenue. As a result, all uncompliant containers cumulatively were stuck in storage areas for a long time reducing the terminal capacity and ultimately affecting its efficiency. Although, the relocation of these activities onto a new site out of the terminal could relieve congestions and minimize dwell time. Typically, customs clearance does not exceed 4 days in Tunisia (World Bank, 2018b) and considering all formalities, the assumption of 8 days of dwell time is achievable by accelerating the clearance and administrative processes. Therefore, the Tunisian government has to make those decisions not only to enhance the terminal efficiency but also to ameliorate the logistics chain reliability.

In this respect, the creation of an integrated management system that digitizes and computerizes administrative formalities, customs procedures, technical controls, transactions, licensing requirements and all international trade steps will simplify and accelerate procedures, then container transit time will tremendously reduce. Known also as single window, the system will link and coordinate all involved parties through a single digitized network point to transmit documents, deliver permits and proceed all needed transactions even before the ships arrival which will provide more transparency to shippers, eliminate unexpected additional formalities that extend dwell time and avoid high fines due to delays then reduce the final consignment costs. Consequently, digitization and new Information Technology systems will offer more simplicity and predictability of customs procedures which will speed up container delivery, reduce dwell time, minimize congestions and permit efficient berth and yard planning.

Despite that some new importers are not sufficiently familiarized with customs clearance procedures and administrative formalities to import goods which contributed to long dwell time, some other shippers are using the terminal as a storage area due to low tariffs imposed by the STAM which is highlighted in the following table.

Time period	Container storage tariffs/day ($)	
	20'	40' or more
From the 3rd to the 7th day	0,4	0,5
From 8th to 15th	1,8	2
16 days or more	4,6	6

Table 19. Container's storage tariffs (JORT, 2014)

Hence, low storage tariffs have aggravated the dwell time situation and it have to be revised urgently.

➢ Port governance and investment funding

As discussed in Appendix A, the structure and the governance model that RCT is operating reveal too many obstacles for securing funds for investments which could explain the aged and outdated port super-infrastructure. The total reluctant on the state budget, the absence of the port self-funding and the dependence to the government decisions eradicate the chances for the port authority to respond to the fast changes of the maritime transport. For instance, the national debt to the GDP ratio was 62,28% in 2016 and it is expected to reach 78,68% by the end of 2020 (Statista, 2020b), explaining the serious shortcoming of ports infrastructure due to the stagnated public investment. Results, it is no longer being possible to secure funds for national projects through debt financing.

However, financing public projects could be secured away from the government budget, loans or credits such as alliances co-funding stands for covering a part of the project costs through grants to governments from being members in regional or international union agreements, takes the case of the European Structural and Funds (ESIF), Connecting Europe Funds (CEF) and so many others. However, it might not be the case for the Tunisian government.

Another way of financing is to open the door for the private sector to invest in the infrastructure development project through Public Private Partnership (PPP).
The projects could be financed by private investor through:

- Built, Operate and Transfer contract (BOT) or derivative forms with the OMMP through long term arrangements. The private partner finance, build, operate and maintain the infrastructure for a specified period where the investor collects all vessels and cargo dues on top of cargo handling fees, then transfer the assets to the OMMP without any compensation at the end of the contract. This will shift all investment expenses and risks to investors and it will introduce at the same time an intra-port completion that will have an impact on increasing the quality of services at lower costs.

- Private Finance Initiative (PFI) where the investor builds the infrastructure without delegating the public service itself. After the project construction the asset is directly transferred to the port authority and the investor is reimbursed through a rent agreement with the port authority for a determined period (rarely achieved in the port sector).

- Institutional PPP (IPPP) which consist of cooperation between public and private parties through joint venture allowing private investors to hold corporation shares in return for his investment. It is more likely applicable to the STAM where the government can cede up to 49% of the corporate shares in order to secure funds for equipment purchase and to take advantage of the private know how in managing the company and its resources.

In this context, PPP is only feasible with the following measures:

- Deregulation and laws relaxation, consist of opening the public sector monopolies to private sector competition by partially eliminating governmental rules and preadaptation of laws that constitute a barrier for PPP.

- Corporatize the port authority to run on a commercialized basis by giving it the status of a private company while the public sector still retains ownership. The OMMP will operate under market discipline, decentralize decision making from the central government, regain control of its financial income, can get more flexibility on budgeting and procurement and can also resort to the IPPP financing solutions.

- Liberalize the cargo handling operations from public monopoly to set the stage to private companies to invest and operate in the terminal and to compete with the STAM which will provide better quality of service and price reductions.

To conclude, investing in the suggested projects will address the main detected deficiencies and bottlenecks of RCT and it will increase its efficiency and productivity, but a clear strategy, appropriate reforms, good planning and management and all the above mentioned conditions and recommendations are decisive to achieve the intended outcomes.

Chapter 6: Conclusion and limitations

6.1 Research conclusion

This research is a study of Rades Container Terminal that looks for reasons for the terminal low performance and its implication on the national economy. Thereafter, it examines possible solutions for the detected deficiencies and suggests the best alternative to take from the lenses of the CBA.

This paper has answered the following four main research questions:

RQ 1: *What are the root causes that hinder Rades container terminal from fostering the national economy?*

To answer this question, different KPIs of RCT were calculated from different data sources and comparing them to benchmarks of similar ports in the region and internationally, it has been revealed that the main problems are related to low operational performances that have led to high berth occupancy, berth unavailability and long vessels turnaround time. As a result, the country has lost in liner shipping connectivity due to the abandonment of shipping lines calling into the terminal, other companies findings solutions in carrying containers on board Roro ships causing higher unit costs and others imposing congestion surcharges to consignments, affecting the competitiveness of local product and incurring losses of foreign currency and to the national economy. Low operational performances are mainly related to the unavailability of equipment and frequent breakdowns resulting low productivity rates and excessive delays. In addition, the interference between container ships and Roro cargo traffic, shortages in container vessel berth numbers and inadequate infrastructure to accommodate bigger container feeders are leading to congestion problems deterioration and time losses. Long containers dwelling time is another issue that the terminal should deal with as it greatly affects the annual yard capacity.

RQ 2: *What is needed to resolve the problems to get the port back on the right developmental track and have it play its role in driving economic growth?*

Investing in new equipment and establishing a clear TOS was the short term solution to deal with low performance of container handling operations. An efficient cargo handling operation needs sophisticated equipment and appropriate maintenance. Thus, investing in new equipment and technologies will fosterer the terminals performance and result in lowering berth occupancy and vessel turnaround time. As a consequence, RCT would be able to accommodate more ships, increase its annual throughput and decrease the overall maritime logistics costs.

Enhancing RCT's performances will encourage shipping lines to again call in to the terminal which will increase annual container throughput in the medium and long term. Hence, infrastructure expansion will be needed in the future to cope with the expected and increasing cargo volume. For instance, investing in the terminal infrastructure consists of separating Roro and container activities, provide sufficient berth depth and linearity for container ships and ensure sufficient yard space by eliminating unnecessary warehouses. Gate operations also have to be adapted to the expected container volume growth. Therefore, it will realize to some extent economies of scale and a better quality of service at lower expenses.

RQ 3: *How to classify and adopt the selected projects that might address port performance problems on the basis of ROI?*

The use of CBA has permitted not only to classify potential projects that address the problem but also to assess its financial feasibility by projecting its future returns during their economic life cycle. It, hence, helped the decision makers to choose between alternatives and to decide whether to endorse the project or not. Firstly, by using the methodology, tractor-trailer with RTG system has been identified as the most profitable operation system rather than the straddle carrier system. Secondly, the analysis also suggests the purchase of STS gantry cranes to replace mobile cranes. Finally, the results obtained regarding port expansions show that the project is not financially profitable if evaluated for the port alone and in the short term, however, it has to be accepted as a strategic asset while considering its benefits to other stakeholders and to the national economy.

RQ 4: *What are the necessary measures that need to be taken in order to overcome the issues of implementing a solution and the feasibility of the selected project in the field?*

Mainly there are five pillars that should be considered to ensure the success of the investment plan. Firstly, good management practices and the planning of berth, yard and gate operations. Secondly, the establishment of an appropriate terminal layout and moving from conventional to a more advanced terminal configuration. Thirdly, appropriate equipment maintenance and monitoring policy and plans that are needed in order to achieve the expected productivity. Fourthly, the digitization of administrative and customs formalities which should be implemented to accelerate the import/export processes and the relocation of those activities outside the terminal with the aim to reduce dwell time and increase the yard capacity. Finally, the reconsideration of regulations and laws that should be put in place to encourage and facilitate the private sector integration to finance the projects and alleviate the burden from the state budget.
In this context, digitization and the use of new Information and Communication Technologies (ICS) would help to achieve the above mentioned measures more effectively.

6.2 Limitation and future research

This study, as with all research, had limitations that were represented in the assumptions of different variables that constitute the CBA. For instance, different equipment productivity and OPEX could vary from one terminal to another. This paper has considered the most reliable sources of information available in recent research relating to the subject, however, on site surveys have to be conducted in order to more accurately assess factors that affect those variables such as the equipment travel distance and speed, ease of access to storage areas, human resources productivity that greatly depends on a degree of skills and motivations and costs to conduct maintenance and repairs which may change from country to country and port to port. As a result, different productivity assumptions and OPEX may vary. Future research could be conducted in simulation approach of the obtained operating system using new software technologies and foreseeing the exact equipment needed for productivity at each leg of the terminal logistics chain.

In the same context, other assumptions could vary over time such as the LIBOR rate, costs escalation, peak time rate, equipment and the utilization rate, for this reason future research may apply a sensitivity analysis that supplement the CBA like, for example, the Monte Carlo simulation model. It consists of creating scenarios with varying assumptions susceptible to change and to see whether the project is still profitable or not. It is obvious to recommend at the end of the research and to adopt the project with the highest NPV, but the NPV is just a predicted value. In performing the sensitivity analysis, the project with the largest NPV may not necessarily be the best alternative under the circumstances. That is why the best alternative is to recommend the project that has the highest NPV value in the worst case circumstances. Therefore, based on this, different benchmarks could be established to ensure the feasibility of those projects and to monitor these outcomes at a later stage and compare them with the initial assumption to ensure that the projects are on the right track.

Finally, this research has focused on the direct financial return of the project to the party who assumed the costs, thus, it could be extended to cover benefits or costs to other parties. For instance, port infrastructure development is considered to be a strategic investment which has other benefits to the economy and society such as creating jobs, enhancing connectivity, encouraging FDIs, providing better logistics solutions, becoming more environmentally friendly, therefore, quantifying all those variables and including them in the analysis will encourage more the adoption of the project. Future research could consider those inductive benefits and costs to all involved parties including port stakeholders and the society in the surrounding areas to enrich the analysis.

References

AAPA. (n.d.). Port industry statistics. Retrieved from https://www.aapa-ports.org/unifying/content.aspx?ItemNumber=21048

Alavi, A., Nguyen, H., Fei, J., & Sayareh, J. (2018). Port logistics integration: Challenges and approaches. *International Journal of Supply Chain Management, 7*(6), 389-402.

Alcalá, F., & Ciccone, A. (2004). Trade and productivity. *The Quarterly Journal of Economics, 119*(2), 613-646.

Alphaliner. (2018, Mar 16,). MSC deploys Roro vessel as feeder to alleviate congestion at tunis.

Artal-Tur, A., Gómez-Fuster, J. M., Navarro-Azorín, J. M., & Ramos-Parreño, J. M. (2016). Estimating the economic impact of a port through regional input–output tables: Case study of the port of cartagena (spain). *Maritime Economics & Logistics, 18*(4), 371-390.

Arvis, J. F., Mustra, M. A., Ojala, L., Shepherd, B., & Saslavsky, D. (2007). Connecting to compete: Trade logistics in the global economy-the logistics performance index and its indicators. world bank. *Washington, DC,*

Arvis, J., Alina Mustra, M., Ojala, L., Shepherd, B., & Saslavsky, D. (2010). *Connecting to compete 2010: Trade logistics in the global economy--the logistics performance index and its indicators* World Bank.

Beuran, M., Hadi Mahihenni, M., Raballand, G., & Refas, S. (2012). *The impact of demand on cargo dwell time in ports in SSA* The World Bank.

Blonigen, B. A., & Wilson, W. W. (2008). Port efficiency and trade flows. *Review of International Economics, 16*(1), 21-36.

Bottasso, A., Conti, M., Ferrari, C., & Tei, A. (2014). Ports and regional development: A spatial analysis on a panel of european regions. *Transportation Research Part A: Policy and Practice, 65*, 44-55.

Brooks, M. R., Cullinane, K. P., & Pallis, A. A. (2017). Revisiting port governance and port reform: A multi-country examination. *Research in Transportation Business & Management, 100*(22), 1-10.

Brooks, M. R., & Pallis, A. A. (2013). Advances in port performance and strategy. *Research in Transportation Business & Management,* (8), 1-6.

Burns, M. G. (2015). *Port management and operations* CRC Press.

Clark, X., Dollar, D., & Micco, A. (2004). Port efficiency, maritime transport costs, and bilateral trade. *Journal of Development Economics, 75*(2), 417-450.

CMA CGM. (2018). Emergency port congestion surcharge in rades, tunisia. Retrieved from https://www.cma-cgm.com/news/2029/emergency-port-congestion-surcharge-in-rades-tunisia

Cullinane, K., & Song, D. (2003). A stochastic frontier model of the productive efficiency of korean container terminals. *Applied Economics, 35*(3), 251-267.

Cullinane, K., Song, D., & Wang, T. (2005). The application of mathematical programming approaches to estimating container port production efficiency. *Journal of Productivity Analysis, 24*(1), 73-92.

Dappe, M. H., Jooste, C., & Suárez-Alemán, A. (2017). *How does port efficiency affect maritime transport costs and trade? evidence from indian and western pacific ocean countries* The World Bank.

de Langen, P., Turró Calvet, M., Fontanet, M., & Caballé, J. (2018). *The infrastructure investment needs and financing challenge of european ports*. ().ESPO. Retrieved from https://globalmaritimehub.com/wp-content/uploads/2019/03/Port-Investment-Study-2018_FINAL_1.pdf

Deng, P., Lu, S., & Xiao, H. (2013). Evaluation of the relevance measure between ports and regional economy using structural equation modeling. *Transport Policy, 27*, 123-133.

Díaz-Hernández, J. J., Martínez-Budría, E., & Salazar-González, J. J. (2014). Measuring cost efficiency in the presence of quasi-fixed inputs using dynamic data envelopment analysis: The case of port infrastructure. *Maritime Economics & Logistics, 16*(2), 111-126.

Dollar, D., Clark, X., & Micco, A. (2002). *Maritime transport costs and port efficiency* The World Bank.

Drewry. (2012). *Ship operating costs annual review and forecast 2012/13*. (). London: Drewry Research. Retrieved from https://commons.wmu.se/cgi/viewcontent.cgi?article=1020&context=lib_reports

Ducruet, C., & Merk, O. (2013). Examining container vessel turnaround times across the world. *Port Technology International, 59*, 18-20.

Dwarakish, G. S., & Salim, A. M. (2015). Review on the role of ports in the development of a nation. *Aquatic Procedia, 4*(1), 295-301.

Ekelund, R. B., Ekelund Jr, R. B., Hébert, R. F., & Hébert, R. F. (1999). *Secret origins of modern microeconomics: Dupuit and the engineers* University of Chicago Press.

Fenton, C., Storrs-Fox, P., Joerss, M., Saxon, S., & Stone, M. (2018). *Container transport in 2043*. ().TT Club. Retrieved from https://www.mckinsey.com/~/media/mckinsey/industries/travel%20transport%20and%20logistics/our%20insights/brave%20new%20world%20container%20transport%20in%202043/brave-new-world-container-transport-in-2043.ashx

Frankel, E. (1999). Intermodal integration. *Lloyd's Shipping Economist, 21*(3), 10-11.

Frankel, J. A., & Romer, D. H. (1999). Does trade cause growth? *American Economic Review, 89*(3), 379-399.

Fuguitt, D., Fuguitt, D. J., & Wilcox, S. J. (1999). *Cost-benefit analysis for public sector decision makers* Greenwood Publishing Group.

Channel, 9. (Producer), & Gharbi, I. (Director). (2016). *Customs procedures in rades port*. [Video/DVD] Tunisia:

Ha, M., Yang, Z., Notteboom, T., Ng, A. K., & Heo, M. (2017). Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators. *Transportation Research Part E: Logistics and Transportation Review, 103*, 1-16.

Han, C. (2018). Assessing the impacts of port supply chain integration on port performance. *The Asian Journal of Shipping and Logistics, 34*(2), 129-135.

Hapag-Lloyd. (2016). Tunisia – revised terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2016/05/tunisia-revised-terminal-congestion-surcharge_48469.html

Hapag-Lloyd. (2017a). Tunisia – revised terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2017/03/tunisia-_-revised-terminal-congestion-surcharge.html

Hapag-Lloyd. (2017b). Tunisia – revised terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2017/05/tunisia-_-revised-terminal-congestion-surcharge.html

Hapag-Lloyd. (2017c). Tunisia – revised terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2017/06/tunisia-_-revised-terminal-congestion-surcharge.html

Hapag-Lloyd. (2018a). Tunisia – reduction of terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2018/11/tunisia---reduction-of-terminal-congestion-surcharge.html

Hapag-Lloyd. (2018b). Tunisia – revised terminal congestion surcharge. Retrieved from https://www.hapag-lloyd.com/en/news-insights/news/2018/04/tunisia-_-revised-terminal-congestion-surcharge.html

Heijman, W., Gardebroek, C., & van Os, W. (2017). The impact of world trade on the port of rotterdam and the wider region of rotterdam-rijnmond. *Case Studies on Transport Policy, 5*(2), 351-354.

Herrera Dappe, M., Jooste, C., & Suarez Aleman, A. (2017). How does port efficiency affect maritime transport costs and trade? evidence from indian and western pacific ocean countries. *Evidence from Indian and Western Pacific Ocean Countries (September 25, 2017).World Bank Policy Research Working Paper,* (8204)

Hinkka, V., Porkka, J., Fatima, Z., Hyvärinen, J., Huovila, A., Morales-Fusco, P., . . . Soley, G. (2018). Terminal planning: The selection of relevant KPIs to evaluate operations. Paper presented at the *7th Transport Research Arena, TRA 2018,* Vienna, Austria.

HPC. (2017). *Equipment selection criteria* . Hamburg: Hamburg Port Consultancy. doi:[PPT: Lecture presented at Port logistics and planning in World Maritime University]

IAPH. (2016). *The study on productivity and key indicators of container terminals*. ().IAPH.

ITF. (2016). *Logistics development strategies and performance measurement*. (). Paris: OECD Publishing. doi:10.1787/bcb574b1-en Retrieved from http://dx.doi.org/10.1787/bcb574b1-en

Jeevan, J., Chen, S., & Cahoon, S. (2019). The impact of dry port operations on container seaports competitiveness. *Maritime Policy & Management, 46*(1), 4-23.

JORT. (2014). *The maximum tariff of loading, unloading, handling and guarding goods in the commercial seaports*. Tunis: The official Gazette of the Republic of Tunisia.

JORT. (2017). *Tunisian seaport charges*. Tunis: The official Gazette of the Republic of Tunisia.

Jouili, T. A. (2019). Impact of seaport infrastructure, logistics performance, and shipping connectivity on merchandise exports. *International Journal of Computer Science and Network Security, 19*(5), 259-264.

Ju, S., & Liu, N. (2015). Efficiency and its influencing factors in port enterprises: Empirical evidence from chinese port-listed companies. *Maritime Policy & Management, 42*(6), 571-590.

Kalmar. (n.d.). *Intermodal handling increasing productivity, saving the environment* Kalmar.

Kraemer, I. (2020). *Container terminal operating systems a general overview, Lecture presented at port management lecture at world maritime university*. Malmo, Sweden:

Lei, Q., & Bachmann, C. (2019). Assessing the role of port efficiency as a determinant of maritime transport costs: Evidence from canada. *Maritime Economics & Logistics,* , 1-23.

Lu, Y. (2014). No title. *Port Performance Benchmarking and Efficiency Analysis,*

Marcadon, J. (1999). Containerisation in the ports of northern and western europe. *GeoJournal, 48*(1), 15-20.

Mendez, R. P. (1992). International public finance: A new perspective on global relations. *OUP Catalogue,*

Micco, A., & Pérez, N. (2002). *Determinants of maritime transport costs, Working paper 441*. (). Washington, DC: IDB Working Paper.

Mills, T. (2018). *Instrumental data for drug analysis* CRC Press.

Ministry of transport. (2015). *Rades port performance indicators 2010-2015*. (). Tunis: Ministry of transport of Tunisia.

Ministry of transport. (2016). *Rades port performance indicators*. (). Tunis: Ministry of Transport of Tunisia.

Ministry of transport. (2018). *Rades port performance indicators*. (). Tunis: Ministry of Transport of Tunisia.

Mishan, E. J., & Quah, E. (2007). *Cost-benefit analysis* Routledge.

Morales-Fusco, P., Saurí, S., Lekka, A. M., & Karousos, I. (2016). Assessing customs performance in the mediterranean ports. KPI selection and best practices identification as part of the MEDNET project. *Transportation Research Procedia, 18*(201), 374-383.

MOŞTEANU, T., & Iacob, M. (2007). Theories and approaches regarding the Cost–Benefit analysis role and principles. *Financial and Monetary Policies in European Union,* , 7.

Munim, Z. H., & Schramm, H. (2018). The impacts of port infrastructure and logistics performance on economic growth: The mediating role of seaborne trade. *Journal of Shipping and Trade, 3*(1), 1.

Musgrave, R. A., & Musgrave, P. B. (1973). Public finance in theory and practice.

Nas, T. F. (2016). *Cost-benefit analysis: Theory and application* Lexington Books.

Newcomer, K. E., Hatry, H. P., & Wholey, J. S. (2015). Cost-effectiveness and cost-benefit analysis. *Handbook of Practical Program Evaluation,* , 636.

Notteboom, T. E. (2004). Container shipping and ports: An overview. *Review of Network Economics, 3*(2)

Notteboom, T., Pallis, A., & Rodrigue, J. (2020). Chapter 6.2 – ports and economic development. *Port economics, management and policy* (). New York: Routledge. Retrieved from https://porteconomicsmanagement.org/?page_id=165

Notteboom, & Yap, W. Y. (2012). Port competition and competitiveness. *The Blackwell Companion to Maritime Economics,* , 549-570.

OBG. (2016). *Tunisia exploring new development for maritime infrastructure*. ().Oxford Business Group. Retrieved from https://oxfordbusinessgroup.com/analysis/exploring-options-already-well-developed-maritimeinfrastructure-looks-set-evolve-further

OBG. (2017). *The report: Tunisia 2017, Tunisia diversifies its logistics segment with private initiatives and investment*. ().Oxford Business Group. Retrieved from https://oxfordbusinessgroup.com/overview/ship-shape-country-diversifying-its-logistics-offerings

OBG. (2018). *The report: Tunisia 2018, Transport infrastructure spending fueling tunisia's economic growth*. ().Oxford Business Group. Retrieved from https://oxfordbusinessgroup.com/overview/revamping-system-transport-infrastructure-spending-set-fuel-economic-growth

OMMP. (n.d.). Rades port: The first container terminal in tunisia. Retrieved from http://www.ommp.nat.tn/rades-en/?lang=en

OOCL. (n.d.). Local surcharges. Retrieved from https://www.oocl.com/tunisia/eng/localinformation/localsurcharges/Pages/default.aspx?site=tunisia&lang=eng

Ortiz-Ospina, E. (2018). Does trade cause growth? Retrieved from https://ourworldindata.org/trade-and-econ-growth

Paardenkooper, K. (2019). Port 6 competition and the containerisation of hinterland transport, 1966–2010. *Transnational regions in historical perspective* (pp. 152-183) Routledge.

Panayides, P. M., Parola, F., & Lam, J. S. L. (2015a). The effect of institutional factors on public–private partnership success in ports. *Transportation Research Part A: Policy and Practice, 71*, 110-127.

Panayides, P. M., Parola, F., & Lam, J. S. L. (2015b). The effect of institutional factors on public–private partnership success in ports. *Transportation Research Part A: Policy and Practice, 71*, 110-127.

Rodrigue, J. P. (2020). *The geography of transport systems* (5th ed.). New York: Routledge.

Santos, A. M., Salvador, R., Dias, J. C. Q., & Soares, C. G. (2018). Assessment of port economic impacts on regional economy with a case study on the port of lisbon. *Maritime Policy & Management, 45*(5), 684-698.

Santos, A., Salvador, R., & Soares, C. G. (2018). A dynamic view of the socioeconomic significance of ports. *Maritime Economics & Logistics, 20*(2), 169-189.

Sarkar, P. K., Maitri, V., & Joshi, G. J. (2017). *Transportation planning: Principles, practices and policies* PHI Learning Pvt. Ltd.

SHEN, X., & YANG, F. (2010). Empirical analysis on coordinated development of port logistics and regional economic in the pearl river delta [J]. *Logistics Sci-Tech, 2*, 67-71.

Sorgenfrei, J. (2018). *Port business* (2nd ed.) Walter de Gruyter GmbH & Co KG.

STAM. (2019). *RCT equipment status*. Tunisia: STAM Technical dept.

Statista. (2020a). Container market volume growth rate worldwide 2021. Retrieved from https://www.statista.com/statistics/253931/global-container-market-demand-growth/

Statista. (2020b). Tunisia: National debt in relation to gross domestic product (GDP) from 2014 to 2024. Retrieved from https://www.statista.com/statistics/524541/national-debt-of-tunisia-in-relation-to-gross-domestic-product-gdp/

Steenken, D., Vob, S., & Stahlbock, R. (2004). Terminal structure and handling equipment. *Container Terminal Operation and Operations Research, 6*

Suárez-Alemán, A., Sarriera, J. M., Serebrisky, T., & Trujillo, L. (2016). When it comes to container port efficiency, are all developing regions equal? *Transportation Research Part A: Policy and Practice, 86*, 56-77.

Sun, J., & Yu, S. (2019). Research on relationship between port logistics and economic growth based on VAR: A case of shanghai. *American Journal of Industrial and Business Management, 9*(07), 1557.

Talley, W. K., Ng, M., & Marsillac, E. (2014). Port service chains and port performance evaluation. *Transportation Research Part E: Logistics and Transportation Review, 69*, 236-247.

TANG, S. L., & JOHN TANG, H. (2003). Technical note : The variable financial indicator irr and the constant economic indicator npv. *The Engineering Economist, 48*(1), 69-78. doi:10.1080/00137910308965052

Tovar, B., Jara-Diaz, S., & Trujillo, L. (2007). Econometric estimation of scale and scope economies within the port sector: A review. *Maritime Policy & Management, 34*(3), 203-223.

Turi, A., Goncalves, G., & Mocan, M. (2014). Challenges and competitiveness indicators for the sustainable development of the supply chain in food industry. *Procedia-Social and Behavioral Sciences, 124*, 133-141.

UNCTAD. (2016). *Port performance: Linking performance indicators to strategic objectives*. (PORT MANAGEMENT SERIES No. 4). Geneva: UNCTAD. Retrieved from https://unctad.org/en/PublicationsLibrary/dtlkdb2016d1_en.pdf

UNCTAD. (2018). *Review of maritime transport 2018*. (). Geneva: UNCTAD. Retrieved from https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

UNCTAD. (2019). *Review of maritime transport 2019*. (). Geneva: UNCTAD.

UNCTAD. (2020). Liner shipping connectivity index. Retrieved from https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=92

Verhoeven, P. (2009). European ports policy: Meeting contemporary governance challenges. *Maritime Policy & Management, 36*(1), 79-101.

Wan, Y., Yuen, A. C., & Zhang, A. (2014). Effects of hinterland accessibility on US container port efficiency. *International Journal of Shipping and Transport Logistics 5, 6*(4), 422-440.

Wilmsmeier, G., & Hoffmann, J. (2008). Liner shipping connectivity and port infrastructure as determinants of freight rates in the caribbean. *Maritime Economics & Logistics, 10*(1-2), 130-151.

Wilmsmeier, G., Hoffmann, J., & Sanchez, R. J. (2006). The impact of port characteristics on international maritime transport costs. *Research in Transportation Economics, 16*, 117-140.

World Bank. (2018a). Country score card: Tunisia 2018 logistics performance index. Retrieved from https://lpi.worldbank.org/international/scorecard/radar/254/C/TUN/2018/R/MNA/2018/I/NOC/2007

World Bank. (2018b). *Doing business 2018 reforming to create jobs.* (). Washington DC: World Bank. Retrieved from https://www.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2018-Full-Report.pdf

Woxenius, J. (2012). Directness as a key performance indicator for freight transport chains. *Research in Transportation Economics, 36*(1), 63-72.

WPS. (2020). *Rades port infrastructure and logistic zone studies*. Tunis: OMMP.

WSC. (n.d.). How liner shipping works. Retrieved from http://www.worldshipping.org/about-the-industry/how-liner-shipping-works

WTO. (2018). Strong trade growth in 2018 rests on policy choices. Retrieved from https://www.wto.org/english/news_e/pres18_e/pr820_e.htm

Xiao, Y., Wang, S., Liu, J. J., Xiao, J., & Hu, Y. (2016). Throughput estimation based port development and management policies analysis. *Maritime Policy & Management, 43*(1), 84-97.

Yudhistira, M. H., & Sofiyandi, Y. (2018). Seaport status, port access, and regional economic development in indonesia. *Maritime Economics & Logistics, 20*(4), 549-568.

Zhang, J., & Ning, L. (2012). The grey correlation degree between port logistics and regional economic. *Logistics Sci-Tech,* (7), 3.

Appendices

Appendix A: General description of Rades Container Terminal

➢ General description: Location and infrastructure

Start in service since 1987 and located on the Mediterranean Sea, approximately 10 Kilometers East of central Tunis, Rades port is the main commercial seaport of the greater Tunis area. Geographically, it is the extension of the passenger port of La Goulette in the South Bank of the access canal. It compromises two terminals for both containers and bulk cargo like it shows in the figure below (Office of Merchant Marine and Ports [OMMP], 2017).

La Goulette and Rades port location Map

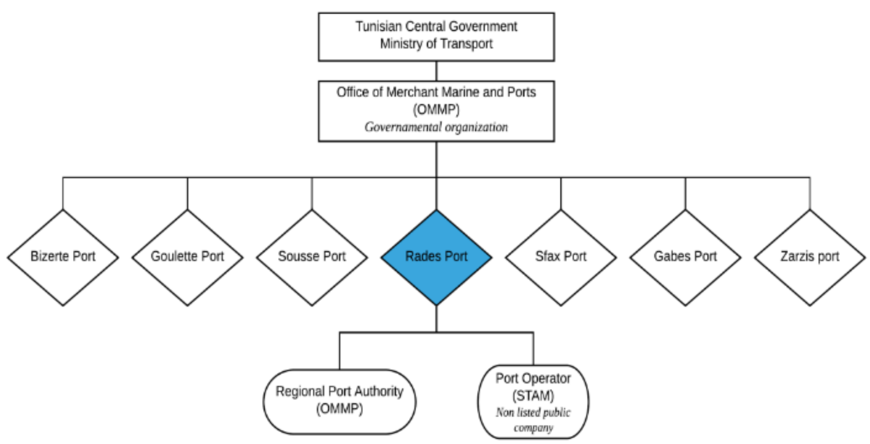
Beside its activity for bulk and wet cargoes, the port encompasses the biggest gateway container terminal that serve feeder ships, and since it being in the capital city, it gains an advantage over other ports thanks to its proximate to the most of production sites in the country in one side and the main liner shipping routes crossing the north of Tunisia in the other side.

➢ Rades port governance model

The port is governed under the landlord model where the port authority belongs to the Office of Merchant Marine and ports (OMMP) and the port operations are secured by the Tunisian Stevedoring Company (STAM), a state owned company.

1- The port authority:

As shown in figure 12, the governance model of all Tunisian port is following the Latin model where the central port authority is controlling each port authority or administration. The OMMP is a governmental organization that exercise the function of both maritime authority and administration and port authority by virtue of the law number 98/109 dated December 28th, 1998. It assures the governance of all Tunisian ports including Rades port, all under the auspices of the central government represented by the Ministry of transport.



Rades port governance model (Source: Author)

In the first sight it seems that the Rades port authority have a certain degree of autonomy where the port management have control over budgeting, procurement and purchasing, formulation of strategies and programming, salary and employment conditions and setting performance target and objectives, however, the process of decision making should be always in accordance with the central authority and the final decision for big investment or procurement have to be approved by the central authority.

The OMMP in general as a central port authority runs on a commercial basis enabling it to operate under market disciplines which alleviate to a certain degree the interference of the government in decision making but restrain it to have full autonomy on port financial incomes that have to be accounted in the annual country budget. Furthermore, as public entity, the OMMP is bound to follow the law of public procurement regulation which is a very slow process that doesn't respond to the fast changes in the immature liner shipping market and customer's needs.

The most problems that could be identified from the structure of the port authority are:

- Port's strategic decisions, objectives and performance targets are subject to central port authority approval, also procurement and maintenance budget should be priory accepted by it and with limited budget. As result, decision making take longer time and implementation is limited due to finance shortage.
- Disguised autonomy of the central port authority because of the interference of the government in port decisions and limited accessibility to port incomes.
- Inefficient and lack of implementation of strategies while contracting practices and procurement are subject to national government regulations.
- All ports are governed by the same body that eliminate competition between ports and attenuate market pressure that may leads to a potential lack of efficiency.
- Total dependence to the national budget which make the port development and investment tightly related to the economic situation of the country that is already exhausted.

2- The port operator:

RCT is operated by the STAM which is a non-listed public company that have the monopoly in operating Rades port by virtue of a concession agreement with the OMMP (Decree n° 2014-1471 dated 23 April 2014) as well as jointly operating all other ports in Tunisia with the private sector.
In one hand, being a non-listed company deprived the STAM from private financial support, therefore, it retained from raising its capital and upgrade its activities.

In the other hand, it has been observed that introducing private sector in port operations and creating inter-port competition have enhanced port performance and increased service quality with a reduced cargo handling costs. For this reason, it might be beneficial for the STAM to be in monopolistic position but it is not the case for the port stakeholders and customers.

However, a counter-example of Singapore port which is operated by a single public company has challenged this hypothesis. Furthermore, the size of RCT might not allow for a second port operator to be involved in the terminal operation while it might cause conflict in the management of limited storage areas and the operations of different equipment.

To summarize, the centralization of decision making, the luck of full financial autonomy and the absence of competition are strong reasons to observe RCT performance indicators and assess the efficiency of its container handling operations.

Appendix B: RCT performance indicators

I. Liner shipping operator's statistics in 2019 and KPIs calculations

	CTN (roro)			CMA (roro + container ships)						GRIMALDI (roro)		
	TEU	TIME	calls	TEU RORO	TIME RORO	calls	TEU CONT	TIME	calls	TEU	TIME	calls
JAN	3545	209	5	7976	170	12	501	126	1	3896	59	10
FEB	7090	325	10	7288	216	12	1002	218	2	2752	47	8
MAR	10635	332	15	8594	286	15	1953	362	3	4928	78	14
APR	9926	359	11	7288	263	12	3611	652	4	3096	48	9
MAY	7799	250	11	4194	127	7	2571	697	3	688	11	2
JUN	8508	297	12	7700	251	14	2726	760	4	4128	75	13
JUL	7799	285	11	9970	236	15	4089	705	5	2408	51	8
AUG	9926	470	13	6806	162	13	3117	885	4	4816	84	15
SEP	7090	280	8	8388	342	14	4324	909	6	5272	94	15
OCT	8508	378	12	8800	332	16	4711	837	5	4472	86	14
NOV	9926	347	13	7906	301	15	2913	726	3	4472	87	14
DEC	8508	543	11	7494	340	13	3432	818	4	6264	173	16
Total	99260	4075	132	92404	3026	158	34950	7695	44	47192	893	138
Teu/H	24.358282			30.53668			4.54191			52.8466		
% container carried	21%			19%			7%			10%		
avg vessel time at berth	30.871212			19.1519			174.886			6.47101		
avg TEU per ship	751.9697			584.8354			794.318			341.971		

	MSC (roro + container)						ARKAS (container)			LINEA MESSINA (roro)			XPRESS (container)			SEALAND (container)		
	TEU roro	TIME	calls	Teu cont	time	calls	TEU	TIME	calls	TEU	TIME	calls	TEU	TIME	calls	TEU	TIME	calls
JAN	4488	155	6				2626	220	2	1730	42	1	-	-		4405	1168	5
FEB	3688	153	5				1139	216	1	-	-		862	195	1	4411	730	5
MAR	6264	382	9				3183	613	3	1464	142	3	5338	797	6	2592	314	3
APR	4664	275	7				6249	621	6	976	63	2	5106	595	6			
MAY	5300	180	7	1118	272	1	6017	306	6	976	23	2	6052	634	7			
JUN	4664	240	7				4765	356	5	1952	153	4	6058	1179	7			
JUL	4982	430	6	1118	200	1	3858	234	4	1464	140	3	4383	1113	5			
AUG	6440	397	10	1118	272	1	4995	409	5	2440	161	5	6156	1051	7			
SEP	5700	339	9				6017	407	6	1952	174	4	7012	1177	8			
OCT	5700	334	9				4995	389	5	2440	194	5	5282	921	6			
NOV	6800	355	10				4088	448	4	1952	176	4	5282	1081	6			
DEC	6200	374	10				4088	316	4	2440	217	5	4572	945	5			
Total	64890	3614	95	3354	744	3	52020	4535	51	19786	1485	38	56103	9688	64	11408	2212	13
Teu/H	17.9552			4.50806			11.4708			13.3239			5.79098			5.15732		
% container carried	13%			1%			11%			4%			12%			2%		
avg vessel time at berth	38.0421			248			88.9216			39.0789			151.375			170.154		
avg TEU per ship	683.053			1118			1020			520.684			876.609			877.538		

Turn around time roro (h)	26.723
Turn around time cont. ships (h)	166.667
total avg TEU/RORO	576.503
Total avg TEU/cont. ship	937.293
AVG TEU/H RORO	21.5732
AVG TEU/H Cont.	5.62374
roro throughput	323532
Cont. throughput	157835
TEUs per roro ship hour at berth/h	27.8041
TEUs per cont. ship hour at berth/h	6.29381
number of calls container ships	175
number of calls roro ships	561
total throughput	481367
Bearth Occupancy	95%

The above figure highlights the main liner shipping companies that secure services from and to Rades container terminal. Data were collected from AXS marine where it identifies 8 liner shipping service operators in 2019 and the service type they provide (Roro or Container).

Container throughputs were counted for each operator every month depending on the type of service they provide (RoRo or Container). As well, the time spent at berth for all their vessels per type per month and its monthly calls was counted during 2019.

Explanation of different rows calculations:

- $TEU\ per\ H = \frac{Total\ TEUs\ per\ operator}{Total\ Time\ spent\ at\ berth\ for\ the\ same\ operator}$
- $\%\ of\ container\ carried = \frac{Total\ carried\ container\ per\ operator\ per\ service\ type}{Total\ carried\ container\ by\ all\ operators}$
- $AVG\ vessel\ time\ at\ berth = \frac{Total\ Time\ spent\ at\ berth\ per\ operator}{Nbr\ of\ calls\ of\ the\ same\ operator}$
- $AVG\ TEU\ per\ ship = \frac{Total\ TEUs\ per\ operator}{Nbr\ of\ calls\ of\ the\ same\ operator}$
- $Turnaround\ Time\ (roro) = \frac{\sum AVG\ vessel\ time\ at\ berth\ of\ all\ roro\ operators}{Number\ of\ roro\ operators}$
- $Turnaround\ Time\ (cont.) = \frac{\sum AVG\ vessel\ time\ at\ berth\ of\ all\ cont.\ operators}{Number\ of\ cont.\ operators}$
- $Total\ avg\ TEU\ per\ RoRo = \frac{\sum AVG\ TEU\ per\ roro\ operator\ ships}{Number\ of\ roro\ operators}$
- $Total\ avg\ TEU\ per\ Cont. = \frac{\sum AVG\ TEU\ per\ cont.\ operator\ ships}{Number\ of\ cont.\ operators}$
- $TEUs\ per\ roro\ ship\ hour\ at\ berth = \frac{\sum TEU\ per\ H\ of\ roro\ operators}{Number\ of\ roro\ operators}$
- $TEUs\ per\ cont.ship\ hour\ at\ berth = \frac{\sum TEU\ per\ H\ of\ cont.\ operators}{Number\ of\ roro\ operators}$
- $Cont. berth\ Occup. = \frac{\sum Total\ time\ spent\ at\ berth\ by\ cont.\ operator}{Working\ days\ p.a. * berth\ avail.\ hours\ p.d./Nbr.\ of\ cont.\ berths}$

II. Crane downtime in January 2019

	Shift No	Crane breakdown	Transfer berth to yard	Transfer yard to berth
1/1/2019	1	12	3.5	1.5
	2	0	0	0
	3	6	0	0
1/2/2019	1	2	0	5.5
	2	3	2	5
	3	7	0	1.5
1/3/2019	1	8.5	0	10.5
	2	0	0	0
	3	0	0	0
1/4/2019	1	6.2	0	4.45
	2	0	0	0
	3	10	0	2.5
1/5/2019	1	8.5	1	5.5
	2	2	4	1.5
	3	6		2.5
1/6/2019	1	6		6.5
	2	11		1.5
	3	9		
1/7/2019	1			
	2			
	3	6		
1/8/2019	1	6.5		
	2	8		3
	3	13.5		1.5
1/9/2019	1	2.5	2	
	2	2.5	6	
	3	3.75	9	
1/10/2019	1	5.5	4	
	2	9.5	1	4
	3	6	10.5	2
1/11/2019	1		8	2.5
	2	11	4	4
	3	16.5	1.5	2.5
1/12/2019	1			
	2	6	9	3
	3	6	6	7
1/13/2019	1	7.5	3	5
	2	8.25		5
	3	9		1

1/14/2019	1		8	1.5
	2			5
	3	1	3.5	
1/15/2019	1	2		3
	2	9		4
	3		11	3
1/16/2019	1	6	3.5	
	2		6	9.5
	3		6	
1/17/2019	1	1	5.5	2.75
	2			
	3			
1/18/2019	1	10		
	2	3.5		1
	3			
1/19/2019	1	10.5	2	1.5
	2	6.5	6.6	
	3	6	2.5	
1/20/2019	1	11	1.5	1
	2			
	3	6		
1/21/2019	1	5.5		
	2			
	3			
1/22/2019	1			
	2			
	3			
1/23/2019	1	7		
	2			
	3	10.5		
1/24/2019	1	3	3.5	
	2	11.5		
	3	14		
1/25/2019	1	3.5		
	2	7.5		
	3	13.25		
1/26/2019	1	17		
	2	4.5		2
	3		4	
1/27/2019	1	3	5.25	1.5
	2	3.5	1.5	1
	3	12	3.5	3

1/28/2019	1	7	3		
	2	3.25	6	3	
	3	11.75	2.25		
1/29/2019	1	8.5	6	2	
	2	13	3		
	3				
1/30/2019	1	1.5		4.5	
	2	6	7	2	
	3		4		
1/31/2019	1	6		2.25	
	2	6.25	3.5	1	
	3	4			
Total		480.7	183.1	143.45	807.25
percentage of suspension per category		59.5%	22.7%	17.8%	
daily average per crane (h)		3.876612903	1.476612903	1.156854839	
Crane utilization		64%			
Working hours available cranes per month		2232			

The above figure summarizes the container handling operation interruption time during January 2019. Three main reasons were identified and for each one, the wasted time was counted for every shift.

At the end of the table, the total unproductive time was around 807 hours where almost 60% of it was due to the crane breakdown, each crane is stopped to work for almost 4 hours every day due to breakdown, 1,5 hours due to container transfer from the berth to the yard and 1 hour due to interruptions of container transfer from the yard to the berth. Thus, the resulting crane utilization rate is 64% obtained by the following formula.

$$Crane\ utilization\ rate = \frac{Crane\ available\ working\ hours\ \ per\ month - Total\ unproductive\ Time}{Crane\ available\ working\ hours\ \ per\ month}$$

Where:

Crane available working hours per month = Working hours p.d. (18) * Month days (31) * Number of cranes (4)

Appendix C: Cost-Benefit Analysis of different investment projects

- Loan and equity conditions:

The world bank loan terms and conditions have been used as a reference for all investment projects presented in the following analysis.

- The advance ratio: the world bank has financed the Tunisia third export development project (EDP III) in 2015 which aims to enhance customs procedures efficiency and reduce delays. The total project cost was US$ 74.50 million where the bank has accorded US$ 50.00 million as a loan. Thus, the loan amount was around 67% of the total project cost (World Bank, n.d.).

- Interest rate: The world bank finance support to the Tunisian government is provided by the International Bank for Reconstruction and Development (IBRD) in terms of Fixed Spread Loans (FSL) of 4.13% (World Bank, 2020).

- Amortization and repayment: The repayment maturity for IBRD Fixed Spread Loans (FSL) is settled between 5 and 10 years and 3 to 5 year grace period with 6 months of repayment frequency. Therefore, for the case study, the loan maturity is fixed for 8 years with semiannual repayment without a grace period (World Bank, 2018).

- Front-end fee: IBRD has fixed a front-end fee of 1% of the loan amount (IBRD, n.d.). This percentage is generalized as well for the equity amount.

- LIBOR:

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0,83	1,01	0,68	0,56	0,79	1,38	1,79	2,76	2,37	1,02

The historical 12 Month LIBOR rate (Macrotrends, 2020)

LIBOR rate is fluctuating over time, for this reason, the LIBOR rate utilized in this case study (1,3%) was obtained in averaging the last 10 years 12 month LIBOR rate.

- Equity: The investor has to provide 33% of the project cost

- Preference share coupon: The preference share coupon is considered as the equity interest. Thus, in Tunisia, the interest rate of local banks is composed of the Money Market Average rate (TMM) fixed by the central bank at 6,82% for July 2020 (BCT, 2020) and a margin estimated at 1,18% for corporate loans.

- Corporate Tax: The standard corporate income Tax in Tunisia is 25% (Tradingeconomics, 2020).

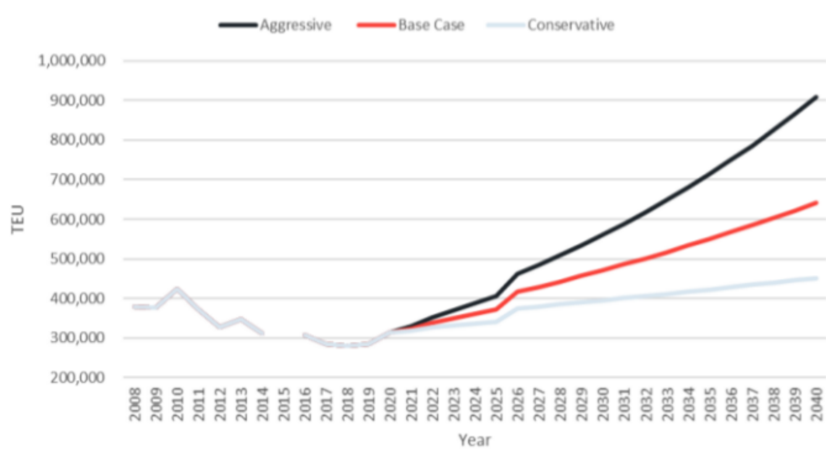
➢ General Assumption:

- Annual throughput evolution: future projection for the container throughput evolution is provided by WPS (2020) on three scenarios basis.

1. Base Case: Projected on a TEU/GDP multiplier of recent years and IMF projected growth for 2019-2024 resulting in a national TEU growth rate of 3.03%. Assumes the current market share between Rades (60%) and Sfax (20%) remains constant. This would generate total container throughputs in 2040 of 641,464 TEU.

2. Aggressive Case: Assumes a national TEU growth rate of 5% based on comparisons with World Bank funded studies. However, these growth rates do not consider the relationship between GDP growth rates and trade volumes and have clearly not materialized so far. This case considers a market share allocation of Rades (65%), Sfax (30%) and remaining Tunisian ports (5%). This would generate total container throughputs in 2040 of 908,403 TEU.

3. Conservative Case: Assumes economic conditions in Tunisia deteriorate with a TEU growth rate of only 1.5%. Assumes the current market share between Rades (60%) and Sfax (20%) remains constant. This would generate total container throughputs in 2040 of 451,965 TEU.



Annual container throughput projection in Rades from 2017-2040 (WPS, 2020)

In this case study, the base case seems to be the most reasonable to achieve while in 2010 the terminal handled 424000 TEUs without any amelioration in equipment technology and infrastructure.

Therefore, annual throughput was assumed to be constant at 285,000 TEUs for the first 2 years (2020&2021) as the volume recorded in 2019 while the cargo handling performance will not be perceived immediately after the project is done. Thereafter, the volume is estimated to increase constantly with 20,277 TEUs every year to reach in 2040 650,000 TEUs as the base case indicates, assuming also that after 2040 the volume will stop increasing.

- Benefits: The benefit of each project investment is calculated based on the cash incomes derived from the direct activity of the project itself. Cargo tariffs and port dues are fixed by the Tunisian law, however, the case study introduced 5% of fee escalation every 5 years that reflect the willingness to pay of the port customers to the enhanced performance that increases the efficiency of their supply chain and reduces their container delivery time.

- TEU factor: Estimated at 1,5

  No. of TEUs = No. of equipment moves * TEU factor

  Statistics provided by the port authority shows that in 2019, the terminal around handled 285,000 TEUs where almost half of the are 40 feet containers.

- Working hours: Actually, the port is working 362 days p.a. and 18 hours/day divided into 3 shifts of 6 hours. Calculation of CBA considered 24h working time, 8h/shift as a recommended reform for better performance.

- Equipment utilization rate: equipment are used at a 67% rate, thus, with new equipment, an estimation of 80% was adopted.

- Peak time factor: It was estimated by WPS (2020) at a level of 10%.

- OPEX escalation: Operational expenses were estimated to increase by 2% every two years. While the big portion of those expenses is the manning cost of equipment drivers and the maintenance team. Estimation was based on the frequency of increasing wages in the public sector in Tunisia where wages are increased every 2-3 years.

I. CBA of STS Gantry crane project investment

CASHFLOW PROJECTION	
Project Cost	$32,000,000
Advance Ratio	67%
Loan Amount	$21,440,000
Repayment per Year	$2,680,000
Equity	$10,560,000
Equity repayment per year	$1,320,000
Amortization (no of years)	8
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Opex/year	$1,898,859.20
Opex Escalation/2 years	2%
TEU/year/crane (2019)	95000
TEU/year/crane escalation (2022-2039)	6760
Fees/TEU	$40
Fees escalation/ 5 years	5%

PROJECT COST ESTIMATION	
3 Panamax STS cranes	$30,000,000
Rail installation	$2,000,000
Total	$32,000,000

TOTAL PROJECT COSTS	
WB Loan Amount	**$21,440,000**
Front-end fee (1%)	$214,400
Local Banks Loan (Equity)	**$10,560,000**
Front-end fee (1%)	$105,600
Total	$32,320,000

General Information	
Cranes No	3
Shifts No	3
Working days/year	362
Max Crane Utilization rate	80%
working hours	24
Life cycle (years)	25

OPEX		
WAGES	Monthly salary	$800
	Employee (1.5 head count/crane)	4
	Total wages costs (14 months/25yrs)	$3,360,000
ELECTRICITY	Kwh/move	8
	TEU factor	1.5
	TEU/crane (2020-2021)	95000
	TEU/year/crane escalation (2022-2040)	6760
	1Kwh price	$0.11
	Expenses for the first 2 years	$334,400
	Expanses for the next 18 years	$9,812,968
	expanses for the remaining 5 years	$2,649,284
	Total Electricity expanses	$12,796,652
MAINTENANCE	Major overhaul cost (Every 12 yrs)	$15,000,000
	Repair and refurbishment cost	$24,040,749
	Preventive maintenance cost	$4,546,800
	Total maintenance cost	$28,587,549
INVENTORY HOLDING COST	Total Inventory cost	$2,684,835
Employee Training	Course price/Employee	$3,537
	Total	$42,444
TOTAL		$47,471,480

Elect. expanses for the next 18 years/crane	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
	$167,696	$168,191	$168,687	$169,183	$169,679	$170,174	$170,670	$171,166	$171,662	$172,157	$172,653	$173,149	$173,645	$174,140	$174,636	$175,132	$175,627	$176,123	$176,619

Repair and refurbishment cost	3-7 yrs	8-12 yrs	13-17 yrs	18-22 yrs	23-25 yrs
	$520,712	$759,790	$5,540,760	$521,065	$671,256

Inventory cost	1-5 yrs	6-10 yrs	11-15 yrs	16-20 yrs	20-25 yrs
	$506,580	$521,750	$536,970	$552,170	$567,365

Year	2020		2021		2022		2023		2024		2025		2026	
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
COSTS														
L/O Period	$21,440,000	$20,100,000	$18,760,000	$17,420,000	$16,080,000	$14,740,000	$13,400,000	$12,060,000	$10,720,000	$9,380,000	$8,040,000	$6,700,000	$5,360,000	$4,020,000
Principal Payment	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000	$1,340,000
Interest on Principal	$582,096	$545,715	$509,334	$472,953	$436,572	$400,191	$363,810	$327,429	$291,048	$254,667	$218,286	$181,905	$145,524	$109,143
Total	$1,922,096	$1,885,715	$1,849,334	$1,812,953	$1,776,572	$1,740,191	$1,703,810	$1,667,429	$1,631,048	$1,594,667	$1,558,286	$1,521,905	$1,485,524	$1,449,143
E/O Period	$10,560,000	$9,900,000	$9,240,000	$8,580,000	$7,920,000	$7,260,000	$6,600,000	$5,940,000	$5,280,000	$4,620,000	$3,960,000	$3,300,000	$2,640,000	$1,980,000
Principal Payment	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000	$660,000
Interest on Principal	$422,400	$396,000	$369,600	$343,200	$316,800	$290,400	$264,000	$237,600	$211,200	$184,800	$158,400	$132,000	$105,600	$79,200
Total	$1,082,400	$1,056,000	$1,029,600	$1,003,200	$976,800	$950,400	$924,000	$897,600	$871,200	$844,800	$818,400	$792,000	$765,600	$739,200

2027		2028
S1	S2	
$2,680,000	$1,340,000	
$1,340,000	$1,340,000	Total interest
$72,762	$36,381	
$1,412,762	$1,376,381	$4,947,816
$1,320,000	$660,000	
$660,000	$660,000	Total interest
$52,800	$26,400	
$712,800	$686,400	$3,590,400

Year	2020	2021	2022	2023	2024	2025	2026	2027
Opex/year	$1,897,161.44	$1,897,161.44	$1,935,104.67	$1,935,104.67	$1,973,806.76	$1,973,806.76	$2,013,282.90	$2,013,282.90

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
$2,053,548.56	$2,053,548.56	$2,094,619.53	$2,094,619.53	$2,136,511.92	$2,136,511.92	$2,179,242.16	$2,222,827.00	$2,222,827.00	$2,267,283.54

2038	2039	2040	2041	2042	2043	2044
$2,267,283.54	$2,312,629.21	$2,312,629.21	$2,358,881.79	$2,358,881.79	$2,406,059.43	$2,406,059.43

TOTAL	$53,522,675.63

- Cranes purchase price: $ 10,000,000 (Gantrex, 2017; WPS, 2020)

- Rail installation costs: $ 2,000,000 estimated to be between 1.5M$ and 2.5 M$ for 500 m of quay wall (Gantrex, 2017).

- Cranes life cycle: estimated to be 25 years (Miranda & Gil, 2014; WPS, 2020).

- Crane productivity: 22 moves/hour as suggested by WPS (2020), a typical value for peak production of an STS crane is between 30-40 moves per hour therefore a productivity of 22 moves per hour is considered achievable.

- Headcount: Estimated to be 1.5 employees per crane per gang.

- Electricity consumption: Estimated to be 8 Kwh/move (Wilmsmeier & Spengler, 2016).

- Electricity price: 0.11$ for industry use provided by the Tunisian Electricity and gas company (STEG, 2019).

- Energy expenses were divided into 3 segments assuming that during the first 2 years the annual container throughput will still the same (285,000 TEUs), thereafter for the next 18 year energy expenses will rise with the yearly container increasing volume (20,277 TEUs), for the rest of the 5 years the annual throughput will stop at a level of 650,000 TEUs and electricity expenses are calculated on this base.

- Maintenance costs: Divided into two categories, repair and refurbishment cost which include a major overhaul in the half life cycle of the cranes estimated at 50% of the crane costs (WPS, 2020). Estimating as well that during the first two year repairs will be offered by the equipment provider company as a warranty. The second category is the preventive maintenance cost, all data for the sum of maintenance expenses was extracted from Miranda & Gil, (2014).

- Inventory costs: Calculated on 5 years escalation basis (Miranda & Gil, 2014), Inventory cost estimations are generated for all other equipment investment.

- Training course: STS gantry cranes are new equipment for the employees therefore a training course is needed. Costs are calculated for 12 drivers and the course cost is provided by the National Maritime College of Ireland (NMCI, 2020). While this cost is not recurring, it has been eliminated from the OPEX after the first year.

- The above figures show calculations of amortization repayment of the loan and equity for the first 8 years of the project life cycle as well as OPEX for 25 years escalated at 2% every 2 years.

	Year	2020		2021		2022		2023		2024		2025	
	Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
	BENEFITS												
	Cash inflow	$5,700,000	$ 5,700,000	$ 5,700,000	$ 5,700,000	$5,970,400	$ 5,970,400	$ 6,240,800	$ 6,240,800	$ 6,511,200	$ 6,511,200	$ 7,120,680	$ 7,120,680
	Yearly	$11,400,000		$11,400,000		$11,940,800		$12,481,600		$13,022,400		$14,241,360	
	CASH inflow-OPEX	$9,502,839		$9,502,839		$10,005,695		$10,546,495		$11,048,593		$12,267,553	
	Cash Surplus	$1,384,479.28	$1,809,704.28	$1,872,485.28	$1,935,266.28	$2,249,475.67	$2,312,256.67	$2,645,437.67	$2,708,218.67	$3,022,048.62	$3,084,829.62	$3,757,090.62	$3,819,871.62
	TAX (25%)	$798,545.89		$951,937.89		$1,140,433.08		$1,338,414.08		$1,526,719.56		$1,894,240.56	
	Net income	$2,395,637.67		$2,855,813.67		$3,421,299.25		$4,015,242.25		$4,580,158.68		$5,682,721.68	
	CUMULATIVE	$258,810,520.40											
cash inflow minus (opex+interests+tax)	-$32,000,000	$6,758,081.67		$6,855,813.67		$7,421,299.25		$8,015,242.25		$8,580,158.68		$9,682,721.68	

2026		2027		2028	2029	2030	2031	2032	2033	2034
S1	S2	S1	S2							
$ 7,404,600	$ 7,404,600	$ 7,688,520	$ 7,688,520	$ 15,660,960	$ 15,944,880.00	$ 17,039,564.00	$ 17,337,004.00	$ 17,634,444.00	$ 17,931,884.00	$ 18,229,324.00
$14,809,200		$15,377,040		$ 15,660,960	$ 15,944,880	$ 17,039,564	$ 17,337,004	$ 17,634,444	$ 17,931,884	$ 18,229,324
$12,795,917		$13,363,757								
$4,146,834.55	$4,209,615.55	$4,556,316.55	$4,619,097.55	$ 13,607,411.44	$ 13,891,331.44	$ 14,944,944.47	$ 15,242,384.47	$ 15,497,932.08	$ 15,795,372.08	$ 16,050,081.84
$2,089,112.53		$2,293,853.53		$3,401,852.86	$3,472,832.86	$3,736,236.12	$3,810,596.12	$3,874,483.02	$3,948,843.02	$4,012,520.46
$6,267,337.58		$6,881,560.58		$10,205,558.58	$10,418,498.58	$11,208,708.36	$11,431,788.36	$11,623,449.06	$11,846,529.06	$12,037,561.38
$10,267,337.58		$10,881,560.58		$10,205,558.58	$10,418,498.58	$11,208,708.36	$11,431,788.36	$11,623,449.06	$11,846,529.06	$12,037,561.38

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
$2,222,827.00	$2,222,827.00	$2,267,283.54	$2,267,283.54	$2,312,629.21	$2,312,629.21	$2,358,881.79	$2,358,881.79	$2,406,059.43	$2,406,059.43
$ 19,451,750.20	$ 19,762,710.20	$ 20,073,670.20	$ 20,384,630.20	$ 20,695,590.20	$ 22,054,849.71	$ 23,157,592.20	$ 23,157,592.20	$ 23,157,592.20	$ 23,157,592.20
$ 19,451,750	$ 19,762,710	$ 20,073,670	$ 20,384,630	$ 20,695,590	$ 22,054,850	$ 23,157,592	$ 23,157,592	$ 23,157,592	$ 23,157,592
$ 17,228,923.20	$ 17,539,883.20	$ 17,806,386.66	$ 18,117,346.66	$ 18,382,960.99	$ 19,742,220.50	$ 20,798,710.40	$ 20,798,710.40	$ 20,751,532.77	$ 20,751,532.77
$4,307,230.80	$4,384,970.80	$4,451,596.67	$4,529,336.67	$4,595,740.25	$4,935,555.13	$5,199,677.60	$5,199,677.60	$5,187,883.19	$5,187,883.19
$12,921,692.40	$13,154,912.40	$13,354,790.00	$13,588,010.00	$13,787,220.74	$14,806,665.38	$15,599,032.80	$15,599,032.80	$15,563,649.57	$15,563,649.57
$12,921,692.40	$13,154,912.40	$13,354,790.00	$13,588,010.00	$13,787,220.74	$14,806,665.38	$15,599,032.80	$15,599,032.80	$15,563,649.57	$15,563,649.57

Cost-Benefit Analysis for Panamax STS Gantry cranes			
COSTS		WACC	
Project cost	$32,320,000	5.62%	
Total Interest	$8,538,216	NPV	$115,118,737.81
Opex	$53,565,119.63	IRR	26%
Cumulative Tax	$86,270,173.47	MIRR	12%
Total costs	$180,693,509	Payback Period (yrs)	
BENEFITS		4.09	
Cumulative Incomes	$439,504,029		
NET before TAX	$345,080,694		
NET after TAX	$258,810,520		

- Cash inflow = Annual moves/crane * No. cranes* Move price
- Move price: 40$ escalated by 5% every 5 years
- Annual moves/crane: escalated by 6760 TEU/year/crane for the period 2022-2039
- Cash surplus = Cash inflow – (loan and equity payment (principle+interest) + OPEX)
- Cash inflows minus (OPEX+interest+tax) is used to calculate the payback period without including the project cost. The same row is utilized to calculate IRR including the first cell (- $ 32,000,000) which is the project cost.
- Net income Row is utilized to calculate the NPV.
- A summary of the CBA results is shown in the above figure.

II. CBA of Berth-Yard transfer project investment

A- Straddle carrier system

- Number of needed straddles

No of straddles for:					
STS-Yard transfer					
sts moves /h	22		TEU factor		1.5
nbr sts	3		Annual throuput (TEU)		650000
Struddle Utilization rate	80%		Working days/yr		362
	Daily handling volume (moves) per activity (peak)				
	Total STS moves /h	66	moves/h		
	Peak surcharge	10%			
	moves peak/h	72.60	Moves		
	Hourly performance	8	moves/hr/straddle		
	Resulting no of straddle	9	no.		

Straddle carrier productivity has to be synchronized with STS crane productivity. Thus, in peak time STS cranes are expected to perform around 73 moves/h with 80% utilization rate. Considering that a straddle performs 8 moves/h then the resulting number of straddles is 9.

No. straddles = STS cranes move peak per h / Straddle hourly performance

CASHFLOW PROJECTION	
Project Cost	$14,850,000
Advance Ratio	67%
Loan Amount	$9,949,500
Repayment per Year	$1,243,688
Equity	$4,900,500
Equity repayment per year	**$612,563**
Amortization (no of years)	8
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Opex/year	$2,335,624.21
Opex Escalation/2 years	2%
Annual throughput	285000
Annual throughput escalation (2022-2032)	20277
Fees/TEU	$30
Fees escalation/ 5 years	5%

PROJECT COST ESTIMATION	
9 Straddle Carriers	$9,000,000
Terminal operating system	$2,350,000
TOS Implementation	$3,500,000
Total project cost	**$14,850,000**

TOTAL PROJECT COSTS	
WB Loan Amount	**$9,949,500**
Front-end fee (1%)	$99,495
Local Banks Loan (Equity)	**$4,900,500**
Front-end fee (1%)	$49,005
Total	$14,998,500

General Information		
straddle No		9
Shifts No		3
Working days/year		362
Max equipment Utilization rate		80%
working hours		24
Life cycle (years)		12

OPEX		
WAGES	Monthly salary	$600
	Employee (1.5 head count/straddle)	40
	Total wages costs (14 months/12yrs)	$4,032,000
DIESEL COSTS	Consumption (L)/straddle/hour	23.3
	TEU factor	1.5
	Moves/h	8
	1L Diesel price	$1.00
	Expenses for the first 2 years	$1,106,750
	Expanses for the next 10 years	$8,685,623
	Total Diesel expanses	$9,792,373
MAINTENANCE	Yearly maintenance cost (percentage of capital cost)	12%
	Total maintenance cost	$12,960,000
INVENTORY HOLDING COST	Total Inventory cost	$1,243,118
TOTAL		$28,027,491

Inventory cost	1-5 yrs	6-10 yrs	11-12 yrs
	$506,580	$521,750	$214,788

YEAR	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
ANNUAL MOVES	190000	190000	203518	217036	230554	244072	257590	271108	284626	298144	311662	325180	338698
STRADDLE HRS	23750	23750	25439.75	27129.5	28819.25	30509	32198.75	33888.5	35578.25	37268	38957.75	40647.5	42337.25

Year	2020		2021		2022		2023		2024		2025		2026		2027		2028
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	
COSTS																	
L/O Period	$9,949,500	$9,327,656	$8,705,813	$8,083,969	$7,462,125	$6,840,281	$6,218,438	$5,596,594	$4,974,750	$4,352,906	$3,731,063	$3,109,219	$2,487,375	$1,865,531	$1,243,688	$621,844	
Principal Payment	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	$621,844	Total interest
Interest on Principal	$270,129	$253,246	$236,363	$219,480	$202,597	$185,714	$168,831	$151,948	$135,064	$118,181	$101,298	$84,415	$67,532	$50,649	$33,766	$16,883	
Total	$891,973	$875,090	$858,207	$841,324	$824,440	$807,557	$790,674	$773,791	$756,908	$740,025	$723,142	$706,259	$689,376	$672,493	$655,610	$638,727	$2,296,096
E/O Period	$4,900,500	$4,594,219	$4,287,938	$3,981,656	$3,675,375	$3,369,094	$3,062,813	$2,756,531	$2,450,250	$2,143,969	$1,837,688	$1,531,406	$1,225,125	$918,844	$612,563	$306,281	
Principal Payment	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	$306,281	Total interest
Interest on Principal	$196,020	$183,769	$171,518	$159,266	$147,015	$134,764	$122,513	$110,261	$98,010	$85,759	$73,508	$61,256	$49,005	$36,754	$24,503	$12,251	
Total	$502,301	$490,050	$477,799	$465,548	$453,296	$441,045	$428,794	$416,543	$404,291	$392,040	$379,789	$367,538	$355,286	$343,035	$330,784	$318,533	$1,666,170

Year	2020	2021	2022	2023	2024	2025	2026	2027
Opex/year	$1,939,866.67	$1,939,866.67	$1,978,664.00	$1,978,664.00	$2,018,237.28	$2,018,237.28	$2,058,602.03	$2,058,602.03

2028	2029	2030	2031
$2,099,774.07	$2,099,774.07	$2,141,769.55	$2,141,769.55

TOTAL	$29,466,800.11

- Straddle carrier purchase price: According to Logistics Middle East (2015), DP world Southampton has invested 9.1 M$ in 10 new Kalmar straddle carriers. Thus, the 2020 straddle carrier price is estimated to be around $ 1,000,000.

- Straddle carrier life cycle: Estimated to be 12 years (Huang & Chu, 2003)

- Productivity: 8 moves/h (Thomas & Roach, 1987).

- TOS purchase and installation cost: In virtue of the PDE III program supported by the world bank, the STAM will benefit of 7 million Dinars to purchase the TOS and 10.5 MD to implement it (Business News, 2019). Also, Cerderqvist & Holmgren (2010) highlighted that the cost of TOS is 2 M$.

- Straddle hours/year: it is the result of the division of each year's total moves by the straddle moves/h.

- Diesel consumption: Each straddle is estimated to consume 23,3 L/h for all activity combined (traveling, hoisting, lowering and adjustment) (Hangga, Shinoda, Takahashi, & Hiyoshi, 2014).

- Diesel price: 3 dinars in Tunisia equal to 1$

- Maintenance cost: Estimated at 12% of the purchase price. It is the mean of estimated annual maintenance costs that vary between 8% and 15% (UNCTAD, 1985; Thomas & Roach, 1987).

- The above figures show calculations of amortization repayment of the loan and equity for the first 8 years of the project life cycle as well as OPEX for 12 years escalated at 2% every 2 years.

	Year	2020		2021		2022		2023		2024		2025	
	Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
	BENEFITS												
	Cash inflow	$4,275,000	$ 4,275,000	$ 4,275,000	$ 4,275,000	$4,883,310	$ 4,883,310	$ 5,491,620	$ 5,491,620	$ 6,099,930	$ 6,099,930	$ 7,043,652	$ 7,043,652
	Yearly	$8,550,000		$8,550,000		$9,766,620		$10,983,240		$12,199,860		$14,087,304	
	CASH inflow-OPEX	$6,214,376		$6,214,376		$7,384,283		$8,600,903		$9,769,877		$11,657,321	
	Cash Surplus	$1,564,413.97	$1,742,048.28	$1,771,182.58	$1,800,316.89	$2,414,404.96	$2,443,539.27	$3,080,983.57	$3,110,117.88	$3,723,738.82	$3,752,873.13	$4,725,729.44	$4,754,863.75
	TAX (25%)	$826,615.56		$892,874.87		$1,214,486.06		$1,547,775.36		$1,869,152.99		$2,370,148.30	
	Net income	$2,479,846.68		$2,678,624.61		$3,643,458.17		$4,643,326.09		$5,607,458.96		$7,110,444.89	
	CUMULATIVE	$91,916,783											
cash inflow minus (opex+interests+tax)	-$14,850,000	$4,484,596.68		$4,534,874.61		$5,499,708.17		$6,499,576.09		$7,463,708.96		$8,966,694.89	

2026		2027		2028	2029	2030	2031
$ 7,682,378	$ 7,682,378	$ 8,321,103	$ 8,321,103	$ 17,280,932	$ 17,919,657.00	$ 19,484,780.85	$ 20,153,921.85
$15,364,755		$16,642,206		$ 17,280,932	$ 17,919,657	$ 19,484,781	$ 20,153,922
$12,886,172		$14,163,623		$14,752,777	$15,391,502	$16,906,063	$17,575,204
$5,398,423.72	$5,427,558.03	$6,095,417.83	$6,124,552.14	$ 14,752,776.74	$ 15,391,502.24	$ 16,906,062.99	$ 17,575,203.99
$2,706,495.44		$3,054,992.49		$3,688,194.18	$3,847,875.56	$4,226,515.75	$4,393,801.00
$8,119,486.31		$9,164,977.48		$11,064,582.55	$11,543,626.68	$12,679,547.25	$13,181,403.00
$9,975,736.31		$11,021,227.48		$11,064,582.55	$11,543,626.68	$12,679,547.25	$13,181,403.00

Cost-Benefit Analysis for Straddle carriers			
COSTS		WACC	
Project cost	$14,998,500	5.62%	
Total Interest	$3,962,266	NPV	$59,657,459.58
Opex	$29,466,800	IRR	40%
Cumulative Tax	$30,638,928	MIRR	20%
Total costs	$79,066,494	Payback Period (yrs)	
BENEFITS		2.86	
Cumulative Incomes	$170,983,276		
NET before TAX	$122,555,710		
NET after TAX	$91,916,783		

- Cash inflow = Annual throughput (TEUs)* Move price
- Move price: 30$ escalated by 5% every 5 years
- Annual Throughput: escalated by 20,277 TEU/year for 12 years period
- Cash surplus = Cash inflow – (loan and equity payment (principle+interest) + OPEX)
- Cash inflows minus (OPEX+interest+tax) is used to calculate the payback period without including the project cost. The same row is utilized to calculate IRR including the first cell (- $ 14,850,000) which is the project cost.
- Net income Row is utilized to calculate the NPV.
- A summary of the CBA results is shown in the above figure.

B- Tractor-trailer with RTG system

- Number of needed Tractors, Trailers and RTGs

No of RTGs for:				
STS-Yard transfer	sts moves /h	22	TEU factor	1.5
	nbr sts	3	Annual throuput (TEU in 2019)	285000
	RTG Utilization rate	80%	escalation throughput /yr (2022-2040)	20277
	Existing RTGs	5	Working days/yr	362

Daily handling volume (moves) per activity (peak)		
Total STS moves	66	moves/h
Peak surcharge	10%	
moves peak/h	72.60	Moves
Hourly performance	20	moves/hr/RTG
Resulting no of RTGs	4	no.
Equipment hours	9,500	

Daily handling volume (moves) per activity (peak)		
Total STS moves /h	66	moves/h
Peak surcharge	10%	
moves peak/h	72.60	Moves
Hourly performance	8	moves/hr/Tractor
Resulting no of Tractors	9	no.
Equipment hours	23,750	

Similarly, to straddle carriers, with estimated productivity of 8 moves/h the terminal needs 9 tractors to ensure the container berth-yard transfer.

RTGs have higher productivity of 20 moves/h, consequently, the resulting number of RTGs is 4.

The STAM has already 5 available RTGs starts operating at the end of 2019, thus there is no need to purchase more.

For the 9 tractors, it has been estimated that each one needs 2 trailers.

The equipment hours/year is the result of the division of each year's total moves by the equipment type productivity.

CASHFLOW PROJECTION	
Project Cost	$7,110,000
Advance Ratio	67%
Loan Amount	$4,763,700
Repayment per Year	$595,462.50
Equity	$2,346,300
Equity repayment per year	$293,287.50
Amortization (no of years)	8
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Opex/year	$2,183,806.86
Opex Escalation/2 years	2%
Annual throughput	285000
TEU/year/crane escalation (2022-2034)	20277
Fees/TEU	$30
Fees escalation/ 5 years	5%

PROJECT COST ESTIMATION	
9 Tractor Trailer	$900,000
18 Trailers	$360,000
Terminal Operating System	$2,350,000
TOS Implementation	$3,500,000
Total project cost	**$7,110,000**

TOTAL PROJECT COSTS	
WB Loan Amount	**$4,763,700**
Front-end fee (1%)	$47,637
Local Banks Loan (Equity)	**$2,346,300**
Front-end fee (1%)	$23,463
Total	$7,181,100

General Information	
Tractor No	9
RTG No	4
Trailer No	18
RTG price /unit	$2,500,000
Shifts No	3
Working days/year	362
Max equipment Utilization rate	80%
working hours	24
Life cycle (years)	15

OPEX		
WAGES	Monthly salary (Tractor driver)	$600
	Employee (1.5 head count/tractor)	40
	Total T. drivers wages (14 months/15yrs)	$5,040,000
	Monthly salary (RTG driver)	$800
	Employee (1.5 head count/RTG)	18
	Total RTG drivers wages (14 months/15yrs)	$3,024,000
Energy expenses	Kwh/h (RTG)	40
	1Kwh price	$0.11
	Consumption (L)/tractor/hour	10
	1L Diesel price	$1
	Total Electricity cost	$897,630
	Total Diesel cost	$5,100,173
	Total energy cost	$5,997,803
MAINTENANCE	Tractor maintenance/yr (% of puchase price	30%
	Trailers maintenance/yr (% of puchase price	20%
	RTG maintenance/yr (% of puchase price)	8%
	Tractors total maintenance cost	$4,050,000
	Trailers total maintenance cost	$1,080,000
	RTG total maintenance cost	$12,000,000
	Total Maintenance cost	$17,130,000
INVENTORY HOLDING COST	Total Inventory cost	$1,565,300
TOTAL		$32,757,103

ENERGY CONSUMPTION FORECAST

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual Throughput	285000	285000	305277	325554	345831	366108	386385	406662	426939	447216	467493	487770	508047	528324	548601
Annual berth moves	190000	190000	203518	217036	230554	244072	257590	271108	284626	298144	311662	325180	338698	352216	365734
berth-yard RTG hours	9500	9500	10175.9	10851.8	11527.7	12203.6	12879.5	13555.4	14231.3	14907.2	15583.1	16259	16934.9	17610.8	18286.7
Tractor trailer hours	23750	23750	25439.75	27129.5	28819.25	30509	32198.75	33888.5	35578.25	37268	38957.75	40647.5	42337.25	44027	45716.75
RTG Energy cost	$41,800	$41,800	$44,774	$47,748	$50,722	$53,696	$56,670	$59,644	$62,618	$65,592	$68,566	$71,540	$74,514	$77,488	$80,461
Tractor energy cost	$237,500	$237,500	$254,398	$271,295	$288,193	$305,090	$321,988	$338,885	$355,783	$372,680	$389,578	$406,475	$423,373	$440,270	$457,168

Inventory cost	1-5 yrs	6-10 yrs	11-15 yrs
	$506,580	$521,750	$536,970

Year	2020		2021		2022		2023		2024		2025		2026	
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
COSTS														
L/O Period	$4,763,700	$4,465,969	$4,168,238	$3,870,506	$3,572,775	$3,275,044	$2,977,313	$2,679,581	$2,381,850	$2,084,119	$1,786,388	$1,488,656	$1,190,925	$893,194
Principal Payment	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731	$297,731
Interest on Principal	$129,334	$121,251	$113,168	$105,084	$97,001	$88,917	$80,834	$72,751	$64,667	$56,584	$48,500	$40,417	$32,334	$24,250
Total	$427,066	$418,982	$410,899	$402,815	$394,732	$386,649	$378,565	$370,482	$362,398	$354,315	$346,232	$338,148	$330,065	$321,981
E/O Period	$2,346,300	$2,199,656	$2,053,013	$1,906,369	$1,759,725	$1,613,081	$1,466,438	$1,319,794	$1,173,150	$1,026,506	$879,863	$733,219	$586,575	$439,931
Principal Payment	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644	$146,644
Interest on Principal	$93,852	$87,986	$82,121	$76,255	$70,389	$64,523	$58,658	$52,792	$46,926	$41,060	$35,195	$29,329	$23,463	$17,597
Total	$240,496	$234,630	$228,764	$222,899	$217,033	$211,167	$205,301	$199,436	$193,570	$187,704	$181,838	$175,973	$170,107	$164,241
Opex/year	$2,183,806.86		$2,183,806.86		$2,227,482.99		$2,227,482.99		$2,272,032.65		$2,272,032.65		$2,317,473.31	

	2027		2028	2029	2030	2031	2032	2033	2034
	S1	S2							
L/O Period	$595,463	$297,731							
Principal Payment	$297,731	$297,731	Total interest						
Interest on Principal	$16,167	$8,083							
Total	$313,898	$305,815	$1,099,343						
E/O Period	$293,288	$146,644							
Principal Payment	$146,644	$146,644	Total interest						
Interest on Principal	$11,732	$5,866							
Total	$158,375	$152,510	$797,742						
Opex/year	$2,317,473.31		$2,363,822.77	$2,363,822.77	$2,411,099.23	$2,411,099.23	$2,459,321.21	$2,459,321.21	$2,508,507.64

- Tractors and Trailers purchase price: Estimated at $ 100,000 and $ 20,000 respectively per unit (WPS, 2020).

- Equipment life cycle: 20 years for RTGs and 15 years for Tractors (Thomas & Roach, 1987). The total project life is counted as the lowest equipment life cycle (15 years)

- Productivity:

eRTG: Estimated productivity for container handling: Loading and unloading of railcars: 30 moves/hour, stack work: 20 moves/hour and for loading and unloading of road trucks: 15 moves/hour. Then, 20 moves/h was estimated as an average of eRTGs productivity (Kalmar, n.d.).

Tractors: Estimated to have a productivity rate of 8 moves/h (Thomas & Roach, 1987)

- Diesel consumption and maintenance cost: Thomas and Roach (1987) have estimated that each tractor is consuming 10 l/h and needs 30% of its purchase price for maintenance every year.

- eRTG electricity consumption and maintenance cost: Thomas and Roach (1987) estimated that maintenance cost is counted at 8% every year of its purchase price. Also, an eRTG consumes 40 Kw/h (VUOJOLAINEN & VAN DER WAAL, 2015).

- The total energy cost is the sum of diesel and electricity costs which are calculated on the equipment working hours that depends on the projected increasing container volume for the next 15 years as the figure above shows.

- Trailer maintenance: It consists mainly of tires replacement, estimated at 20% of its purchase cost every year (Thomas & Roach, 1987)

- The above figures show calculations of amortization repayment of the loan and equity for the first 8 years of the project life cycle as well as OPEX for 15 years escalated at 2% every 2 years.

		2020		2021		2022		2023		2024		2025	
	Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
	BENEFITS												
	Cash inflow	$4,275,000	$ 4,275,000	$ 4,275,000	$ 4,275,000	$4,883,310	$ 4,883,310	$ 5,491,620	$ 5,491,620	$ 6,099,930	$ 6,099,930	$ 7,043,652	$ 7,043,652
	Yearly	$8,550,000		$8,550,000		$9,766,620		$10,983,240		$12,199,860		$14,087,304	
	CASH inflow-OPEX	$6,366,193		$6,366,193		$7,539,137		$8,755,757		$9,927,827		$11,815,271	
	Cash Surplus	$2,444,435.12	$2,529,484.27	$2,543,433.42	$2,557,382.58	$3,157,803.66	$3,171,752.81	$3,794,011.97	$3,807,961.12	$4,407,945.45	$4,421,894.60	$5,379,565.75	$5,393,514.91
	TAX (25%)	$1,243,479.85		$1,275,204.00		$1,582,389.12		$1,900,493.27		$2,207,460.01		$2,693,270.16	
	Net income	$3,730,439.54		$3,825,612.00		$4,747,167.36		$5,701,479.82		$6,622,380.03		$8,079,810.49	
	CUMULATIVE	$143,552,338											
cash inflow minus (opex+interests+tax)	-$7,110,000	$4,690,289.54		$4,714,362.00		$5,635,917.36		$6,590,229.82		$7,511,130.03		$8,968,560.49	

2026		2027		2028	2029	2030	2031	2032	2033	2034
S1	S2	S1	S2							
$ 7,682,378	$ 7,682,378	$ 8,321,103	$ 8,321,103	$ 17,280,932	$ 17,919,657.00	$ 19,484,780.85	$ 20,153,921.85	$ 20,823,062.85	$ 21,492,203.85	$ 22,161,344.85
$15,364,755		$16,642,206		$ 17,280,932	$ 17,919,657	$ 19,484,781	$ 20,153,922	$ 20,823,063	$ 21,492,204	$ 22,161,345
$13,047,282		$14,324,733		$14,917,109	$15,555,834	$17,073,682	$17,742,823	$18,363,742	$19,032,883	$19,652,837
$6,023,469.23	$6,037,418.39	$6,690,093.04	$6,704,042.19	$ 14,917,108.73	$ 15,555,834.23	$ 17,073,681.62	$ 17,742,822.62	$ 18,363,741.64	$ 19,032,882.64	$ 19,652,837.21
$3,015,221.90		$3,348,533.81		$3,729,277.18	$3,888,958.56	$4,268,420.41	$4,435,705.66	$4,590,935.41	$4,758,220.66	$4,913,209.30
$9,045,665.71		$10,045,601.42		$11,187,831.54	$11,666,875.67	$12,805,261.22	$13,307,116.97	$13,772,806.23	$14,274,661.98	$14,739,627.91
$9,934,415.71		$10,934,351.42		$11,187,831.54	$11,666,875.67	$12,805,261.22	$13,307,116.97	$13,772,806.23	$14,274,661.98	$14,739,627.91

Cost-Benefit Analysis for RTG+TRACTOR system for bearth-yard interchange			
COSTS		WACC	
Project cost	$7,181,100	5.62%	
Total Interest	$1,897,085	NPV	$86,509,547.90
Opex	$34,978,586	IRR	76%
Cumulative Tax	$47,850,779	MIRR	25%
Total costs	$91,907,550	Payback Period (yrs)	
BENEFITS		1.27	
Cumulative Incomes	$235,459,888		
NET before TAX	$191,403,117		
NET after TAX	$143,552,338		

Similarly to previous calculations and analysis, the above figures show the benefit gathered during the project life where:

Cash inflow = Annual throughput (TEUs)* Move price

- Move price: 30$ escalated by 5% every 5 years

- Annual Throughput: escalated by 20277 TEU/year for 15 years period

- Cash surplus = Cash inflow – (loan and equity payment (principle+interest) + OPEX)

- Cash inflows minus (OPEX+interest+tax) is used to calculate the payback period without including the project cost. The same row is utilized to calculate IRR including the first cell (- $ 7,110,000) which is the project cost.

- Net income Row is utilized to calculate the NPV.

- A summary of the CBA results is shown in the above figure.

III- Yard-Gate interchange

A- Straddle carrier system

- Number of needed Straddles

Yard-truck interchange

$$\text{Daily peak equipment demand } [\#] = \frac{\text{Daily handling volume (moves) per activity * peak factor}}{\text{Hourly performance of equipment * avail. oper. hours per day}}$$

Daily handling volume (moves) per activity (peak)			No Straddels from 2020-2027		
Total annual moves	433,333	Moves	Total annual moves	271,108	Moves
Daily moves	1,197.05	Moves	Daily moves	748.92	Moves
Peak surcharge	10%		Peak surcharge	10%	
Daily moves peak	1,317	Moves	Daily moves peak	823.81	Moves
Avail. oper. hours/day	19.2	hours	Avail. oper. hours/day	19.2	hours
Hourly performance	8	moves/hr/straddle	Hourly performance	8	moves/hr/straddle
Resulting no of straddle	9	no.	Resulting no of straddl	5	no.
Equipment hours	54,167	hours	Equipment hours	33,889	hours

Housekeeping	Daily handling volume (moves) per activity (peak)		
=moves not paid for	5 % of daily moves peal	66	Moves
	Avail. oper. hours/day	19.2	hours
	Hourly performance	8	moves/hr/straddle
	Resulting no of straddle	1	no.
	Equipment hours	2,708	hours

The straddle number needed for container delivery depends on the annual container throughput. Taking into consideration that the terminal has already 8 straddles that can be exploited for the next 8 years, thus there is no need for investment till 2027 where during this period the port is expected to handle 406,662 TEUs (271,108 moves). Thereafter the terminal needs 10 new straddles to secure the delivery of 650,000 TEUs p.a. including the housekeeping moves which are not paid for and counted as extra costs. The resulting number of straddles is obtained through the following formula.

$$\text{Daily peak equipment demand } [\#] = \frac{\text{Daily handling volume (moves) per activity * peak factor}}{\text{Hourly performance of equipment * avail. oper. hours per day}}$$

The resulting equipment hours is the division of the total annual moves by the hourly performance moves of a straddle (8 moves/h)

CASHFLOW PROJECTION	
Project Cost	$10,000,000
Advance Ratio	67%
Loan Amount	$6,700,000
Repayment per Year	$837,500
Equity	$3,300,000
Equity repayment per year	$412,500
Amortization (no of years)	8
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Opex/year (2020-2027)	$1,909,592.63
Opex/year (2028-2039)	$2,125,540.83
Opex Escalation/2 years	2%
Annual throughput	285000
Annual throughput escalation (2022-2039)	20277
Fees/TEU	$30
Fees escalation/ 5 years	5%

PROJECT COST ESTIMATION	
Straddle Carriers	$1,000,000
Total project cost	**$10,000,000**

TOTAL PROJECT COSTS	
WB Loan Amount	**$6,700,000**
Front-end fee (1%)	$67,000
Local Banks Loan (Equity)	**$3,300,000**
Front-end fee (1%)	$33,000
Total	$10,100,000

General Information	
straddle No	10
Shifts No	3
Working days/year	362
Max equipment Utilization rate	80%
working hours	24
Overall Life cycle (years)	20

OPEX for existing 8 straddels (2020-2027)		
WAGES	Monthly salary	$600
	Employee (1 head count/straddle)	30
	Total wages costs (14 months/8yrs)	$2,016,000
DIESEL COSTS	Consumption (L)/straddle/hour	12
	TEU factor	1.5
	Moves/h	8
	1L Diesel price	$1.00
	Expenses for the first 2 years	$598,500
	Expanses for the next 6 years	$2,242,611
	Total Diesel expanses	$2,841,111
MAINTENANCE	Yearly maintenance cost (% of Purchase cost)	12%
	Total maintenance cost	$9,600,000
INVENTORY HOLDING COST	Total Inventory cost	$819,630
TOTAL		$15,276,741

OPEX for Future 8 straddels (2028-2039)		
WAGES	Monthly salary	600
	Employee (1 head count/straddle)	30
	Total wages costs (14 months/12yrs)	$3,024,000
DIESEL COSTS	Consumption (L)/straddle/hour	12
	TEU factor	1.5
	Moves/h	8
	1L Diesel price	$1.00
	Total Diesel expanses	$6,784,650.00
MAINTENANCE	early maintenance cost (% of Purchase cos	12%
	Total maintenance cost	$14,400,000
INVENTORY HOLDING COST	Total Inventory cost	$1,297,840
TOTAL		$25,506,490

Inventory cost	1-5 yrs	6-8 yrs	9-10 yrs	11-15 yrs	16-20 yrs
	$506,580	$313,050	$208,700	$536,970	$552,170

YEAR	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
ANNUAL MOVES	199500	199500	213694	227888	242082	256276	270470	284664	298858	313052
STRADDLE HRS	24937.5	24937.5	26711.75	28486	30260.25	32034.5	33808.75	35583	37357.25	39131.5

YEAR	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
ANNUAL MOVES	327246	341440	355634	369828	384022	398216	412410	426604	440798	454992
STRADDLE HRS	40905.75	42680	44454.25	46228.5	48002.75	49777	51551.3	53325.5	55099.8	56874

- OPEX: the operational costs are divided into two periods, the first 8 years to be secured by the available straddles and the next 12 years with new ones where the investment took place.

- Diesel costs (2020-2027): calculated on the base of straddle working hours in accordance with the increasing yearly moves. Taking into account that the first 2 years the annual throughput still the same and to be increased with 20277 TEUs p.a. thereafter. Besides, an additional 5% of annual moves are added for housekeeping activities.

- Diesel costs (2028-2039): During the remaining life cycle of the project, diesel cost is counted as well based on total equipment hours in relation with the escalated annual throughput and housekeeping moves.

- Project life cycle: It is the summation of the existed and the new equipment economic life

Year	2020		2021		2022		2023		2024		2025		2026		2027		2028		2029	
Semiannual																	S1	S2	S1	S2
COSTS																				
I/O Period	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,700,000	$6,281,250	$5,862,500	$5,443,750
Principal Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$418,750	$418,750	$418,750	$418,750
Interest on Principal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$181,905	$170,536	$159,167	$147,798
Total	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$600,655	$589,286	$577,917	$566,548
E/O Period	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,300,000	$3,093,750	$2,887,500	$2,681,250
Principal Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$206,250	$206,250	$206,250	$206,250
Interest on Principal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$132,000	$123,750	$115,500	$107,250
Total	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$338,250	$330,000	$321,750	$313,500
Opex/year	$1,909,592.63		$1,909,592.63		$1,947,784.48		$1,947,784.48		$1,986,740.17		$1,986,740.17		$2,026,474.97		$2,026,474.97		$2,168,051.65		$2,168,051.65	

2030		2031		2032		2033		2034		2035		2036	2037	2038	2039
S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2				
$5,025,000	$4,606,250	$4,187,500	$3,768,750	$3,350,000	$2,931,250	$2,512,500	$2,093,750	$1,675,000	$1,256,250	$837,500	$418,750				
$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	$418,750	Total interest			
$136,429	$125,060	$113,691	$102,322	$90,953	$79,583	$68,214	$56,845	$45,476	$34,107	$22,738	$11,369				
$555,179	$543,810	$532,441	$521,072	$509,703	$498,333	$486,964	$475,595	$464,226	$452,857	$441,488	$430,119	$1,546,193			
$2,475,000	$2,268,750	$2,062,500	$1,856,250	$1,650,000	$1,443,750	$1,237,500	$1,031,250	$825,000	$618,750	$412,500	$206,250				
$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	$206,250	Total interest			
$99,000	$90,750	$82,500	$74,250	$66,000	$57,750	$49,500	$41,250	$33,000	$24,750	$16,500	$8,250				
$305,250	$297,000	$288,750	$280,500	$272,250	$264,000	$255,750	$247,500	$239,250	$231,000	$222,750	$214,500	$1,122,000			
$2,211,412.68		$2,211,412.68		$2,255,640.94		$2,255,640.94		$2,300,753.76		$2,300,753.76		$2,346,768.83	$2,346,768.83	$2,393,704.21	$2,393,704.21
TOTAL	$43,093,848.61														

- The investment will occur in 2028, therefore, the loan and equity repayment will extend till 2035
- OPEX is escalated by 2% every 2 years during the 20 years of the project life.

	Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	
	Semiannual									S1	S2
	BENEFITS										
	Cash inflow									$6,678,666	$ 6,678,666
	Yearly	$8,550,000	$8,550,000	$9,158,310	$9,766,620	$10,374,930	$11,532,402	$12,140,712	$12,749,022	$13,357,332	
	CASH inflow-OPEX	$6,640,407.38	$6,640,407.38	$7,210,525.52	$7,818,835.52	$8,388,189.83	$9,545,661.83	$10,114,237.03	$10,722,547.03	$11,189,280	
	Cash Surplus	$6,640,407	$6,640,407	$7,210,526	$7,818,836	$8,388,190	$9,545,662	$10,114,237	$10,722,547	$4,555,735.18	$4,675,354.24
	TAX (25%)	$1,660,101.84	$1,660,101.84	$1,802,631.38	$1,954,708.88	$2,097,047.46	$2,386,415.46	$2,528,559.26	$2,680,636.76	$2,307,772.35	
	Net income	$4,980,305.53	$4,980,305.53	$5,407,894.14	$5,864,126.64	$6,291,142.37	$7,159,246.37	$7,585,677.77	$8,041,910.27	$6,923,317.06	
	CUMULATIVE	$181,358,990									
cash inflow minus (opex+interests+tax)	-$10,000,000	$4,980,305.53	$4,980,305.53	$5,407,894.14	$5,864,126.64	$6,291,142.37	$7,159,246.37	$7,585,677.77	$8,041,910.27	$8,273,317.06	

2029		2030		2031		2032		2033		2034		2035		2036	2037	2038	2039
$ 6,982,821	$ 6,982,821	$7,651,325	$ 7,651,325	$ 7,955,480	$ 7,955,480	$ 8,259,635	$ 8,259,635	$ 8,563,790	$ 8,563,790	$ 8,867,945	$ 8,867,945	$ 9,630,705	$ 9,630,705	$ 19,910,274	$ 20,559,137.58	$ 22,256,235.46	$ 22,945,653.46
$13,965,642		$15,302,649.60		$15,910,959.60		$16,519,269.60		$17,127,579.60		$17,735,889.60		$19,261,409.58		$ 19,869,720	$ 20,478,080	$ 21,086,340	$ 21,694,650
$11,797,590		$13,091,237		$13,699,547		$14,263,629		$14,871,939		$15,435,136		$16,960,656		$17,522,951	$18,131,261	$18,692,635	$19,300,945
$4,999,128.30	$5,018,747.36	$5,685,189.71	$5,704,808.77	$6,028,582.83	$6,048,201.90	$6,349,861.83	$6,369,480.89	$6,693,254.96	$6,712,874.02	$7,014,091.67	$7,033,710.73	$7,816,089.79	$7,835,708.85	$ 17,563,504.75	$ 18,212,368.75	$ 19,862,531.25	$ 20,551,949.25
$2,504,468.92		$2,847,499.62		$3,019,196.18		$3,179,835.68		$3,351,532.24		$3,511,950.60		$3,912,949.66		$4,390,876.19	$4,553,092.19	$4,965,632.81	$5,137,987.31
$7,513,406.75		$8,542,498.86		$9,057,588.55		$9,539,507.04		$10,054,596.73		$10,535,851.81		$11,738,848.98		$13,172,628.56	$13,659,276.56	$14,896,898.44	$15,413,961.94
$8,763,406.75		$9,792,498.86		$10,307,588.55		$10,789,507.04		$11,304,596.73		$11,785,851.81		$12,988,848.98		$13,132,074.56	$13,578,168.56	$13,727,002.56	$14,162,958.06

Cost-Benefit Analysis for Straddle carriers			
COSTS		WACC	
Project cost	$10,100,000	5.62%	
Total Interest	$2,668,193	NPV	$96,408,397.45
Opex	$43,093,849	IRR	55%
Cumulative Tax	$60,452,997	MIRR	19%
Total costs	$116,315,038	Payback Period (yrs)	
BENEFITS		0.89	
Cumulative Incomes	$214,852,032		
NET before TAX	$241,811,987		
NET after TAX	$181,358,990		

Similarly to previous calculations and analysis, the above figures show the benefit gathered during the project life where:

Cash inflow = Annual throughput (TEUs)* Move price

- Move price: 30$ escalated by 5% every 5 years
- Annual Throughput: escalated by 20277 TEU/year for 20 years period
- Cash surplus = Cash inflow – (loan and equity payment (principle+interest) + OPEX)
- Cash inflows minus (OPEX+interest+tax) is used to calculate the payback period without including the project cost. The same row is utilized to calculate IRR including the first cell (- $ 10,000,000) which is the project cost.
- Net income Row is utilized to calculate the NPV.
- A summary of the CBA results is shown in the above figure.

B- RTG system

- Number of needed RTGs

Yard-truck interchange

Daily handling volume (moves) per activity (peak)		
Total annual moves	190,000	Moves
Daily moves	524.86	Moves
Peak surcharge	10%	
Daily moves peak	577	Moves
5% housekeeping move	606.22	Moves
Avail. oper. hours/day	19.2	hours
Hourly performance	20	moves/hr/RTG
Resulting no of RTG	2	no.
Equipment hours	9,975.00	hours

Daily peak equipment demand [#] = Daily handling volume (moves) per activity * peak factor / Hourly performance of equipment * avail. oper. hours per day

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Annual Throughput	285000	285000	305277	325554	345831	366108	386385	406662	426939	447216
Annual moves	190000	190000	203518	217036	230554	244072	257590	271108	284626	298144
Daily move peak	577	577	618	660	701	742	783	824	865	906
Daily move + 5% housekeeping	606.22	606.22	649.35	692.48	735.61	778.74	821.87	865.00	908.13	951.26
NO. RTGs	2	2	2	2	2	2	2	2	2	2

Year	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Annual Throughput	467493	487770	508047	528324	548601	568878	589155	609432	629709	649986
Annual moves	311662	325180	338698	352216	365734	379252	392770	406288	419806	433324
Daily move peak	947	988	1,029	1,070	1,111	1,152	1,194	1,235	1,276	1,317
Daily move + 5% housekeeping	994.39	1,037.52	1,080.65	1,123.78	1,166.91	1,210.04	1,253.18	1,296.31	1,339.44	1,382.57
NO. RTGs	3	3	3	3	3	3	3	3	3	4

The above calculations reveal that the terminal needs 2 RTGs from 2020 till 2029, 3 RTGs for the period between 2030 and 2038 and 4 RTGs starting from 2039. However, to cover the 20 years period, similarly to the straddle carrier project life cycle period, and to simplify calculations, we assume that during the last year the terminal will continue working with 3 RTGs. Thus, taking into account the remaining available RTG, the terminal needs to invest in 2 new RTGs to ensure Yard-Gate transfer.

The number of RTGs is obtained taking into consideration the evolution of annual container throughput, the equipment productivity and the housekeeping moves with 80% of equipment utilization rate and 10% of peak surcharge.

CASHFLOW PROJECTION	
Project Cost	$5,000,000
Advance Ratio	67%
Loan Amount	$3,350,000
Repayment per Year	$418,750.00
Equity	$1,650,000
Equity repayment per year	$206,250.00
Amortization (no of years)	8
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Opex/year	$677,262.23
Opex Escalation/2 years	2%
Annual throughput	285000
TEU/year/crane escalation (2022-2034)	20277
Fees/TEU	$30
Fees escalation/ 5 years	5%

PROJECT COST ESTIMATION	
eRTG	$2,500,000
Total project cost	$5,000,000

TOTAL PROJECT COSTS	
WB Loan Amount	$3,350,000
Front-end fee (1%)	$33,500
Local Banks Loan (Equity)	$1,650,000
Front-end fee (1%)	$16,500
Total	$5,050,000

General Information	
eRTG No	2
Shifts No	3
Working days/year	362
Max equipment Utilization rate	80%
working hours	24
Life cycle (years)	20

OPEX		
WAGES	Monthly salary (RTG driver)	$800
	Employee (1.5 head count/RTG)	9
	Total RTG drivers wages (14 months/20yrs)	$2,016,000
Energy expenses	Kwh/h (RTG)	40
	1Kwh price	$0.11
	Total Electricity cost	$1,411,775
MAINTENANCE	RTG maintenance/yr (% of puchase price)	8%
	RTG total maintenance cost	$8,000,000
INVENTORY HOLDING COST	Total Inventory cost	$2,117,470
TOTAL		$13,545,245

ENERGY CONSUMPTION FORECAST

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Annual Throughput	285000	285000	305277	325554	345831	366108	386385	406662	426939	447216
Annual moves	190000	190000	203518	217036	230554	244072	257590	271108	284626	298144
Yard-Truck RTGs hours	9975	9975	10684.695	11394.39	12104.085	12813.78	13523.475	14233.17	14942.865	15652.56
RTG Energy cost	$43,890	$43,890	$47,013	$50,135	$53,258	$56,381	$59,503	$62,626	$65,749	$68,871

Year	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Annual Throughput	467493	487770	508047	528324	548601	568878	589155	609432	629709	649986
Annual moves	311662	325180	338698	352216	365734	379252	392770	406288	419806	433324
Yard-Truck RTGs hours	16362.255	17071.95	17781.645	18491.34	19201.035	19910.73	20620.425	21330.12	22039.815	22749.51
RTG Energy cost	$71,994	$75,117	$78,239	$81,362	$84,485	$87,607	$90,730	$93,853	$96,975	$100,098

Inventory cost	1-5 yrs	6-10 yrs	11-15 yrs	16-20 yrs
	$506,580	$521,750	$536,970	$552,170

- eRTG purchase price: Estimated by WPS (2020) to be around $ 2,500,000.

- Energy cost: It is calculated based on the resulting annual working hours of RTGs (annual moves/ RTG moves per hour), Then the total cost is the sum of all energy costs for the next 20 years.

Year	2020		2021		2022		2023		2024		2025		2026		2027		2028	2029
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2		
COSTS																		
L/O Period	$3,350,000	$3,140,625	$2,931,250	$2,721,875	$2,512,500	$2,303,125	$2,093,750	$1,884,375	$1,675,000	$1,465,625	$1,256,250	$1,046,875	$837,500	$628,125	$418,750	$209,375		
Principal Payment	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	$209,375	Total interest	
Interest on Principal	$90,953	$85,268	$79,583	$73,899	$68,214	$62,530	$56,845	$51,161	$45,476	$39,792	$34,107	$28,423	$22,738	$17,054	$11,369	$5,685		
Total	$300,328	$294,643	$288,958	$283,274	$277,589	$271,905	$266,220	$260,536	$254,851	$249,167	$243,482	$237,798	$232,113	$226,429	$220,744	$215,060	$773,096	
E/O Period	$1,650,000	$1,546,875	$1,443,750	$1,340,625	$1,237,500	$1,134,375	$1,031,250	$928,125	$825,000	$721,875	$618,750	$515,625	$412,500	$309,375	$206,250	$103,125		
Principal Payment	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	$103,125	Total interest	
Interest on Principal	$66,000	$61,875	$57,750	$53,625	$49,500	$45,375	$41,250	$37,125	$33,000	$28,875	$24,750	$20,625	$16,500	$12,375	$8,250	$4,125		
Total	$169,125	$165,000	$160,875	$156,750	$152,625	$148,500	$144,375	$140,250	$136,125	$132,000	$127,875	$123,750	$119,625	$115,500	$111,375	$107,250	$561,000	
Opex/year	$677,262.23		$677,262.23		$690,807.47		$690,807.47		$704,623.62		$704,623.62		$718,716.09		$718,716.09		$733,090.41	$733,090.41
TOTAL	$14,977,393.32																	

2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
$747,752.22	$747,752.22	$762,707.27	$762,707.27	$777,961.41	$793,520.64	$809,391.05	$825,578.87	$842,090.45	$858,932.26

The above figures highlight the loan and equity repayment over 8 years as well as the sum of operational costs for the next 20 years escalated by 2% every 2 years.

	Year	2020		2021		2022		2023		2024		2025		2026		2027		2028
	Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	
	BENEFITS																	
	Cash inflow	$4,275,000	$ 4,275,000	$ 4,275,000	$ 4,275,000	$4,883,310	$ 4,883,310	$ 5,491,620	$ 5,491,620	$ 6,099,930	$ 6,099,930	$ 7,043,652	$ 7,043,652	$ 7,682,378	$ 7,682,378	$ 8,321,103	$ 8,321,103	$ 17,280,932
	Yearly	$8,550,000		$8,550,000		$9,766,620		$10,983,240		$12,199,860		$14,087,304		$15,364,755		$16,642,206		$ 17,280,932
	CASH inflow-OPEX	$7,872,738		$7,872,738		$9,075,813		$10,292,433		$11,495,236		$13,382,680		$14,646,039		$15,923,490		$16,547,841
	Cash Surplus	$3,416,916.39	$3,476,725.92	$3,486,535.45	$3,496,344.98	$4,107,691.89	$4,117,501.42	$4,735,620.95	$4,745,430.48	$5,356,641.94	$5,366,451.47	$6,319,983.00	$6,329,792.53	$6,971,281.33	$6,981,090.86	$7,629,625.89	$7,639,435.42	$ 16,547,841.09
	TAX (25%)	$1,723,410.58		$1,745,720.11		$2,056,298.33		$2,370,262.86		$2,680,773.35		$3,162,443.88		$3,488,093.05		$3,817,265.33		$4,136,960.27
	Net income	$5,170,231.73		$5,237,160.32		$6,168,894.98		$7,110,788.58		$8,042,320.06		$9,487,331.65		$10,464,279.14		$11,451,795.99		$12,410,880.81
	CUMULATIVE	$255,361,930																
cash inflow minus (opex+interests+tax)	-$5,000,000	$5,845,231.73		$5,862,160.32		$6,793,894.98		$7,735,788.58		$8,667,320.06		$10,112,331.65		$11,089,279.14		$12,076,795.99		$12,410,880.81

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
$ 17,919,657.00	$ 19,484,780.85	$ 20,153,921.85	$ 20,823,062.85	$ 21,492,203.85	$ 22,161,344.85	$23,938,553.09	$24,607,694.09	$25,276,835.09	$25,945,976.09	$26,615,117.09
$ 17,919,657	$ 19,484,781	$ 20,153,922	$ 20,823,063	$ 21,492,204	$ 22,161,345	$ 23,938,553	$ 24,607,694	$ 25,276,835	$ 25,945,976	$ 26,615,117
$17,186,567	$18,737,029	$19,406,170	$20,060,356	$20,729,497	$21,383,383	$23,145,032	$23,798,303	$24,451,256	$25,103,886	$25,756,185
$ 17,186,566.59	$ 18,737,028.63	$ 19,406,169.63	$ 20,060,355.58	$ 20,729,496.58	$ 21,383,383.44	$ 23,145,032.45	$ 23,798,303.04	$ 24,451,256.22	$ 25,103,885.64	$ 25,756,184.83
$4,296,641.65	$4,684,257.16	$4,851,542.41	$5,015,088.90	$5,182,374.15	$5,345,845.86	$5,786,258.11	$5,949,575.76	$6,112,814.05	$6,275,971.41	$6,439,046.21
$12,889,924.94	$14,052,771.47	$14,554,627.22	$15,045,266.69	$15,547,122.44	$16,037,537.58	$17,358,774.34	$17,848,727.28	$18,338,442.16	$18,827,914.23	$19,317,138.62
$12,889,924.94	$14,052,771.47	$14,554,627.22	$15,045,266.69	$15,547,122.44	$16,037,537.58	$17,358,774.34	$17,848,727.28	$18,338,442.16	$18,827,914.23	$19,317,138.62

Cost-Benefit Analysis for RTG system			
COSTS		WACC	
Project cost	$5,050,000	5.62%	
Total Interest	$1,334,096	NPV	$134,305,363
Opex	$14,977,393	IRR	124%
Cumulative Tax	$85,120,643	MIRR	29%
Total costs	$106,482,133	Payback Period (yrs)	
BENEFITS		0.64	
Cumulative Income	$361,844,063		
NET before TAX	$340,482,574		
NET after TAX	$255,361,930		

The above figures show the benefit gathered during the project life where:

Cash inflow = Annual throughput (TEUs)* Move price

- Move price: 30$ escalated by 5% every 5 years
- Annual Throughput: escalated by 20277 TEU/year for 20 years' period
- Cash surplus = Cash inflow – (loan and equity payment (principle + interest) + OPEX)
- Cash inflows minus (OPEX + interest + tax) is used to calculate the payback period without including the project cost. The same row is utilized to calculate IRR including the first cell (- $ 5,000,000) which is the project cost.
- Net Income Row is utilized to calculate the NPV.
- A summary of the CBA results is shown in the above figure.

IV. The port authority investment project

CASHFLOW PROJECTION	
Project Cost	$86,980,000
Advance Ratio	67%
Loan Amount	$58,276,600
Repayment per Year	$1,942,553.33
Equity	$28,703,400
Equity repayment per year	$956,780
Amortization (no of years)	30
No. of Repayments/year	2

ASSUMPTIONS	
Margin (spread)	4.13%
LIBOR	1.3%
Preference Share Coupon	8%
Yearly incomes	$4,476,228
Fees escalation/ 10 years	5%

PROJECT COST ESTIMATION	
Project cost estimation	$86,980,000
Total	$86,980,000

TOTAL PROJECT COSTS	
WB Loan Amount	**$58,276,600**
Front-end fee (1%)	$582,766
Local Banks Loan (Equity)	**$28,703,400**
Front-end fee (1%)	$287,034
Total	$87,849,800

General Information	
Berth No	4
Working days/year	362
Berth occupancy rate	60%
Max Crane Utilization rate	80%
working hours	24
Life cycle (years)	50

Costs		
construction cost	New Wharf (combi-wall)	$31,150,000
	crane beam on piles	$7,840,000
	Earth work & basin dredging (-12m)	$16,130,000
	Terminal works-civil & yards	$5,550,000
	Execution engineering	$1,520,000
	construction contingencies	$12,750,000
	Total construction cost	$74,940,000
Design & supervision	design fees	$2,500,000
	construction supervision	$1,790,000
	Design & supervision contingencies	$880,000
	Total Design & Supervision costs	$5,170,000
T2 gate cost	weighbridges	$1,000,000
	Scanners	$500,000
	OCR	$500,000
	Canopies	$700,000
	T2 total Gate cost	$2,700,000
T1 gate cost	weighbridges	$600,000
	Scanners	$300,000
	OCR	$300,000
	T1 total Gate cost	$1,200,000
Demolition cost	Demolition T1	$310,000
	Demolition T2	$2,660,000
	Total demolition cost	$2,970,000
TOTAL		$86,980,000

Vessel dues per day based on volume classes

	CLASSES DE VOLUME (en m³)	REDEVANCE PAR PERIODE DE 24h (en EURO)
1	0 - 10 000	$0{,}059/m^3$
2	10 001 - 25 000	$590 + 0{,}0536/m^3 > 10\ 000$
3	25 001 - 40 000	$1\ 394 + 0{,}0496/m^3 > 25\ 000$
4	40 001 - 75 000	$2\ 138 + 0{,}047/m^3 > 40\ 000$
5	75 001 - 150 000	$3\ 783 + 0{,}044/m^3 > 75\ 000$
6	> 150 000	$7\ 083 + 0{,}0415/m^3 > 150\ 000$

Container dues perceived by the P.A

(Dinar/ Conteneur)

	C ≤ 20'	**C > 20'**
Conteneur plein	4,000	8,000
Conteneur vide	2,000	4,000

vessel dimensions								
Berth	Actual				Future			
	Length	Beam	Draft	Volume	Length	Beam	Draft	Volume
6	110	19	8	16720	150	22	9	29700
7	120	19	8	18240	160	22	9	31680
8					200	29	10.5	60900
9					200	29	10.5	60900

Vessel incomes										
Berth		Ship dues/day	AVG Teu	Calls p.a.	Annual berth throughput	Time at berth (day)	Cargo dues/TEU	Total vessel dues	Marginal total vessel incomes	Total incomes
6	actual	$1,486	937	58	119900	7	$54,346	$603,393.95	$87,192	$744,932.16
	future	$2,867	1100	109		2	$119,900	$625,032.16		
	difference	$1,629	163	51		5	$65,554	$21,638		
7	actual	$1,568	937	58	119900	7	$54,346	$636,471.58	$75,523.92	$766,341.50
	future	$2,965	1100	109		2	$119,900	$646,441.50		
	difference	$1,649	163	51		5	$65,554	$9,970		
8		$5,900	1800	109	196200	2	$196,200	$1,286,277.17	$1,482,477	$1,482,477
9		$5,900	1800	109	196200	2	$196,200	$1,286,277.17	$1,482,477	$1,482,477
TOTAL					632200				$3,127,670	$4,476,228

- Different project costs are provided by WPS (2020)

- The project is assumed to be financed by both debt and equity with 67% and 33% ratio respectively.

- Cost of capital repayment is assumed to be amortized during 30 years with semiannual repayment.

➢ Benefit calculations:

- Benefits generated by this project was counted in summing vessel and cargo dues handled in the container terminal 2 for the next 50 years. Vessel dues are provided by JORT (2017) where fees are calculated basing on the vessel volume category (Length * beam * Draft) and days vessels spent at berth, in addition to the cargo dues which is around 1$ per TEU taking empty and full 20' containers mean fees as the above figure shows.

- After expansion berth number 6 will be able to accommodate ships up to 150 m of length instead of 120 m length of former vessels. Therefore, estimation of new vessel dimensions would be around 150m * 22m * 9m when fully loaded with approximate carrying capacity of 1100 TEUs, the same approach was also estimated for berth No. 7. Regarding peers No. 8 and 9, they would be able to accommodate Panamax/Feeder ships of 200 m * 29m * 10.5 m dimensions when fully loaded with carrying capacity of 1800 TEUs.

- Ship sizes and carrying capacities are provided by Drewry (2012).

- Container handling at berth 6 and 7 was assumed to be secured with one STS gantry crane with 22 moves per hour, therefore to handle 1100 TEUs ships, their time at berth will be around 2 days as shown in the following formula:

$$Vessel\ time\ in\ berth = \frac{Ship\ carring\ capacity\ (TEUs)}{Crane\ No.*(Crane\ moves\ per\ h*Teu\ factor)*(daily\ working\ hours*equipment\ Utilization\ rate)} + \text{Idle time}$$

Idle time is estimated to be around 2h, then the resulting time in berth equal to:

$$\frac{1100}{1*(22*1{,}5)*(24*80\%)} + 2 = 1.8\ day\ (43\ h)$$

- Berth No. 8 and 9 have been assumed to be handled by 2 STS gantry cranes with the same conditions mentioned above, then ships calling those peers will not exceed 2 days to handle their cargo.

$$\frac{1800}{2*(22*1{,}5)*(24*80\%)}+2=\ 1.4\ \text{day}\ (36\ \text{h})$$

- Yearly container ships call for each berth is calculated as well to estimate total vessel dues incomes that the terminal gain.

$$Berth\ yearly\ calls=\frac{Working\ days\ per\ year}{Time\ in\ berth\ per\ ship*berth\ occupancy\ rate}$$

The port is working 362 days p.a. and occupancy rate have to be around 60% for efficient port operation, then each berth will be able to accommodate 109 ships p.a.

- Total annual throughput is the sum of annual throughput of all container berth corresponding to vessel size that it can accommodate and its approximate carrying capacity. It is estimated to be around 632.200 TEUs p.a.

- Marginal incomes are basically the difference in incomes between previously and new vessel sizes calling peers No. 6 and 7. It serve to assess the real cash surplus generated from the project. However, to calculate benefits total incomes has been used instead of marginal incomes which is around $ 4,476,228 p.a.

Year	2020		2021		2022		2023		2024		2025		2026		2027		2028	
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
COSTS																		
L/O Period	$58,276,600	$57,305,323	$56,334,047	$55,362,770	$54,391,493	$53,420,217	$52,448,940	$51,477,663	$50,506,387	$49,535,110	$48,563,833	$47,592,557	$46,621,280	$45,650,003	$44,678,727	$43,707,450	$42,736,173	$41,764,897
Principal Payment	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277
Interest on Principal	$1,582,210	$1,555,840	$1,529,469	$1,503,099	$1,476,729	$1,450,359	$1,423,989	$1,397,619	$1,371,248	$1,344,878	$1,318,508	$1,292,138	$1,265,768	$1,239,398	$1,213,027	$1,186,657	$1,160,287	$1,133,917
Total	$2,553,486	$2,527,116	$2,500,746	$2,474,376	$2,448,006	$2,421,636	$2,395,265	$2,368,895	$2,342,525	$2,316,155	$2,289,785	$2,263,415	$2,237,044	$2,210,674	$2,184,304	$2,157,934	$2,131,564	$2,105,194
E/O Period	$28,703,400	$28,225,010	$27,746,620	$27,268,230	$26,789,840	$26,311,450	$25,833,060	$25,354,670	$24,876,280	$24,397,890	$23,919,500	$23,441,110	$22,962,720	$22,484,330	$22,005,940	$21,527,550	$21,049,160	$20,570,770
Principal Payment	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390
Interest on Principal	$1,148,136	$1,129,000	$1,109,865	$1,090,729	$1,071,594	$1,052,458	$1,033,322	$1,014,187	$995,051	$975,916	$956,780	$937,644	$918,509	$899,373	$880,238	$861,102	$841,966	$822,831
Total	$1,626,526	$1,607,390	$1,588,255	$1,569,119	$1,549,984	$1,530,848	$1,511,712	$1,492,577	$1,473,441	$1,454,306	$1,435,170	$1,416,034	$1,396,899	$1,377,763	$1,358,628	$1,339,492	$1,320,356	$1,301,221

2029		2030		2031		2032		2033		2034		2035		2036		2037		2038		2039		2040	
S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
$40,793,620	$39,822,343	$38,851,067	$37,879,790	$36,908,513	$35,937,237	$34,965,960	$33,994,683	$33,023,407	$32,052,130	$31,080,853	$30,109,577	$29,138,300	$28,167,023	$27,195,747	$26,224,470	$25,253,193	$24,281,917	$23,310,640	$22,339,363	$21,368,087	$20,396,810	$19,425,533	$18,454,257
$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277
$1,107,547	$1,081,177	$1,054,806	$1,028,436	$1,002,066	$975,696	$949,326	$922,956	$896,585	$870,215	$843,845	$817,475	$791,105	$764,735	$738,365	$711,994	$685,624	$659,254	$632,884	$606,514	$580,144	$553,773	$527,403	$501,033
$2,078,823	$2,052,453	$2,026,083	$1,999,713	$1,973,343	$1,946,973	$1,920,602	$1,894,232	$1,867,862	$1,841,492	$1,815,122	$1,788,752	$1,762,382	$1,736,011	$1,709,641	$1,683,271	$1,656,901	$1,630,531	$1,604,161	$1,577,790	$1,551,420	$1,525,050	$1,498,680	$1,472,310
$20,092,380	$19,613,990	$19,135,600	$18,657,210	$18,178,820	$17,700,430	$17,222,040	$16,743,650	$16,265,260	$15,786,870	$15,308,480	$14,830,090	$14,351,700	$13,873,310	$13,394,920	$12,916,530	$12,438,140	$11,959,750	$11,481,360	$11,002,970	$10,524,580	$10,046,190	$9,567,800	$9,089,410
$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390
$803,695	$784,560	$765,424	$746,288	$727,153	$708,017	$688,882	$669,746	$650,610	$631,475	$612,339	$593,204	$574,068	$554,932	$535,797	$516,661	$497,526	$478,390	$459,254	$440,119	$420,983	$401,848	$382,712	$363,576
$1,282,085	$1,262,950	$1,243,814	$1,224,678	$1,205,543	$1,186,407	$1,167,272	$1,148,136	$1,129,000	$1,109,865	$1,090,729	$1,071,594	$1,052,458	$1,033,322	$1,014,187	$995,051	$975,916	$956,780	$937,644	$918,509	$899,373	$880,238	$861,102	$841,966

2041		2042		2043		2044		2045		2046		2047		2048		2049		2050	2051
S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2		
$17,482,980	$16,511,703	$15,540,427	$14,569,150	$13,597,873	$12,626,597	$11,655,320	$10,684,043	$9,712,767	$8,741,490	$7,770,213	$6,798,937	$5,827,660	$4,856,383	$3,885,107	$2,913,830	$1,942,553	$971,277		
$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	$971,277	Total interest	
$474,663	$448,293	$421,923	$395,552	$369,182	$342,812	$316,442	$290,072	$263,702	$237,331	$210,961	$184,591	$158,221	$131,851	$105,481	$79,110	$52,740	$26,370	$48,257,396	
$1,445,940	$1,419,569	$1,393,199	$1,366,829	$1,340,459	$1,314,089	$1,287,719	$1,261,348	$1,234,978	$1,208,608	$1,182,238	$1,155,868	$1,129,498	$1,103,127	$1,076,757	$1,050,387	$1,024,017	$997,647		
$8,611,020	$8,132,630	$7,654,240	$7,175,850	$6,697,460	$6,219,070	$5,740,680	$5,262,290	$4,783,900	$4,305,510	$3,827,120	$3,348,730	$2,870,340	$2,391,950	$1,913,560	$1,435,170	$956,780	$478,390		
$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	$478,390	Total interest	
$344,441	$325,305	$306,170	$287,034	$267,898	$248,763	$229,627	$210,492	$191,356	$172,220	$153,085	$133,949	$114,814	$95,678	$76,542	$57,407	$38,271	$19,136	$35,018,148	
$822,831	$803,695	$784,560	$765,424	$746,288	$727,153	$708,017	$688,882	$669,746	$650,610	$631,475	$612,339	$593,204	$574,068	$554,932	$535,797	$516,661	$497,526		

Year	2020		2021		2022		2023		2024		2025		2026		2027	
Semiannual	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
BENEFITS																
Cash inflow	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114	$2,238,114.00	$ 2,238,114
Yearly	$4,476,228		$4,476,228		$4,476,228		$4,476,228		$4,476,228		$4,476,228		$4,476,228		$4,476,228	
cumulative	$4,476,228		$8,952,456		$13,428,684		$17,904,912		$22,381,140		$26,857,368		$31,333,596		$35,809,824	
Cash Surplus	-$2,811,698	-$1,896,393	-$1,850,887	-$1,805,381	-$1,759,875	-$1,714,370	-$1,668,864	-$1,623,358	-$1,577,852	-$1,532,346	-$1,486,841	-$1,441,335	-$1,395,829	-$1,350,323	-$1,304,818	-$1,259,312
TAX (25%)	$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00	
Net income	-$4,708,090.94		-$3,656,267.90		-$3,474,244.85		-$3,292,221.81		-$3,110,198.76		-$2,928,175.71		-$2,746,152.67		-$2,564,129.62	
CUMULATIVE	$78,092,205.77															
cash inflow - interests -$86,980,000	-$938,957.61		-$756,934.56		-$574,911.52		-$392,888.47		-$210,865.43		-$28,842.38		$153,180.67		$335,203.71	

2028		2029		2030		2031		2032		2033		2034		2035		2036		2037		2038		2039	
S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
$2,238,114	$2,238,114	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,350,020	$2,467,521	$2,467,521
$4,476,228		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,700,039		$ 4,935,041.38	
$40,286,052		$44,986,091		$49,686,131		$54,386,170		$59,086,210		$63,786,249		$68,486,289		$73,186,328		$77,886,367		$82,586,407		$87,286,446		$92,221,488	
-$1,213,806	-$1,168,300	-$1,010,889	-$965,383	-$919,877	-$874,372	-$828,866	-$783,360	-$737,854	-$692,349	-$646,843	-$601,337	-$555,831	-$510,326	-$464,820	-$419,314	-$373,808	-$328,303	-$282,797	-$237,291	-$191,785	-$146,279	$16,727	$62,233
$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00	
-$1,213,806.17		-$1,010,888.95		-$919,877.42		-$828,865.90		-$737,854.38		-$646,842.85		-$555,831.33		-$464,819.81		-$373,808.28		-$282,796.76		-$191,785.24		$16,727.27	
$517,226.76		$923,061.20		$1,105,084.25		$1,287,107.30		$1,469,130.34		$1,651,153.39		$1,833,176.43		$2,015,199.48		$2,197,222.53		$2,379,245.57		$2,561,268.62		$2,978,293.63	

2040		2041		2042		2043		2044		2045		2046		2047		2048		2049		2050	2051	2052	2053
S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2				
$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,467,521	$2,590,897	$2,590,897				
$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 4,935,041.38		$ 5,181,793		$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793
$97,156,529		$102,091,570		$107,026,612		$111,961,653		$116,896,694		$121,831,736		$126,766,777		$131,701,819		$136,636,860		$141,818,653		$147,000,447	$152,182,240	$157,364,034	$162,545,827
$107,739	$153,245	$198,750	$244,256	$289,762	$335,268	$380,773	$426,279	$471,785	$517,291	$562,796	$608,302	$653,808	$699,314	$744,819	$790,325	$835,831	$881,337	$1,050,219	$1,095,724	$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793
$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00		$0.00	$0.00	$0.00	$0.00
$107,738.79		$198,750.32		$289,761.84		$380,773.36		$471,784.88		$562,796.41		$653,807.93		$744,819.45		$835,830.98		$1,050,218.53		$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45
$3,160,316.68		$3,342,339.73		$3,524,362.77		$3,706,385.82		$3,888,408.86		$4,070,431.91		$4,252,454.96		$4,434,478.00		$4,616,501.05		$5,045,276.16		$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45

2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069
$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12	$ 5,440,883.12
$167,727,621	$172,909,414	$178,091,208	$183,273,001	$188,454,794	$193,895,678	$199,336,561	$204,777,444	$210,218,327	$215,659,210	$221,100,093	$226,540,976	$231,981,859	$237,422,743	$242,863,626	$248,304,509
$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,181,793	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883	$ 5,440,883
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12
$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,181,793.45	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12	$5,440,883.12

- The above figures present different cash flows over 50 years where costs are composed by debt and equity principle and interests' payment over 30 years in semiannual basis.

- Benefits are also projected for the next 50 years with escalation of port dues of 5% every 10 years.

- Tax has been eliminated considering that the project has social benefits and positive impact on the national economy, therefore, the government subsidy would be presented in Tax exemption.

- It has been observed that during the period from 2020 to 2029 costs are higher than incomes, thus, the project cannot pay the Capital cost during that period.

- CBA results are provided in the next figure.

Cost-Benefit Analysis for port infrastructure development			
COSTS		WACC	
Project cost	$87,849,800	6.28%	
Total Interest	$83,275,544	NPV	($13,673,933.50)
Cumulative Tax	$0.00	IRR	2%
Total costs	$171,125,344	MIRR	4%
BENEFITS		Payback Period (yrs)	
Cumulative Incomes	$248,304,509	35.02	

- Results shows that the project is not profitable.

References

BCT. (2020). The main interest rates applied on the money market. Retrieved from https://www.bct.gov.tn/bct/siteprod/stat_page.jsp?id=129&la=AN

Business News. (2019). Put the stam afloat to save the port of radés. Retrieved from https://www.businessnews.com.tn/remettre-la-stam-a-flot-pour-sauver-le-port-de-rades,519,92737,3

Cerderqvist, H., & Holmgren, C. (2010). Investment vs. operating costs: A comparison of automatic stacking cranes and RTGs. *Port Technol.Int., 47*, 64-66.

Drewry. (2012). *Ship operating costs annual review and forecast 2012/13*. (). London: Drewry Research. Retrieved from https://commons.wmu.se/cgi/viewcontent.cgi?article=1020&context=lib_reports

Gantrex. (2017). The cost of crane rail quality: How not to lose usd 35,000 a day. Retrieved from https://www.gantrex.com/ru/stories-article/1/the-cost-of-crane-rail-quality-how-not-to-lose-usd-35000-a-day#:~:text=STS%20cranes%20require%20an%20average,total%20around%20USD%20196%20million.

Hangga, P., Shinoda, T., Takahashi, S., & Hiyoshi, K. (2014). Development of efficiency measurement for container handling equipment-application for hybrid straddle carrier. *日本航海学会論文集, 131*, 139-148.

Huang, W., & Chu, C. (2003). Cost comparison of straddle carrier direct and relay systems in container terminals. *Journal of Marine Science and Technology, 11*(4), 197-204.

IBRD. (n.d.). *Major terms and conditions of the IBRD fixed spread loan (FSL)* World Bank.

JORT. (2014). *The maximum tariff of loading, unloading, handling and guarding goods in the commercial seaports*. Tunis: The official Gazette of the Republic of Tunisia.

JORT. (2017). *Tunisian seaport charges*. Tunis: The official Gazette of the Republic of Tunisia.

Kalmar. (n.d.). *Intermodal handling increasing productivity, saving the environment* Kalmar.

Logistics Middle East. (2015). DP world invests in southampton straddle carrier fleet. Retrieved from https://www.logisticsmiddleeast.com/article-11374-dp-world-invests-in-southampton-straddle-carrier-fleet

Macrotrends. (2020). 1 year LIBOR rate - historical chart. Retrieved from https://www.macrotrends.net/2515/1-year-libor-rate-historical-chart

Miranda, I. G., & Gil, J. B. (2014). Life cycle cost application in ship-to-shore cranes. *Research Gate,*

NMCI. (2020). Container gantry crane operation courses. Retrieved from http://www.nmci.ie/index.cfm/page/course/courseId/21

OMMP. (2017). *Annual report*. (). Tunisia: OMMP.

STEG. (2019). High voltage tariff. Retrieved from https://www.steg.com.tn/fr/clients_ind/tarifs_ht.html

Thomas, B. J., & Roach, D. K. (1987). Operating and maintenance features of container handling systems.

Tradingeconomics. (2020). Tunisia - economic indicators. Retrieved from https://tradingeconomics.com/tunisia/indicators

UNCTAD. (1985). *Port development: A handbook for planners in developing countries* United Nations Publications.

VUOJOLAINEN, M., & VAN DER WAAL, J. (2015). *A longer life for your port cranes*. Helsinki: Kalmar.

Wilmsmeier, G., & Spengler, T. (2016). Energy consumption and container terminal efficiency.

World Bank. (2018). IBRD financial products. Retrieved from https://treasury.worldbank.org/en/about/unit/treasury/ibrd-financial-products/lending-rates-and-fees

World Bank. (2020). WB loan average interest rate by country. Retrieved from https://finances.worldbank.org/Loans-and-Credits/WB-Loan-Average-Interest-Rate-by-Country/cfc3-hhwe

World Bank. (n.d.). Third export development project (EDP III). Retrieved from https://projects.worldbank.org/en/projects-operations/project-detail/P132381?lang=en&tab=details

WPS. (2020). *Rades port infrastructure and logistic zone studies*. Tunis: OMMP.