11-4-2018

Implementation of lean enterprise and renewable energy in port castries Saint Lucia

Thecla Sabrina Joseph

Recommended Citation

Joseph, Thecla Sabrina, "Implementation of lean enterprise and renewable energy in port castries Saint Lucia" (2018). *World Maritime University Dissertations*. 646.
https://commons.wmu.se/all_dissertations/646

WORLD MARITIME UNIVERSITY
Malmö, Sweden

IMPLEMENTATION OF LEAN ENTERPRISE AND RENEWABLE ENERGY TECHNOLOGY IN PORT CASTRIES, SAINT LUCIA

By

THECLA SABRINA JOSEPH
Saint Lucia

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

MASTER OF SCIENCE
In
MARITIME AFFAIRS

PORT MANAGEMENT

2018

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 September 18, 2018

Supervised by: Dr Aykut Ölçer

Supervisor’s Affiliation: Maritime Energy Management

ACKNOWLEDGEMENTS

First, I would like to thank the Almighty God, for his divine mercy, guidance and protection, for bringing me here and strengthening me throughout this journey.

My sincere gratitude goes to my supervisor, Dr Aykut Ölçer for his guidance, advice and assistance leading me in the right direction. Similar profound gratitude to the faculty and staff of World Maritime University (WMU) for their contribution in completion of this MSc program.

Special thanks to my donor “Orient Fund” for awarding me this opportunity to study at the WMU.

Additionally, my appreciation extends to the council, management and staff of the Saint Lucia Air and Sea Ports Authority for the support and assistance provided in the data collection process to undertake this research. I would particularly like to single out Mrs Grace Parkinson for believing and supporting my dreams. Special mention goes to Mr Adrian Hilaire and Mrs Samara Howell, Seaports Operations Department for your cooperation, support and valuable guidance.

Last but not least, I must express my sincere gratitude to my husband, Jesse Charles for his continued love, support and encouragement. To my family and friends for their support and prayers.

ABSTRACT

Title of dissertation: **Implementation of Lean Enterprise and Renewable Energy Technology in Port Castries, Saint Lucia.**

Degree**:** **Master of Science**

This research discusses a proposed implementation of a model comprising of combined Lean Enterprise principles to improving processes and solar PV system for reduction in electricity cost and consumption in Port Castries. The model involved lean enterprise with minimal financial investment potential whilst solar PV system requires substantial investment particularly at the beginning.

The model presents an overview of lean enterprise concept, applications and appropriate tool of value stream mapping to identify and reduce waste within the entire operations process namely ship arrival, berth, yard and gate operations. An assessment was carried out where inefficiencies were evident with countermeasures for future value state and subsequent implementation. It also undertakes a brief look at management responsibilities and involvement in the implementation process and benefits to Port Castries.

The second aspect presented an economic feasibility of undertaking renewable energy generation project namely Solar PV with battery storage, to meet the electricity requirement of Port Castries. Solar PV system was discussed providing cost, benefits and applications in seaports. Analysis of the project viability was achieved by utilizing HOMER software for modelling and selecting the suitable system according to the optimization variable identifying the least-cost option where payback period, Internal Rate of Return (IRR) and Net Present Value (NPV) were calculated. Consideration was made to reduce economic and social cost including greenhouse gases (GHG) emissions.

The concluding chapters examine the results of the application of Lean Enterprise and solar PV system. Recommendations were made as to implementation lean enterprise as the suitable option due to financial constraints of Port Castries, providing timelines for training of management and staff for continuous improvement. Additionally, energy policy to be developed for short-term implementation for reduction of electricity consumption and cost.

Keywords: Port Castries, Lean Enterprise, value stream mapping, performance, continuous improvement, renewable energy, solar PV, feasibility, project appraisal, decision-making criteria.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternating Current
ASYCUDA	Automated System for Customs Data
CARICOM	Caribbean Common Market
CBA	Cost-Benefit Analysis
CDB	Caribbean Development Bank
CO_2	Carbon dioxide
CSA	Caribbean Shipping Association
DC	Direct current
EDI	Electronic Data Interchange
EnMS	Energy Management Systems
eRTG	electrical Rubber Tire Gantry
ETA	Estimated time of arrival
GDP	Gross Domestic Product
GFLC	George F. L. Charles Airport
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
GoSL	Government of Saint Lucia
GRT	Gross Register Tonnage
GW	gigawatts
HOMER	Hybrid Optimization Model for Multiple Energy Resources
ICC	Initial Cost of Capital
IEA	International Energy Agency
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency

IRR	Internal Rate of Return
IT	Information Technology
kW	Kilowatts
kWh	Kilowatts/hour
kWp	Kilowatt peak
LED	light-emitting diode
LUCELEC	Saint Lucia Electricity Services Limited
LCOE	Levelized cost of energy
MW	Megawatts
MWe	Megawatt electric
NEP	National Energy Policy
NPC	Net Present Cost
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NURC	National Utility Regulatory Commission
OJT	On the job training
O&M	Operating and maintenance
OPEX	Operating expenses
PDCA	Plan, Do, Check, Act
PEMP	Port Energy Management Plan
PM	particulate matters
POUS	point-of-use-storage
PPI	Port Performance Indicator
PV	Photovoltaic
REN21	renewable energy policy network for the 21st century

RFID	Radio-frequency identification
ROI	Return on investment
RORO	Roll-on Roll-off
SC-CO_2	social cost of carbon
SLASPA	Saint Lucia Air and Sea Ports Authority
SMED	Single Minute Exchange to Die
SOP	Standard Operating Procedures
STC	Stand test condition
STS	Ship-to-Shore
TEU	Twenty-foot Equivalent Unit
TPM	Total productive maintenance
TPS	Toyota Production System
TVM	Time Value of Money
TWh	terawatt hours
USA	United States of America
USD	United States Dollar
USEPA	United States Environmental Protection Agency
UNCTAD	United Nations Conference on Trade and Development
VSM	Value Stream Mapping

CHAPTER ONE: INTRODUCTION

1.1 Background

According to Review of Maritime Transport 2017, seaborne trade continues to be highly dependent on developments in the world economy and trade. In 2016, world seaborne trade volume totalled about 10.6 billion tons. Globally, over 80% by volume and 70% in value of trade merchandise are carried by shipping and handled by seaports. Today, the maritime transport sector is challenged by the prolonged effects of the economic downturn, mergers and acquisitions, market volatility, trade policies and oil prices. Moreover, among other challenges are factors such as climate change, energy security and cost and environmental sustainability (UNCTAD, 2017).

A port is a sub-system in the transportation network, where import and exports are served and handled, the level of efficiency is essential for productivity and profitability (Park & De, 2015). There are various factors influencing port performance including management, infrastructure, superstructure, and IT systems used. Today, ports are moving away from traditional methods of loading and unloading of cargo to expanding its functions in improving efficiency and eliminating waste within operational processes by use of successful management systems. Therefore, ports are no longer competitive based on price but by minimizing costs throughout the logistic chain with quality and reliable service.

As critical nodes in the transportation chain, seaports provide access to markets and support supply chains connecting producers and consumers. Satisfying customers' needs are paramount to successful ports in this changing market. To gain competitive advantage, ports are required to increase performance levels such as the optimization of operations, cost reduction, time efficiency and promote trade (UNCTAD, 2017). For ports to exceed expectations, customers' requirements must be met and concerns addressed to improve the flow of the information and material. To accomplish this, management and employees must be involved in identifying and eliminating waste within operations processes by use of lean principles.

Lean concept originated from the Toyota Company to eliminate waste within processes. Implementing Lean as a performance improvement method to examine existing operational processes where non-added value activities can be identified and eliminated resulting in efficiency. Various studies consider port performance indicators (PPIs) where measurement of operational process is determined by berth, yard, storage and gate operations separately. This research would examine lean as a performance measurement tool for the entire operational processes, providing value to customers as the primary objective of the port. Furthermore, the analysis intends to identify and separate non-value-added/waste from value added activities, finding root causes and solutions for process improvement and cost reduction. However, ports are highly challenged to improve performance not only in operational processes but in areas such as safety, security and environmental protection (UNCTAD, 2017).

Renewable energy sources such as solar, wind, bioenergy, hydropower, and geothermal, have the potential to meet world's energy demand and can provide energy security and sustainability (IEA, 2017). Renewable energy sources utilization and development would encourage diversification in the energy supply market for long-term sustainability and assist in reducing emissions (Hertzog, Lipman, Kammen, 2001). International Energy Agency (IEA) 2007 report stated that energy services from renewables can meet worldwide energy needs, providing secure supplies and affordability with minimal impact on the environment. However, oil and gas markets price volatility can present security risk and would continue to impact world economies, particularly developing countries. The importation of fossil fuels will have low-income economies vulnerable to price increases impacting balance of payment (IEA, 2007).

Implementing renewable energy sources for electricity generation can contribute to energy security and reduction of greenhouse gas (GHG) emissions in seaports. Therefore, it is imperative to have well-functioning seaports that not only promote trade activities but also environmental sustainability. However, international shipping contributes approximately 2.4% of global GHG emissions (IMO, 2014), which is relatively small in comparison to other transportation sectors.

Saint Lucia, a Small Island Developing State (SIDS) is highly dependent on importation of fossil fuel for electricity and transportation sector, therefore, vulnerable to global market prices. Various research has been conducted on alternative sources of energy namely solar, geothermal, wind, but to date, only solar energy is utilized for heating of water (Emanuel & Gomes, 2014). Saint Lucia electricity is generated from diesel generators and procured from the Saint Lucia Electricity Company (LUCELEC). The power supply to Port Castries over the years has faced many challenges such as power shortage and high cost. Port Castries, a relatively small port, handles 90% of the island cargo. The above challenges can be mitigated by installing renewable energy sources namely solar Photovoltaic (PV) system to supply electricity to the port. Consequently, this research assists Port Castries to take advantage of the abundant yearly solar energy of approximately 27˚Celsius creating footsteps to price stability, emission reduction and energy efficiency.

1.2 Research Aim and Objectives

This research aims at reducing cost and waste in Port Castries operational processes by implementing lean tools and installation of solar PV system for environmental and economic benefits.

This research seeks to achieve the following objectives:

- Examine the application of Lean Enterprise in port operations processes to improve performance.
- Analyse Port Castries current operations processes and integrate Lean tools to identify and eliminate waste from value added activities for cost reduction and efficiency.
- Recommend steps to implementation of Lean Enterprise for continuous improvement.
- Discuss installation of Solar technologies to generate electricity in ports, benefits, operating cost and efficiency.
- Perform a feasibility study to develop energy efficient port operations using the right combination of renewable energy for Port Castries.

1.3 Research Questions

- Would lean Enterprise be the right tool to achieve Port Castries performance goals of reducing waste within the operational processes to meet customer demand and efficiency?
- What are the strategies and techniques required for a smooth transition from existing to improve processes?

- What are the economic benefits of solar energy available commercially and options to deliver electricity in Port Castries at an affordable price?
- What is the right combination of renewable energy sources to reduce electricity consumption and cost, resulting in the expected power output and as a viable investment in regards to Net Present Value (NPV), Internal Rate of Return (IRR) and payback period?

1.4 Research Scope

At present, the Caribbean maritime industry is challenged by various factors such as operations inefficiency, inadequate infrastructure, causing additional delays and costs to shipping. Port Castries has been faced with numerous operational challenges such as equipment age, lack of flow within the operational process, high electricity bill and consumption. Furthermore, other issues such as layout, being a multipurpose port, limited ability for expansion (city port in close proximity to the regional airport), and congestion, hinders the port’s ability to operate effectively and efficiently. To be competitive, investment in equipment and infrastructure is required but due to financial constraints, alternative solutions are required to reduce costs and improve performance.

The proposed model consists of combining lean enterprise tools and solar PV systems to be examined in two pillars:

a) **Pillar I**: Implementation of Lean enterprise for efficiency in port operations with marginal investment for training of employees. This constitute an analysis of the entire operational processes by identifying non-added value activities and minimizing them to enhance asset utilization, yard storage and gate processes. Assessment would include value stream mapping (VSM) for current and future state and implementation plan for continuous improvement, based on ship arrival, berth, yard transfer, cargo storage and gate operations.

b) **Pillar II**: Installation of solar PV system in Port Castries for environmental improvement, reduction in cost of electricity and consumption. Data collection would be assessed utilizing HOMER software from Port Castries 2015-2017 electricity consumption and bills and other factors to simulate project viability. Project appraisal methods and techniques of NPV, IRR and payback period for the project lifetime would be applied.

The model would be used as a pilot project to pave the way for other ports in Saint Lucia and throughout the Caribbean Region. The research is structured in five chapters as illustrated in Table 1.

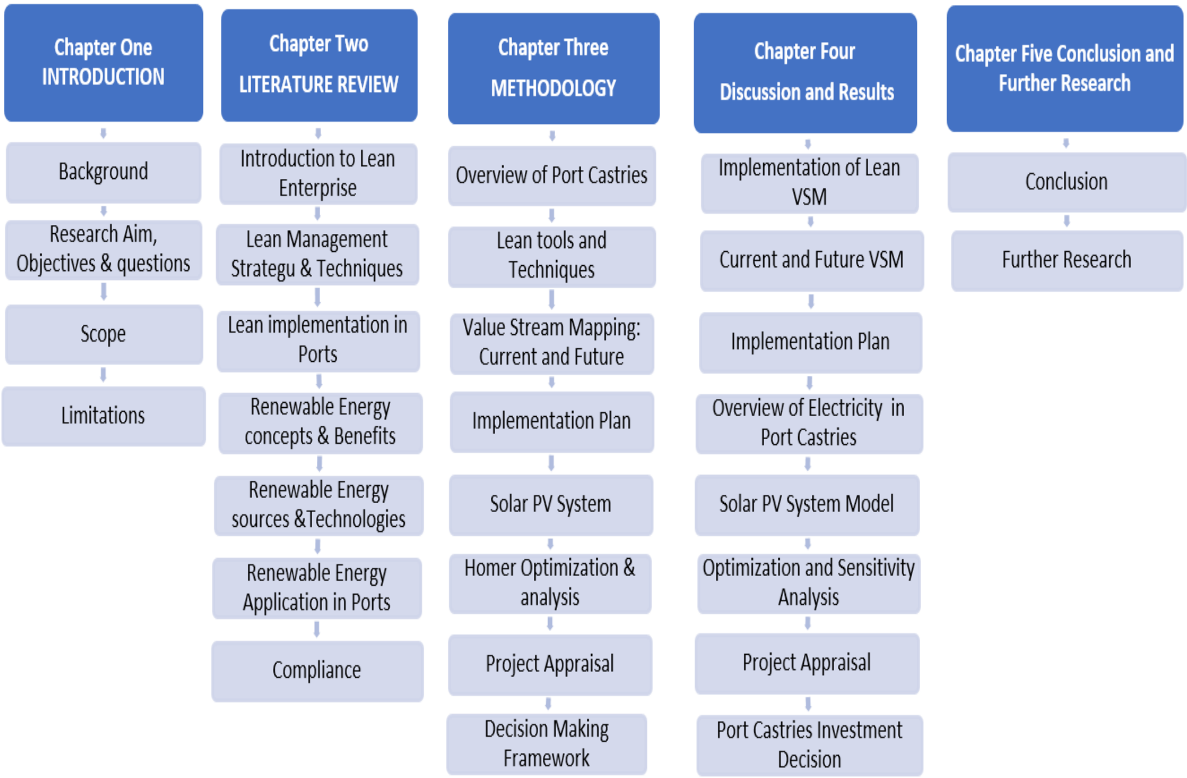


Table 1: Research Flow (Author, 2018)

1.5 Limitations

Solar PV system was considered suitable renewable source for Port Castries based on economic cost. This study is based only on application of Solar PV system and may not be sufficient analysis to reach its full potential. Furthermore, Saint Lucia Government plays a vital role in the approval of works to be undertaken at the Ports and a shareholder of the electricity company. Over the years, most renewable energy projects have stalled or cancelled based on the priority of the government of the day. Although the national electricity company has installed renewable energy systems to improve energy efficiency, legislation is lacking to adapt to new technologies by government, permitting commercial customers to generate electricity from renewables at a higher level. There are still major shortcomings that hinder the growth in the industry. Additionally, due to the limited time for completion, the author may not sufficiently obtain data to critically analyse and assess relevant information to give a comprehensive and extensive result in the development of renewable energy in Port Castries.

CHAPTER TWO: LITERATURE REVIEW

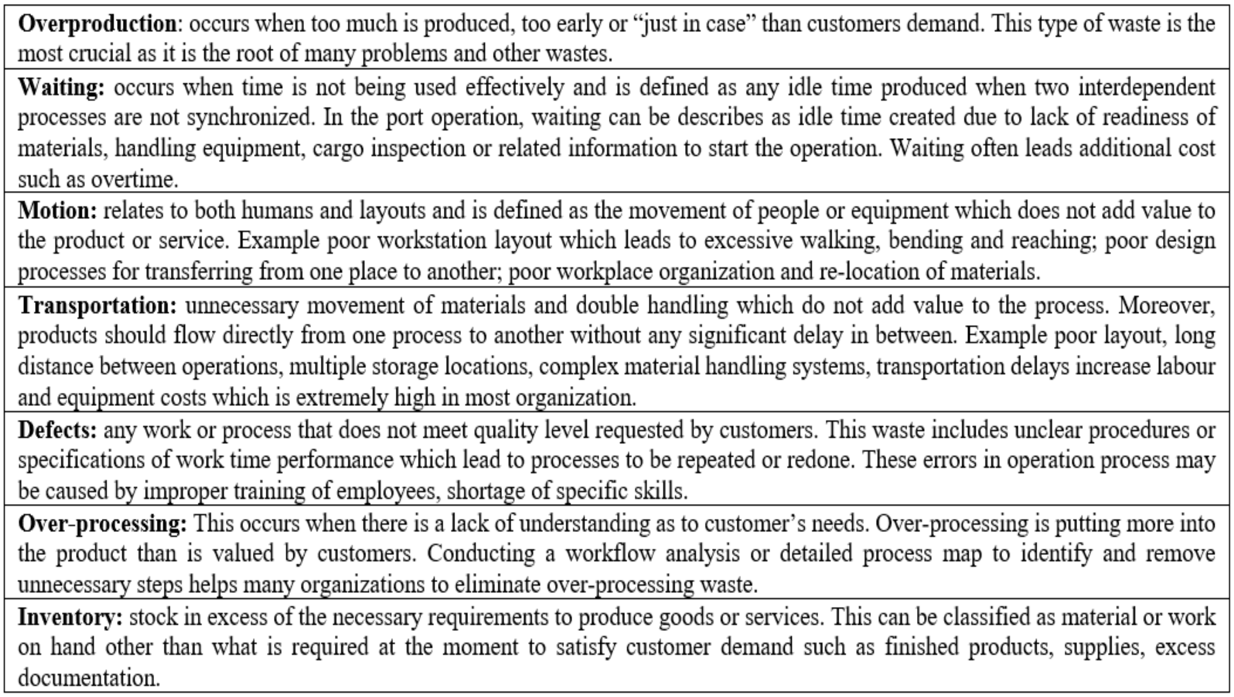
This chapter reviews studies on Lean Enterprise tools and techniques and renewable energy resources with emphasis on application in ports. The main focus of the review is to assess economic and environmental considerations pertinent to planning and undertaking lean techniques and renewable energy technology systems applicable to Seaports. Literature review is divided into three sections: 2.1 Lean Enterprise, 2.2 renewable energy and 2.3 compliance.

2.1: LEAN ENTERPRISE

2.1.1 Lean Enterprise as an Improvement Methodology

Loyd (2007) described Lean Enterprise as *"a systematic approach to identifying and eliminating waste (or non-value-added activities) through a culture of continuous improvement by flowing the product/service at the pull of the customer."* The concept originated from the Toyota production line by Taiichi Ohno and Shigeo Shingo, with the objective of reducing the timeline between customers placing orders to the point when payment is received by eliminating non-value-added activities. Lean's goal is to flow at the pull rate of customer demand (Loyd, 2007). Therefore, to perform this analysis required extensive data in respective of processes versus demand and to evaluate value stream capability of flowing at a desirable rate.

Bicheno & Holweg (2016) fifth edition of "The Lean Toolbox" provides three dimensions to lean transformation for continuous improvement within organization's processes namely waste reduction, value enhancement and involvement of people. Reducing waste known as 7-deadly waste as listed and defined in Table 2.



Overproduction: occurs when too much is produced, too early or "just in case" than customers demand. This type of waste is the most crucial as it is the root of many problems and other wastes.

Waiting: occurs when time is not being used effectively and is defined as any idle time produced when two interdependent processes are not synchronized. In the port operation, waiting can be describes as idle time created due to lack of readiness of materials, handling equipment, cargo inspection or related information to start the operation. Waiting often leads additional cost such as overtime.

Motion: relates to both humans and layouts and is defined as the movement of people or equipment which does not add value to the product or service. Example poor workstation layout which leads to excessive walking, bending and reaching; poor design processes for transferring from one place to another; poor workplace organization and re-location of materials.

Transportation: unnecessary movement of materials and double handling which do not add value to the process. Moreover, products should flow directly from one process to another without any significant delay in between. Example poor layout, long distance between operations, multiple storage locations, complex material handling systems, transportation delays increase labour and equipment costs which is extremely high in most organization.

Defects: any work or process that does not meet quality level requested by customers. This waste includes unclear procedures or specifications of work time performance which lead to processes to be repeated or redone. These errors in operation process may be caused by improper training of employees, shortage of specific skills.

Over-processing: This occurs when there is a lack of understanding as to customer's needs. Over-processing is putting more into the product than is valued by customers. Conducting a workflow analysis or detailed process map to identify and remove unnecessary steps helps many organizations to eliminate over-processing waste.

Inventory: stock in excess of the necessary requirements to produce goods or services. This can be classified as material or work on hand other than what is required at the moment to satisfy customer demand such as finished products, supplies, excess documentation.

Table 2: Toyota's Seven Deadly waste terms and definition (Author, 2018)

Womack and Jones (2003) added an eighth waste of underutilization of people. All of the above increase organizations costs, time and resources. Womack and Jones (2003) also introduced the five basic principles of waste elimination shown in Figure 1.

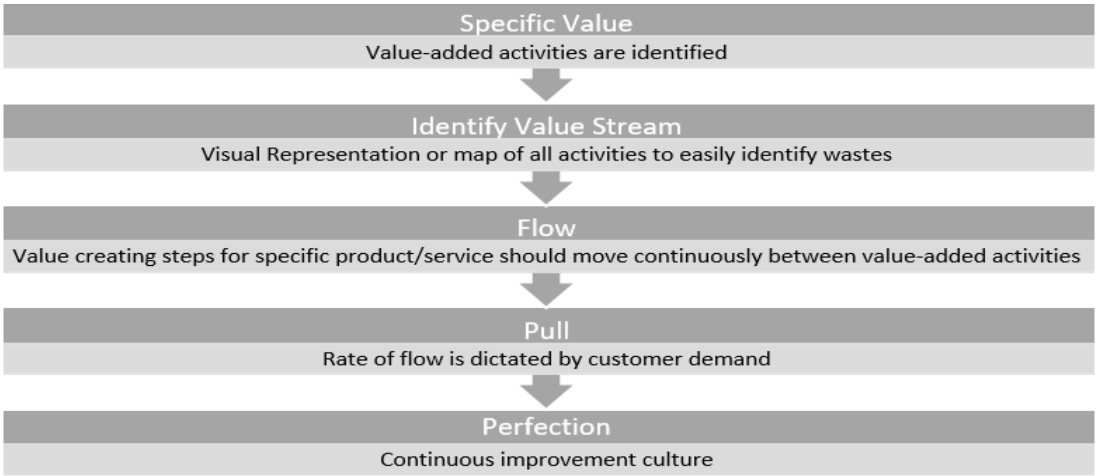


Figure 1: Womack & Jones five basic principles of Lean Thinking (Author, 2018)

Creating value streams maps of existing processes, identifying the non-value added activities and subsequently eliminating waste to promote efficiency and performance improvement. Lean creates job satisfaction by providing immediate feedback on efforts to convert waste into value (Womack & Jones, 2003). Standardized processes within organizations empower employees and eliminate unnecessary documentation (Sullivan, McDonald, & Van Aken, 2002).

2.1.2 Lean Management Tools

Lean Enterprise as a management tool is quite challenging based on complex systems centred on role of organization culture (Bortolotti, Boscari, & Danese, 2015). Lean encourages every organization to construct their own implementation model featuring appropriate tools for their industry or organization. Yang, Hong, & Modi (2011) examine empirical evidence using a different scope by observing lean and environmental management practices with ways to resolve conflict, reduce negative impacts on market and financial performance. Fullerton, Kennedy, & Widener (2014) presented lean practices in accounting departments as a key to achieving financial control and management accounting practices and adopting lean as a holistic business strategy. Mostafa, Dumrak, & Soltan (2015) undertook similar research in maintenance process by identifying waste through value stream mapping (VSM). VSM gives a visual outline of the current and future state of operational process allowing employees the understanding of where and what wastes need to be eliminated (Lovelle, 2001).

2.1.3 Application of lean enterprise in port operations

There are several tools available to achieve lean objective of eliminating waste within seaports operations in response to customer demand. Many benefits have derived from implementing lean tools such as reduction of port time and proper utilization of equipment. To date, several ports have successfully implemented lean in operational processes. Loyd et al, (2009) discussed process improvements in Port of Mobile, Alabama before and after introducing lean including challenges and recommendation. Alfayyadh (2017) presented a study on lean impact on cargo operation processes at the Umm Qasr Port for energy efficiency and eco-friendly environment. Frazer (2015) developed a conceptual framework that demonstrates the use of lean principles in container terminals to drive operational improvements for achieving effective material flow.

Franzen & Streling (2017) described the challenges in executing VSM in four European container terminals namely APM Terminal-Gothenburg, Noatum Container Terminal-Port of Valencia, Port of Helsingborg and Port of Norrköping. The study presented the transition from current to future state and recommendations for improvements for short and long-term as to automation of cargo equipment to eliminate errors and employee involvement for better balance and coordination of flow. Marlow & Paixão Casaca (2003) study described port services as double derived demand and should flow with the logistic trends to remain competitive. Therefore, ports need to consider the entire logistic chain for effective control and capacity utilization.

2.1.4 Port Performance Indicators (PPIs)

PPIs are critical to competitiveness of ports which includes the entire logistics chain where goals are achieved through quality, efficiency and price. PPIs measures various functions of the port's operation vital for benchmarking for improving its operations; for comparison to other ports and planning and future development (Moon, 2018). Port's quality of services depends on speed, reliability, flexibility, availability and efficiency. Generally, operational performance is measured using quantitative methods by calculating service time, idle time and turnaround time. Figure 2 shows port performance indicators highlighting production, productivity, utilization and service time.

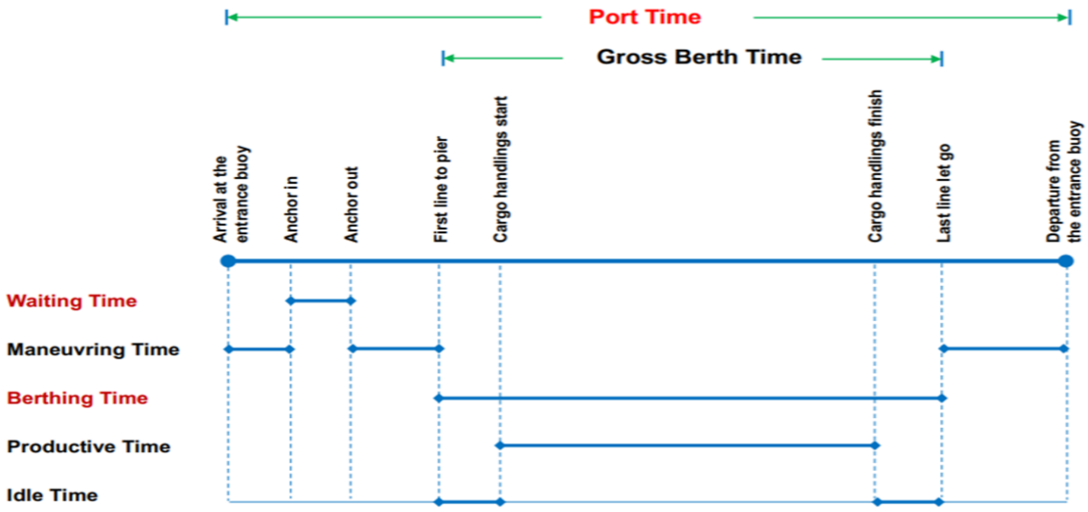


Figure 2: Port Performance Indicators (Moon, 2018)

Marlow & Paixão Casaca, (2003) considered PPIs not only in quantitative aspects but qualitative for visibility within the port environment. Quality port management system implementation should encourage continuous improvement by incorporate lean enterprise qualitative performance indicator vital in meeting the demand of the supply chain. Caribbean Development Bank (2016) study provided an in-depth analysis of the port industry in the Caribbean in relation to policies, practices, trade patterns and requirements in enhancing efficiency, improved viability and development.

2.2 RENEWABLE ENERGY

Coilkosz, (2017) describes renewable energy as *"energy generated from natural resources such as sunlight, geothermal heat, wind, ocean, water, that is constantly replenished and cannot be exhausted*." The evolution of renewable energy is the foundation of a more environmentally friendly system. IEA (2015) reported renewable source for electricity generation is predicted to have a growth of more than one-third by 2022. IRENA (2016) suggested that by 2050, electricity generation from renewable energy sources would account for approximately 60%, with half from solar PV and wind. IRENA (2014) reported renewable energy technologies have the potential to meet countries' policy goals for:

- secure, reliable and affordable energy by utilizing local sustainable energy sources;

- price volatility reduction of electricity;
- energy mix diversification; and
- promote social and economic development

Various literature is available on renewable energy technologies potential and application in developed and developing countries. Boyle (2004) summarizes the main types of renewable energy; outlining physical and technological principles whilst examining the environmental impact and prospects of different energy sources. Kristoferson & Bokalders (2013) analysed renewable energy technologies and growth in developing countries.

Painuly (2001) suggested measures as to overcome barriers to renewable energy penetration by policy approaches such as liberalisation of the sector to introduce competition through economic incentives. However, some governments have implemented subsidies including tax exemptions for installation of renewable energy systems. Verbruggen et al., (2010) also presented similar research on barriers hindering the growth of renewable energy technology to be removed in order to reach full potential. Ellabban, Abu-Rub, & Blaabjerg (2014) presented a study on status of renewable energy, benefits, growth and investment. The study also provided an overview of advantages and disadvantages, future prospects and deployment. Figure 3 illustrates current global renewable energy needs.

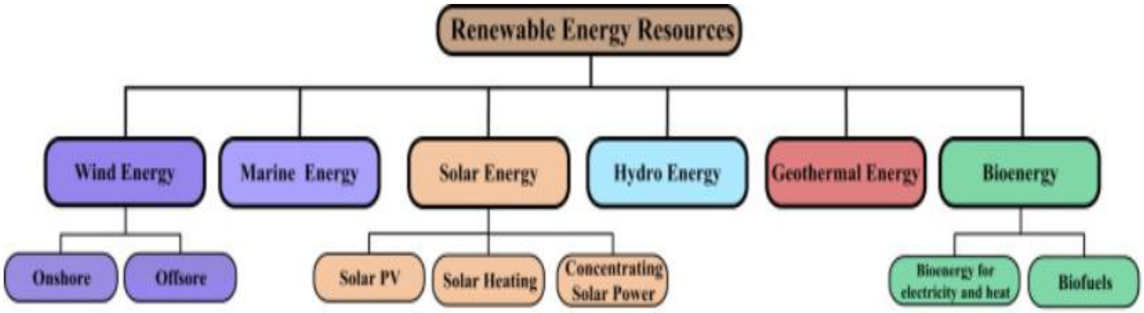


Figure 3 Renewable energy sources (Ellabban et al., 2014)

Caribbean island like Saint Lucia has an abundance of natural resources to harnessed energy technologies at lower capital and operating cost. Many studies have been conducted on renewable energy potential in Saint Lucia and the Caribbean. Ochs et al (2015) give an analysis on baseline roadmap and strategy for the Caribbean Common Market (CARICOM), highlighting renewables current situations, GHG emissions, targets and gaps, with recommendations as to energy efficiency and GHG reduction and strategy to accomplish these targets. IRENA (2012) report gives an overview of the development of renewable energy including energy supply, electricity generation and access for all islands.

2.2.1 Renewable energy sources and Technologies

(a) Wind Energy

IRENA (2016) reported onshore and offshore wind energy has evolved over the years and considered as the fastest-growing renewable energy technologies with detailed and relevant information readily available for potential users. Wind potential is considered globally, as clean energy source and when converted into electricity via wind turbines produces zero emission during power generation (Herzog, Lipman, & Kammen, 2001). In 2016, wind power accounted for approximately 4% of global electricity generation (IEA, 2018). Joselin Herbert, Iniyan, Sreevalsan, & Rajapandian, (2007) investigated wind energy technologies, its challenges, designs and economics for long-term sustainability in providing environmental option and national energy security.

Kaldellis & Zafirakis, (2011) presented the evolution of wind energy technologies for the past 30 years including challenges and progress for 2030. Kumar et al., (2016) discussed wind energy trends and technologies, levelized cost as well as economic and environmental policies encouraging installation of wind energy systems. IEA (2013) presented roadmaps for wind energy including progress and development, policy and finance, action plans and implementation. LCCC (2012) reported that from 1995, Saint Lucia has considered wind power commercially with a potential of 13.5MW.

(b) Solar Energy

Solar energy technology namely solar photovoltaics, concentrating solar power and solar heating, globally has exhibited growth (IEA, 2017). It reduces the dependence on energy imports, assisting in hedging against fossil-fuels price volatility. Panwar, Kaushik, & Kothari (2011) revealed solar energy potential rate of 3.8×1023 kW, with approximately 1.8×1014 kW intercepted by the earth. Solar photovoltaic (PV) potential in Saint Lucia is estimated at 36 MW of installed capacity (NREL, 2015). Solar PV systems can be installed anywhere on the island at a low operating cost and considered to be more economical compared to fossil fuels (Renewable Energy Caribbean, 2017).

(c) Geothermal Energy

Geothermal energy refers to "*stored thermal energy in form of heat produced within the Earth's crust averaging 25 to 30°C/km*" (Haraksingh & Koon, 2011). Each geothermal source is unique to location, temperature and pool depth consisting of dry steam plants or flash plants, harnessing temperatures as high as 180°C (IEA, 2017). Geothermal industry faces many challenges such as high exploration and project development risk, financial constraints and disadvantage to low-cost natural gas (REN21, 2017). Research indicated that "Soufriere" volcano in Saint Lucia provides the potential for geothermal energy exploration and has a potential of more than 30 MW to 170 MW, economically feasible for electricity generation (NREL, 2015). Lund & Boyd (2016) provide a synopsis of geothermal energy globally including countries review as to development, capacity and utilization. The study also provided Saint Lucia status on geothermal research as to negotiation process for conducting new geoscientific studies for power plant of up to 30 MWe capacity.

(d) Solar Energy Technology: Photovoltaic (PV) solar panels

This research is focused on only solar PV system. Solar PV is very modular technology that directly converts solar energy into electricity when combined with batteries are proven to be extremely reliable. Figure 4 exhibits solar PV growth in the global market. PV global capacity in 2013 accounted to over 135 GW, with China installing over 11 GW, followed by Japan 7 GW and United States 4 GW accounting to investment of USD 96 billion (IEA, 2014).

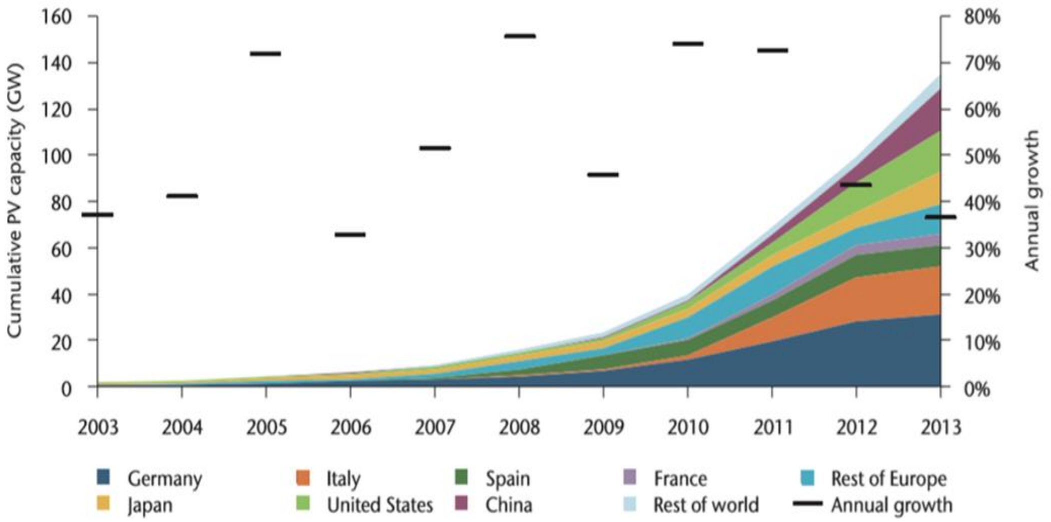
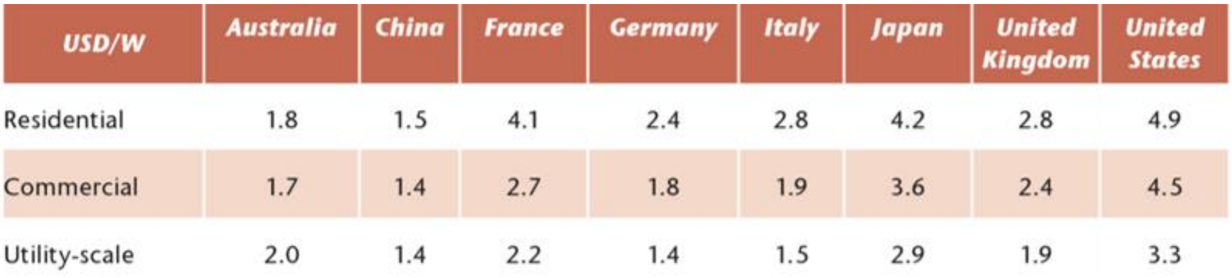


Figure 4: PV capacity: global cumulative growth (IEA, 2014)

Application of solar PV can be on-grid and off-grid ranging from 1 watt to gigawatts. However, with PV grid-connected systems, inverters are required to convert direct current (DC) power into alternating current (AC). PV like most renewable energy sources is very capital-intensive and requires large amount of up-front finance. According to industry analysis, PV has the potential for reducing cost and environmental impact due to simplicity and reliability of the technology (IEA, 2014). Table 3 gives 2014 price comparison of PV modules in various countries.



USD/W	Australia	China	France	Germany	Italy	Japan	United Kingdom	United States
Residential	1.8	1.5	4.1	2.4	2.8	4.2	2.8	4.9
Commercial	1.7	1.4	2.7	1.8	1.9	3.6	2.4	4.5
Utility-scale	2.0	1.4	2.2	1.4	1.5	2.9	1.9	3.3

Table 3 Comparison of PV system prices in various countries (Source: IEA, 2014)

Devabhaktuni et al., (2013a) examined the trends in solar energy technologies addressing economic costs, challenges regarding policies to promote installation of solar energy system. Rehman, Bader, & Al-Moallem (2007) performed a feasibility study of PV system in Saudi Arabia including renewable energy production and economic evaluation.

(e) Hybrid Solar PV/Battery storage

Various literature is available on hybrids using renewable energy technologies to improve economic and environmental cost. Sani Hassan, Cipcigan, & Jenkins, (2017) gave an insight as to tariff incentives available including sensitivity analysis of PV/battery optimization and cost. O'Shaughnessy, Cutler, Ardani, & Margolis (2018) presented similar analysis with load control for residential customers. Maheshn & Sandhu (2015) explored hybrid combination of wind/photovoltaic energy system developments as being reliable and cost effective.

2.2.2 Application of Renewable Energy Technologies in Seaports

Electrifying ports using renewable energy reduces operating cost, improve energy efficiency and environmental footprint. Renewable energy helps achieve financial targets set out in ports strategic plan. Electricity in ports is usually procured from the grid and used for lighting, air conditioning and equipment. The main energy consumption is terminal and equipment with a total of approximately 80% with the remaining 20%

consumed by lighting, workshops and other ancillary buildings (Siemens Annual Report, 2017).

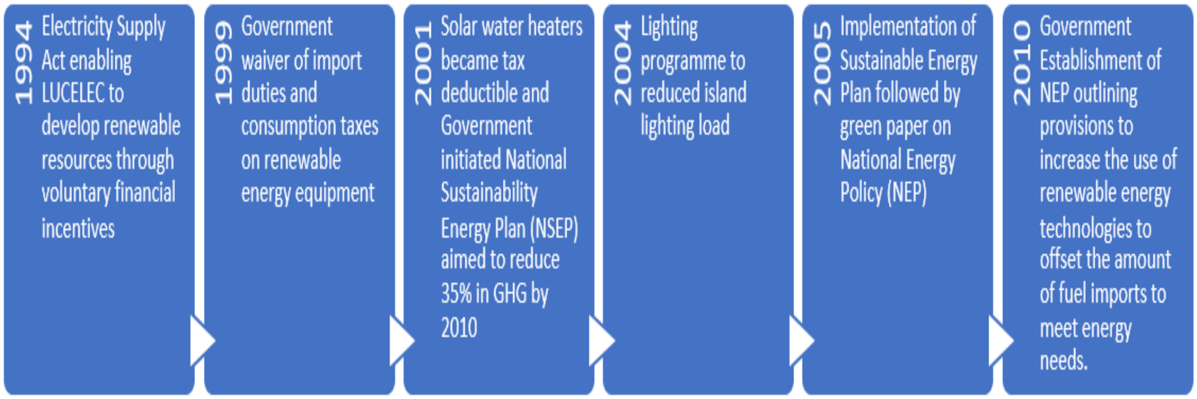
Acciaro, Ghiara, & Cusano (2014) analysed the importance of energy management focusing on Port of Genoa and Hamburg, the need to diversified in response to environmental pressure for revenue and efficiency gains and competitive advantage. A similar study was carried out by Hentschel, Ketter, & Collins (2018) on Rotterdam Port on energy transition including action plan on how to manage sustainable operation of renewable energy cooperatives. Ölçer et al (2018) describe smart micro-grid as an effective energy management tool to be considered by port authorities and terminal managers as source of revenue and energy cost savings. Ports such as Antwerp, Los Angeles, PSA and Gothenburg, have been utilizing renewables such as wind turbines and solar PV system to assist in reducing energy consumption and increasing energy efficiency.

2.3 COMPLIANCE

2.3.1 Saint Lucia National Energy Regulations

(a) Evolution of Saint Lucia’s energy policy

Saint Lucia has abundant of renewable resources such as geothermal, wind, and solar, even partially developed, could meet the demand, resulting in high penetration of renewables onto the grid (Kuang, et al 2016). Table 5 indicates the evolution of Saint Lucia energy sector.



1994 Electricity Supply Act enabling LUCELEC to develop renewable resources through voluntary financial incentives

1999 Government waiver of import duties and consumption taxes on renewable energy equipment

2001 Solar water heaters became tax deductible and Government initiated National Sustainability Energy Plan (NSEP) aimed to reduce 35% in GHG by 2010

2004 Lighting programme to reduced island lighting load

2005 Implementation of Sustainable Energy Plan followed by green paper on National Energy Policy (NEP)

2010 Government Establishment of NEP outlining provisions to increase the use of renewable energy technologies to offset the amount of fuel imports to meet energy needs.

Table 4: Evolution of Saint Lucia Energy Sector (NREL 2015)

(b) Saint Lucia National Energy Policy (NEP)

The government of Saint Lucia (GoSL) in 2001, developed and approved a Sustainable Energy Plan, with a goal to enhance energy supply and use for all sectors. However, this was impeded by lack of appropriate regulatory and policy framework. Therefore, National Energy Policy (NEP) was developed in 2010, with objectives to create an environment for regulatory and institutional framework, introducing renewable energy to diversify national energy supply, for increase energy security and independence (NEP SLU, 2010). NEP targets at lowing the cost of electricity and reducing dependence on fossil fuels by 35% by 2020 and 50% by 2030 (GoSL, 2017). However, this policy has not provided clear guidance as to exactly how unrestrictive the electricity sector or strategy for implementing renewable energy initiatives (Kuang, et al, 2016). GoSL has provided incentives such as 100% duty-free concession on the importation of renewable energy equipment and materials, and tax-refund on the purchase of solar water heaters (NEP SLU, 2010). Exploring solar energy for electricity would cost below US$0.11/kWh compared to diesel generation (Renewable Energy Caribbean, 2017).

(c) Saint Lucia Electricity Services Limited (LUCELEC)

Saint Lucia’s generation, transmission and distribution of electricity service is privately owned by the Saint Lucia Electricity Services Limited (LUCELEC) with an installed capacity of 78.4 megawatts (MW), with a peak demand of 60 MW. Most of the electricity is produced from imported diesel fuel that powers electrical generators. Cost of electricity is highly dependent on global fuel prices. LUCELEC total importation of fuel is approximately 19-million gallons/year. However, in April 2018, LUCELEC installed a 3MW solar farm with generating capacity of 7-million kWh/year, about 1.3% compared to the main diesel power plant (LUCELEC, 2018). LUCELEC is responsible for setting tariffs, standards of service and sustainable energy use. National Utility Regulatory Commission (NURC) was created by the Government as an independent regulatory body, mandated to regulate electricity supply services under the National Utilities Regulatory Commission Act of No.3 of 2016 (NURC, 2018).

2.3.2 International Standards Organization (ISO)

Figure 5 gives an overview of ISO as to membership, standards and application.

International Standard Organisation (ISO) Overview
ISO is an independent, non-governmental international organization with membership of 162 national standards bodies
ISO has published 21571 International Standards and related documents, covering almost every industry, from technology, to food safety and healthcare.
Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges
International Standard is applicable to all types and sizes of organizations, irrespective of geographical, cultural and social conditions. Successful implementation depends on commitment from all levels and functions of the organization, and especially from top management

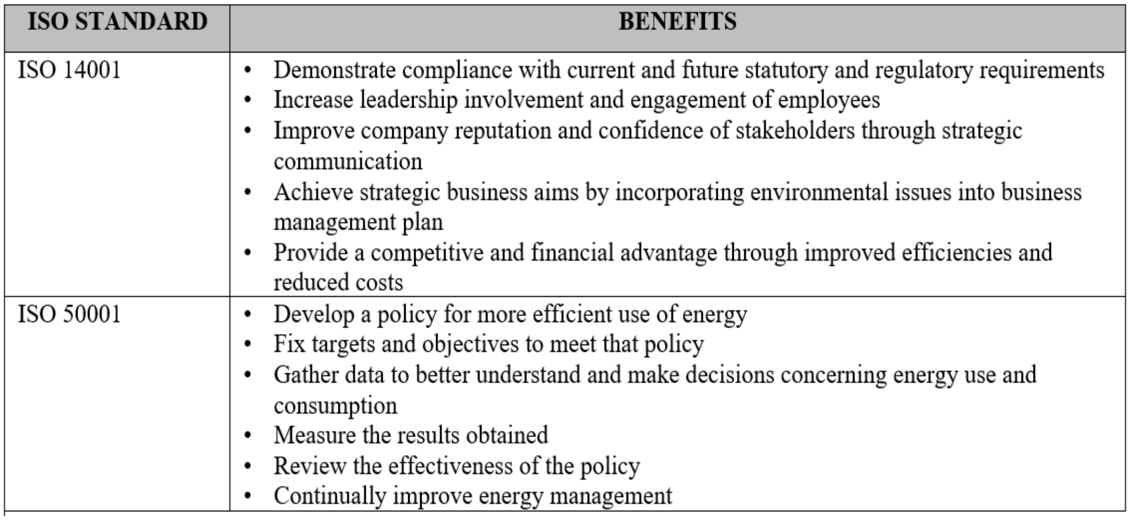
Figure 5: ISO Overview (Source: ISO, 2018)

(a) ISO 14001 Environmental Management

ISO 14001 (2015) sets out the criteria for environmental management system and certification. It standard provides guidelines for organizations in the management of environmental responsibilities while improving operational efficiencies. It also provides detailed framework namely environmental management system to be implemented by organizations.

(b) ISO 50001 Energy management

ISO 50001 (2018) sets criteria for energy management system to improve energy efficiency and use within organizations. It involves developing energy policy, setting objectives and targets and action plans for implementation. This is achieved by improving organizations' current processes, procurement of energy-efficient technologies and reducing energy consumption. Table 6 highlights benefits of implementing ISO 14001 and 50001.



ISO STANDARD	BENEFITS
ISO 14001	• Demonstrate compliance with current and future statutory and regulatory requirements • Increase leadership involvement and engagement of employees • Improve company reputation and confidence of stakeholders through strategic communication • Achieve strategic business aims by incorporating environmental issues into business management plan • Provide a competitive and financial advantage through improved efficiencies and reduced costs
ISO 50001	• Develop a policy for more efficient use of energy • Fix targets and objectives to meet that policy • Gather data to better understand and make decisions concerning energy use and consumption • Measure the results obtained • Review the effectiveness of the policy • Continually improve energy management

Table 5: ISO 14001 and 50001 benefits (Source: ISO, 2018)

Howell (2014) explored EnMS objectives and targets along with important questions and answered as to what are the significant energy uses. PDCA cycle of plan, do, check and act is used to create and implement EnMS. Figure 6 gives an outline EnMS:

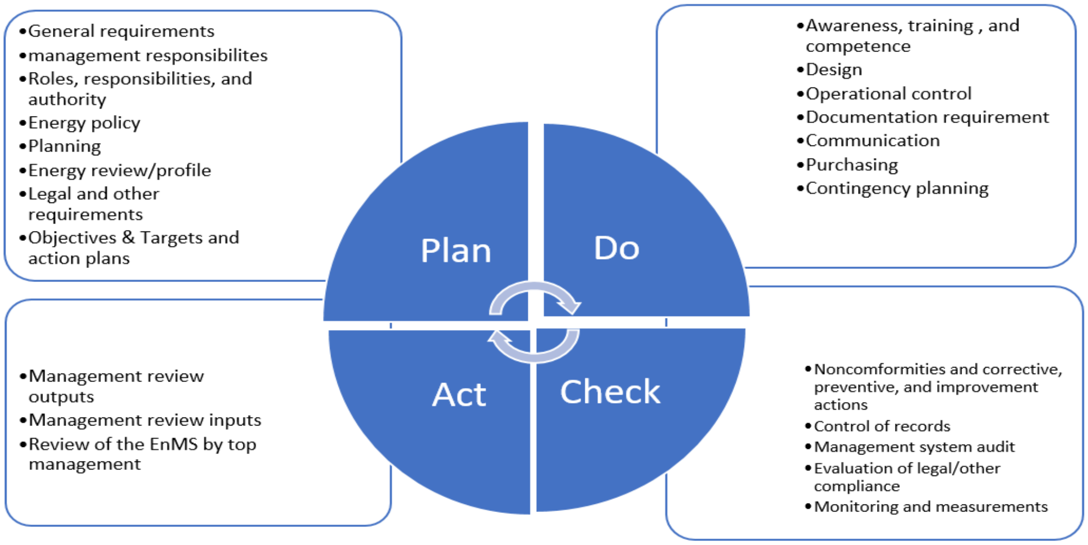


Figure 6: Elements of EnMS using PDCA Cycle (Source Howell, 2014)

CHAPTER THREE: METHODOLOGY

3.1 Methodology Overview

This chapter consists of data collection and structure of the proposed model using qualitative and quantitative methods. It gives an overview of Port Castries including operation processes, electricity cost and consumption. Figure 7 gives the steps for implementing Lean Enterprise and solar technologies.

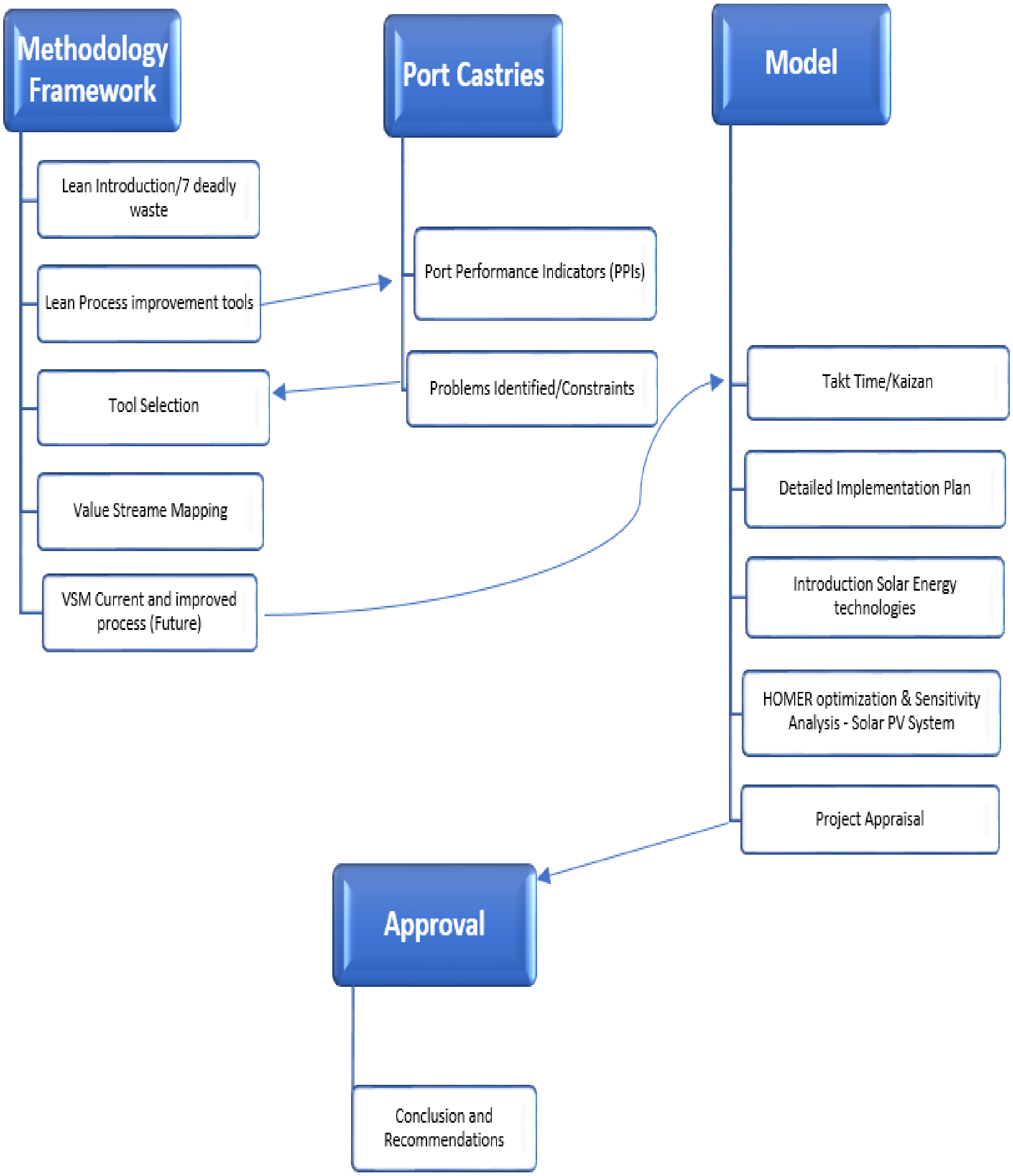


Figure 7: Case study Methodology lean and solar energy (Author, 2018)

3.2 Overview of Port Castries, Saint Lucia

Saint Lucia is a tropical island located in the Eastern Caribbean, with a total area of 616 sq. km (238 sq. miles) and a population of 180,000 (World Population Review, 2018). Foreign trade accounted for approximately 44.3% of the Gross Domestic Product (GDP) which mostly moved by ships (World Bank, 2018). Saint Lucia consists of 2-main ports namely Port Castries, located in the capital city and Port Vieux Fort in the South as shown in Figure 8.

Figure 8 Map of Saint Lucia indicating Port Castries and Vieux Fort (SLASPA Handbook, 2015)

Saint Lucia's Ports faces competition from regional ports such as Jamaica, Trinidad and Barbados being closest. To compete regionally, there is a need to address inefficiencies in operations processes and equipment. Overall, Saint Lucia ports have experienced no noticeable improvement regionally in relation to attracting transhipment.

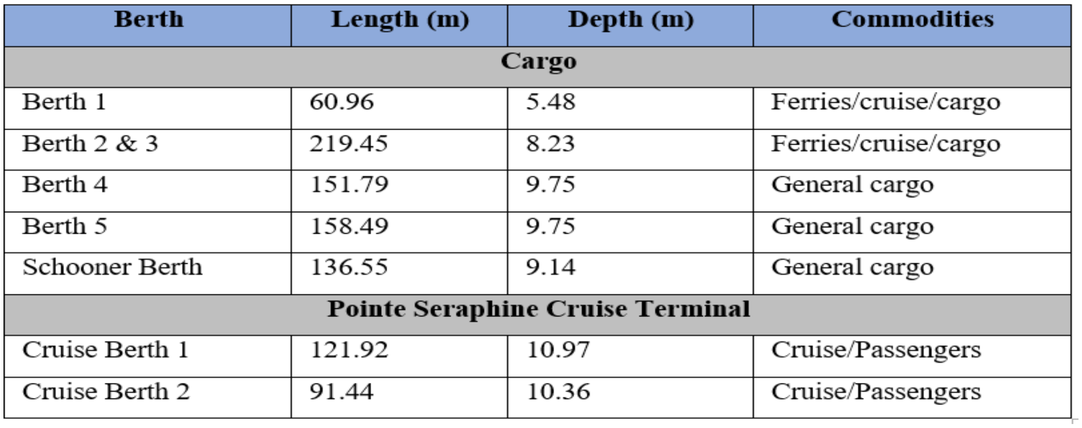
Port Castries is state owned and operated by Saint Lucia Air and Sea Ports Authority (SLASPA), established by Act of Parliament in 1983. SLASPA is a statutory body of the Ministry of Infrastructure, Ports, Energy and Labour, responsible for operating and regulating the activities of the island two main seaports, two airports and oversees other ports of entry (SLASPA Act, 2001). Government play a vital role in the decision making process as to investment which limits SLASPA’s ability to carry out necessary investments in the port (Caribbean Development Bank, 2016).

3.2.1 Operations

Port Castries is a multipurpose port consisting of cargo, cruise and ferry terminals, located within the city and connected to the hinterland via road network. The port consists of 7 berths with a floor capacity of 30,480m. Berth#2-5 currently utilized for cargo operations, Berth#1-2 cruise operations and Berth#6 for ferry service. Figure 9 shows the configuration of the port regarding number of berths.

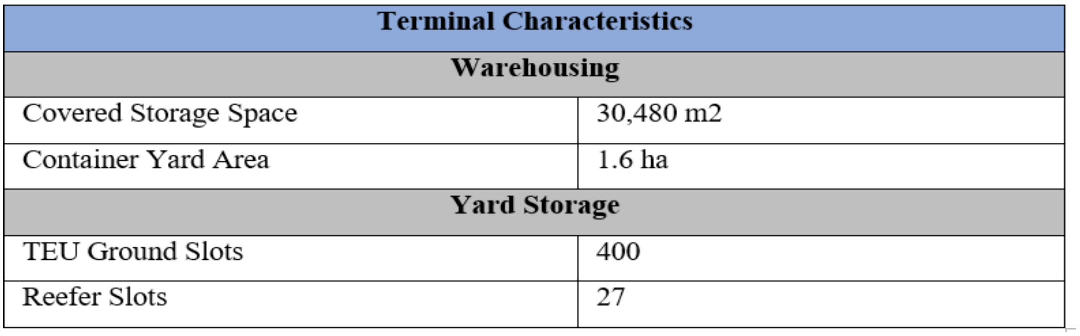
Figure 9: Aerial View of Port Castries (SLASPA 2016)

Table 7 and 8 illustrates characteristics of berths and terminal. The port has sufficient nautical depth, due to geographical characteristics to accommodate vessel size that calls at the port. The length of the quays is sufficient for berthing of 2 vessels simultaneously where pilotage is compulsory for vessels over 100 GRT.



Berth	Length (m)	Depth (m)	Commodities
Cargo			
Berth 1	60.96	5.48	Ferries/cruise/cargo
Berth 2 & 3	219.45	8.23	Ferries/cruise/cargo
Berth 4	151.79	9.75	General cargo
Berth 5	158.49	9.75	General cargo
Schooner Berth	136.55	9.14	General cargo
Pointe Seraphine Cruise Terminal			
Cruise Berth 1	121.92	10.97	Cruise/Passengers
Cruise Berth 2	91.44	10.36	Cruise/Passengers

Table 6 Berth Characteristics (Author, 2018)



Terminal Characteristics	
Warehousing	
Covered Storage Space	30,480 m2
Container Yard Area	1.6 ha
Yard Storage	
TEU Ground Slots	400
Reefer Slots	27

Table 7:Terminal Characteristics (Author, 2018)

Port Castries handles various cargo types such as cars, containerized, general cargo and cement averaging over 400,000 tons and 35,000 TEU annually. Figure 10 provides historical data on container throughput from 2005-2015. The terminal experience inefficiency in operations processes due to layout of yard particularly container yard where stacking area is at a distance from the berth.

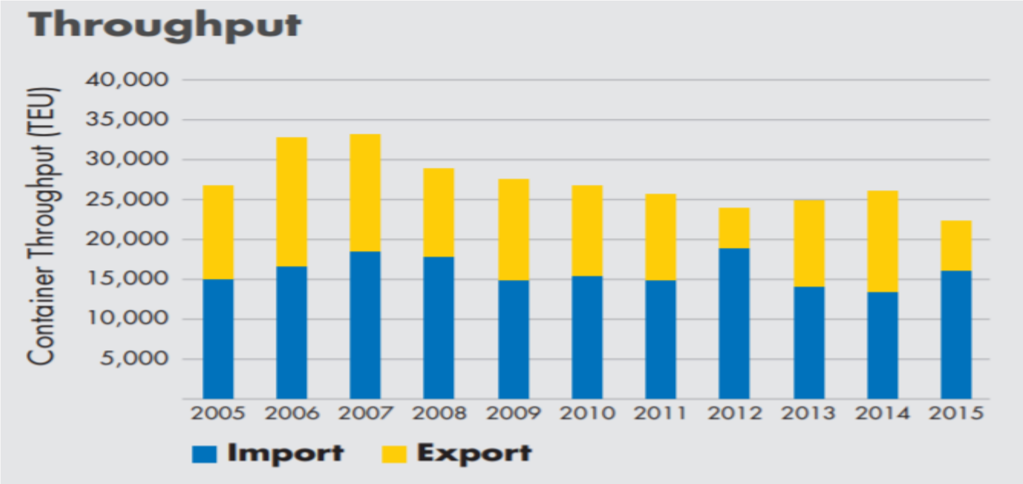


Figure 10 Historical data on Port Castries Throughput (SLASPA, 2016)

3.2.2 Equipment

Port Castries provides the following equipment for ground operations as seen in Table 9. In 2000, SLASPA procured a mobile harbour crane with capacity of 104 tons which was refurbished in 2015 (SLASPA, 2018). The crane can only be utilized on berth#2-4, due to insufficient cargo capacity at the other berths.

Port Castries Equipment		
Equipment	**Amount**	**Capacity**
Liebherr Mobile Crane	1	104 tons
Grove Hydraulic Crane	1	13 tons
Reach Stacker	5	3-45 tons/stack 4 high 2-40 tons/stack 5 high
Terminal Tractors	4	
Trailer Beds	3	
Forklifts	23	5-2 tons; 13-3 tons; 2-15 tons; 2-4 tons; 1-40 tons

Table 8: Port Castries Equipment (Author, Source SLASPA, 2018)

3.2.3 Labour

Cargo handling operations are carried out by SLASPA in collaboration with stevedores from the Seamen’s Union. Stevedores normal working hours starts from 7:00 am to 4:00 pm with overtime upon request. There is no stipulated shift system, therefore, gangs are employed for the duration of work on ships (Caribbean Development Bank, 2016). Moreover, Port Castries opening hours, commences from 8 am to 4:30 pm, Monday to Friday and closed on weekends.

3.2.4 Operational Efficiency

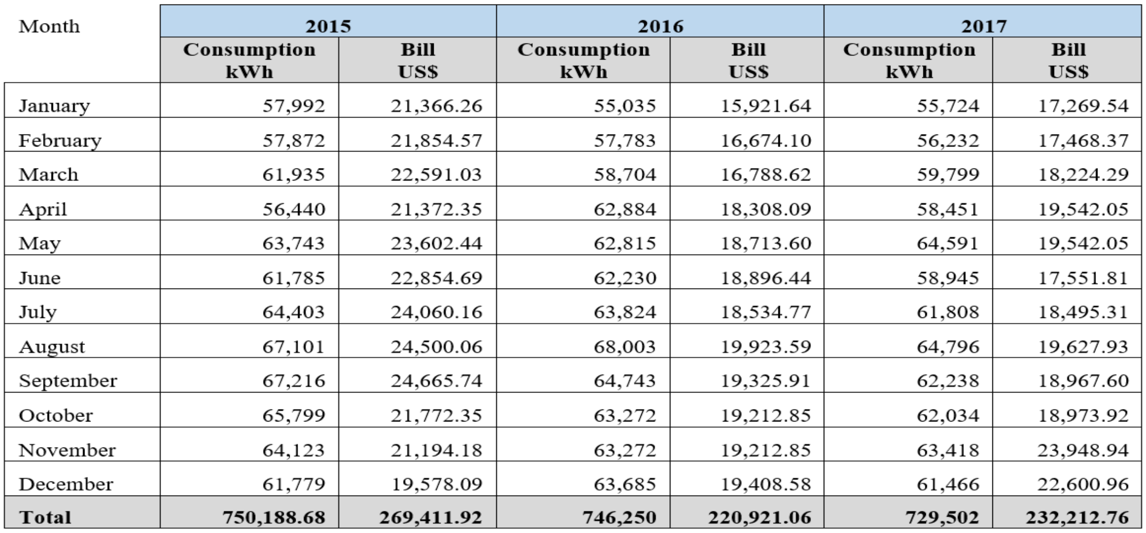
SLASPA mission is *"To maximize air and sea-borne traffic and related services through safe and efficient operations, performed by a highly motivated workforce contributing to the sustainable, social and economic development of Saint Lucia"* (SLASPA, 2018). Over the years, SLASPA invested in various technologies to improve operational efficiencies such as IT system Unitrack for yard management integrated with Customs' ASYCUDA World system; purchased additional cargo handling equipment, reconfiguration of the cargo shed to improve speed of delivery. However, IT systems need to be further developed to include other stakeholders and to accurately track containers within the terminal (SLASPA handbook, 2015). Furthermore, investment was made in training and development of employee focusing on customer service. However, most of the training is conducted by on the job training (OJT).

3.2.5. Bottlenecks

Saint Lucia's heavy reliance on imported goods has increased port volumes particularly in RORO (cars) where port capacity has not been able to meet demand. This poses serious challenges to Port Castries regarding efficiency and competitiveness. However, increasing port capacity is quite difficult, even though there are sufficient dock space for loading and unloading, there are issues such as road congestion, limited area for expansion (Caribbean Development Bank, 2016). These issues combined with financial constraints and lengthy timetables are obstacles that hinders additional capacity planning to be handled in an expedited manner. Also, the port is challenged by lack of autonomy due to Government control in investment decisions. Therefore, Port Castries require a method to increase port efficiency and capacity without substantial investment in additional resources.

3.2.6 Port Castries Electricity Cost and Consumption

For decades, SLASPA growing concern on energy conservation has increase, aiming to reduce energy consumption by 20%. Table 10 provides total electricity cost and consumption from 2015-2017.



Month	2015		2016		2017	
	Consumption kWh	**Bill US$**	**Consumption kWh**	**Bill US$**	**Consumption kWh**	**Bill US$**
January	57,992	21,366.26	55,035	15,921.64	55,724	17,269.54
February	57,872	21,854.57	57,783	16,674.10	56,232	17,468.37
March	61,935	22,591.03	58,704	16,788.62	59,799	18,224.29
April	56,440	21,372.35	62,884	18,308.09	58,451	19,542.05
May	63,743	23,602.44	62,815	18,713.60	64,591	19,542.05
June	61,785	22,854.69	62,230	18,896.44	58,945	17,551.81
July	64,403	24,060.16	63,824	18,534.77	61,808	18,495.31
August	67,101	24,500.06	68,003	19,923.59	64,796	19,627.93
September	67,216	24,665.74	64,743	19,325.91	62,238	18,967.60
October	65,799	21,772.35	63,272	19,212.85	62,034	18,973.92
November	64,123	21,194.18	63,272	19,212.85	63,418	23,948.94
December	61,779	19,578.09	63,685	19,408.58	61,466	22,600.96
Total	**750,188.68**	**269,411.92**	**746,250**	**220,921.06**	**729,502**	**232,212.76**

Table 9:Total Electricity Bill and Consumption 2015 - 2018 (Author, 2018)

The high cost of electricity combined with other OPEX has Port Castries searching for ways to reduce cost without compromising efficiency and vessel turnaround time.

Data Collection

To fulfil the objectives of this research, the Author has gathered information and data focusing on application of Lean Enterprise and renewable energy technologies, the economic and environmental impacts and performance in ports. In addition, the data presented is obtained from reliable sources such as government agencies, International Energy Agency (IEA), the United States Environmental Protection Agency (EPA), National Renewable Energy Laboratory (NREL), the International Renewable Energy Agency (IRENA), World Bank. Additionally, various literature comprising of books, electronic sources, journals, articles, periodicals and reports. The current study presents Port Castries annual data from 2015 to 2017. Port Castries data was collected from SLASPA management, operations manuals, reports, strategic plan and direct observations.

The proposed model focused on two aspects. Firstly, implementing Lean concept requiring marginal financial investment known as “low-hanging fruits,” primarily for training of management and employees. The objective is to measure and improve port performance, reducing cost and waste in operations processes. Secondly, investment in solar PV system to reduce the economic and environmental cost associated with electricity generated from fossil fuels. This would require substantial capital investment at the beginning with long-term financial and environmental benefits to the port. The results would provide management of the port on whether to invest in lean or solar PV only or combined.

3.3 Port Performance Indicator (PPI)

Port implementing lean can utilize both performance measurement and improvement methods. Lean would provide ports with a holistic approach to efficient operational processes such as berthing and yard operations and throughout the logistic chain. Lean approach uses qualitative methods taking into consideration customer demand. The Author uses PPIs as a performance measurement to identify existing processes for implementation of Lean Enterprise in port operations.

3.4 Lean Enterprise

Lean main objective is to reduce the timeline between customer orders and payment received by eliminating non-added value activities within the process. Lean basic tools have grown from the manufacturing industry to any industry where meeting customer demand is paramount. Lean Enterprise concept identifies and eliminates waste within work processes that do not add value to customers. The lean tool identified in this case study is value stream mapping (VSM) which is considered as the most suitable method to eliminate waste in seaport operations.

3.4.1 Understanding Waste

For proper value stream mapping, there must be a good understanding as to what waste exist within each process. Wastes are grouped into 7-deadly wastes identified by Toyota that hinders product/service's ability to add value. In this case study, wastes are identified as unnecessary delays between ship arrival, berthing, transfer to yard, storage, cargo delivery and gate processes. Figure 11 shows photograph of related deadly waste in Ports.

Waste of Motion

Waste of inventory

Waste of Transportation

Waste of Waiting

Waste of Overproduction

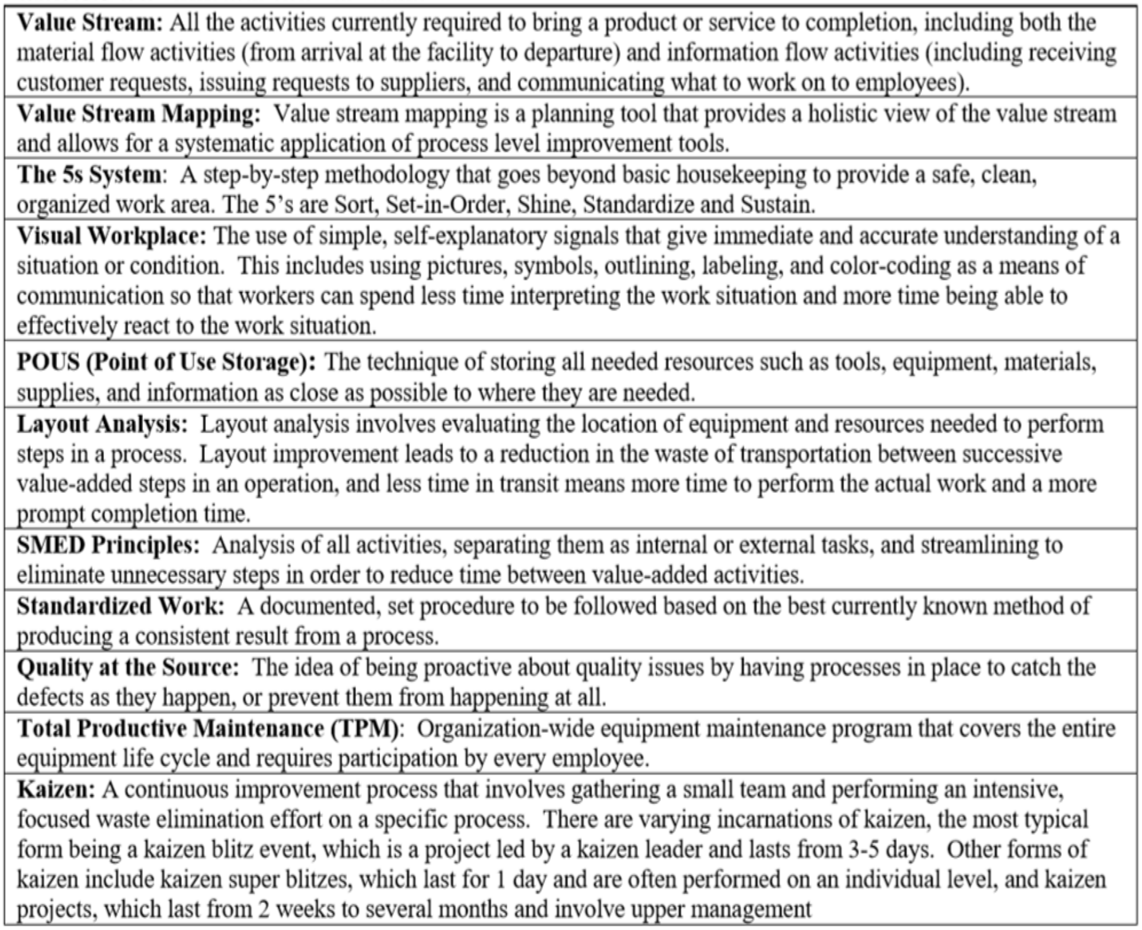
Waste of Over-processing

Figure 11:Deadly Waste in Ports (Photos courtesy of University of Alabama Huntsville)

In dealing with 7-deadly waste, it is strongly recommended that management be involved in the development of lean policies and employee training to raise awareness as to the big picture. This is required for identifying waste and finding suitable solutions/best practices to reduce costs. Key features of the process should be outlined and documented regarding information and material flows.

3.4.2 Lean Tools

The utilization of Lean tools is essential for port managers to identify non-value added activities in operation processes, increase performance efficiency and to be proactive in finding the right solutions for a continuous improvement culture. Table 11 list and defines lean tools available for workplace optimization.



Value Stream: All the activities currently required to bring a product or service to completion, including both the material flow activities (from arrival at the facility to departure) and information flow activities (including receiving customer requests, issuing requests to suppliers, and communicating what to work on to employees).

Value Stream Mapping: Value stream mapping is a planning tool that provides a holistic view of the value stream and allows for a systematic application of process level improvement tools.

The 5s System: A step-by-step methodology that goes beyond basic housekeeping to provide a safe, clean, organized work area. The 5's are Sort, Set-in-Order, Shine, Standardize and Sustain.

Visual Workplace: The use of simple, self-explanatory signals that give immediate and accurate understanding of a situation or condition. This includes using pictures, symbols, outlining, labeling, and color-coding as a means of communication so that workers can spend less time interpreting the work situation and more time being able to effectively react to the work situation.

POUS (Point of Use Storage): The technique of storing all needed resources such as tools, equipment, materials, supplies, and information as close as possible to where they are needed.

Layout Analysis: Layout analysis involves evaluating the location of equipment and resources needed to perform steps in a process. Layout improvement leads to a reduction in the waste of transportation between successive value-added steps in an operation, and less time in transit means more time to perform the actual work and a more prompt completion time.

SMED Principles: Analysis of all activities, separating them as internal or external tasks, and streamlining to eliminate unnecessary steps in order to reduce time between value-added activities.

Standardized Work: A documented, set procedure to be followed based on the best currently known method of producing a consistent result from a process.

Quality at the Source: The idea of being proactive about quality issues by having processes in place to catch the defects as they happen, or prevent them from happening at all.

Total Productive Maintenance (TPM): Organization-wide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee.

Kaizen: A continuous improvement process that involves gathering a small team and performing an intensive, focused waste elimination effort on a specific process. There are varying incarnations of kaizen, the most typical form being a kaizen blitz event, which is a project led by a kaizen leader and lasts from 3-5 days. Other forms of kaizen include kaizen super blitzes, which last for 1 day and are often performed on an individual level, and kaizen projects, which last from 2 weeks to several months and involve upper management

Table 10 Definition of Lean Terms (Loyd et al, 2009)

3.4.3 Value stream mapping (VSM)

VSM technique is selected for this study, consisting of current and future state and detailed implementation plan to identify gaps and eliminate wastes in operations processes. VSM approach identifies the root causes of port inefficiency. Establishing VSM would assist in finding optimal solutions as to the areas that require improvement. This study presents a proposed port's performance measurement framework of lean implementation to determine improvement in each process. VSM was conducted using Port Castries reports, operations manual, strategic and direct observations.

(a) Current Value Stream Mapping

Firstly, VSM would be developed for current state where a visual representation on how existing process operates and integrating the necessary steps in the flow of information and resources. The current and future VSM analysis were based on ship arrival, berth operations, yard transfer, yard storage and gate operations processes as illustrated in Figure 12. The diagram shows that the bottleneck exists in quay operations and yard storage indicated by the smaller links.

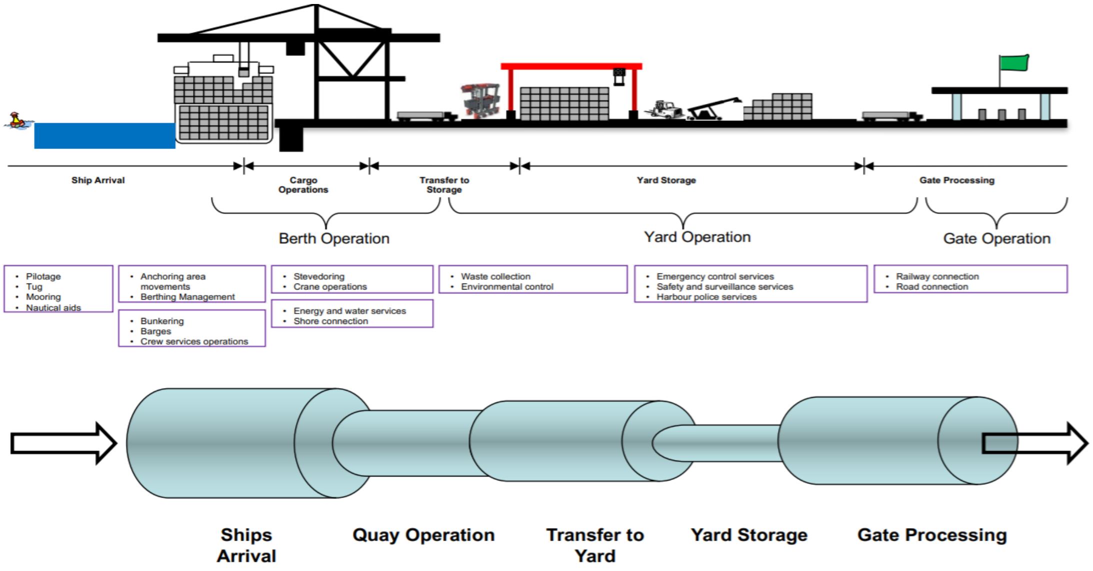


Figure 12: Schematic Diagram on Container Terminal Operations (Moon, 2018)

An assessment is carried out, transforming current state to future state where a detailed sketch of procedures of the existing process, combined with the flow of information and material, outlining the steps involved in port operations. The objective is to simplify the operations processes by use of diagram that allows the opportunity to identify wastes that is evident. Undertaking current VSM help assess the present mode of operations and allowing opportunities to identify waste and subsequent elimination. Countermeasures are then developed to address these waste for future VSM or improve processes. Implementing Lean would allow these processes to meet the productivity level, thus, having the entire terminal at the same efficiency level.

(b) Future Value Stream Mapping

Future VSM would be developed as countermeasures to waste identified in current VSM, highlighting improve processes with allocated timeline. This provides a blueprint on how the value stream's processes should operate. It is designed on being proactive by displaying countermeasures for implementing desirable improvements. As a guide for improving process, this study uses takt time for calculating quay, cargo and RORO productivity regarding customer demand per day.

(i) Takt Time

"Takt time" is a German word meaning "pulse" referring to heart rate as it increases or decreases. It is considered the rate at which the process is required to be completed to meet customer demand. Takt time is beneficial to all stakeholders and applicable in yard operations in synchronizing and balancing the processes. Calculating Takt time is recommended for each process to avoid bottlenecks between and within processes. Any differences in Takt time means that more resources are used, longer time is required to move one unit of cargo (Lovelle, 2001).

(ii) Calculating Takt Time

Calculating takt time is important in identifying and eliminating waste, hence optimizing resources regarding customer demand and efficiency. Takt time is calculated as daily total available production time divided by daily customer demand (Lovelle, 2001). For process improvement culture, Takt time was used to measure and calculate port operations process whilst Kaizen for continuous improvement involving the employees focusing on waste elimination within processes (Loyd, et al., 2009). Several other techniques are available to assist in the implementation of lean including teamwork, 5s, total productive maintenance (TPM) and visual management.

(c) Detailed Implementation Plan

This detailed roadmap provides recommendations to move from current to future state with proposed countermeasures converted into detailed action plans, prioritized with timeline. Figure 13 gives a diagram of value stream sequence.

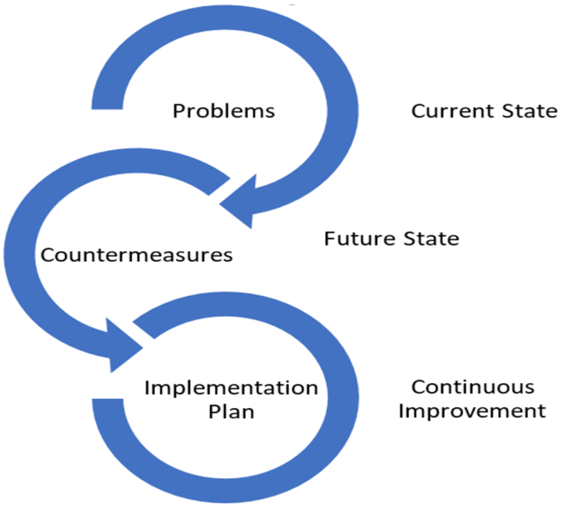


Figure 13: Lean Value Stream Process Stages (Author, 2018)

For a successful lean transformation, management and employees require understanding of the key lean principles of identifying and eliminating waste based on customer's demand. Achievement requires teamwork where responsibilities are assigned for each task to be completed. Furthermore, each department should perform VSM to set a manageable implementation roadmap prior to application. This would determine the required steps in delivering a particular service that generates value within the operational processes. It is dependent on numerous factors such as the level of education of employees within the department, type of equipment and yard layout. After completing the plan, managers are responsible for administering and updating to ensure that the processes are properly managed (Marlow, 2003). However, feedback is required regarding performance so that comparisons would be made against the expected results. This process is illustrated in Figure 14.

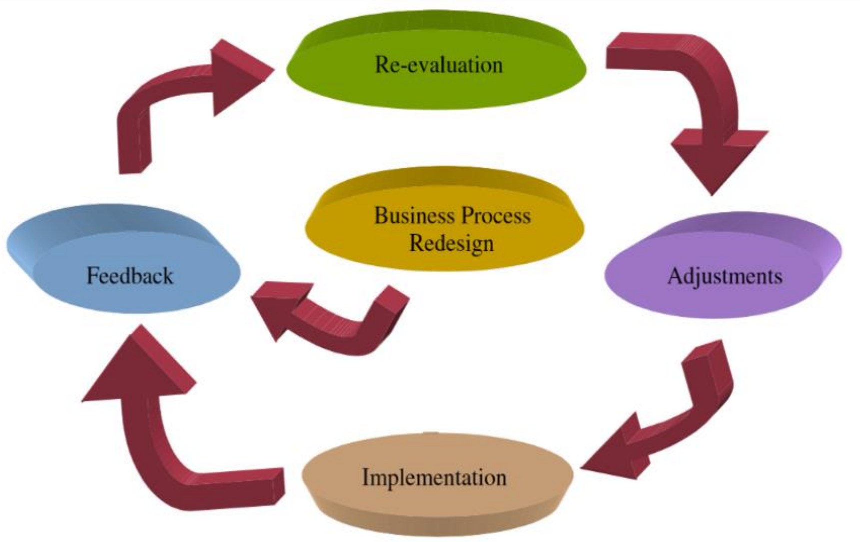


Figure 14: Implementation of Port Total Quality Management System (Marlow, 2003)

3.4.4 Lean Model

The proposed lean model is represented by the 3-tier house as seen in Figure 15. The foundation represents workplace organization as the starting point, with second and third level being workplace analysis and optimization and roof as continuous improvement culture.

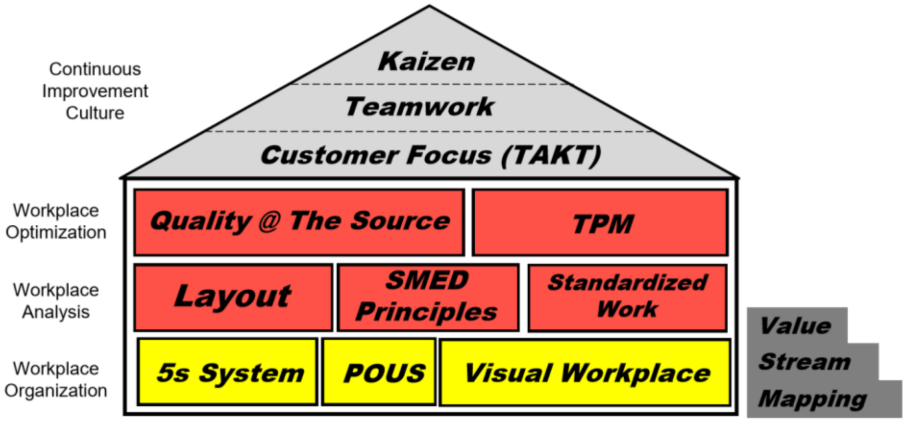


Figure 15: Lean Implementation Model for Seaports (Loyd et al, 2009)

(a) Workplace Organization Tools

This concept of clean, safe and organized work area for easy access to eliminated unnecessary movements. This is the foundation and consist of 5s system, visual workplace and point-of-use-storage (POUS). The 5s (sort, set in order, shine, standardize and sustain) when properly applied, leads to an environment where all necessary resources are assigned to designated area avoiding unnecessary delay in searching (Loyd et al, 2009) as seen in Figure 16.

Figure 16: Before and After maintenance workshop (Photos courtesy University of Alabama Huntsville)

(b) Workplace analysis Tools

This includes layout analysis, Single Minute Exchange to Die (SMED) principles, and standardized work necessary to examine processes and elimination of waste. Layout analysis deals with assessment of the port and planning for optimization of the space. This will reduce unnecessary movement of employees and materials. Proper layout saves time in performing value-added activities. SMED principles analyses opportunities for improvement within the performed process and can be both internal and external as shown in Figure 17.

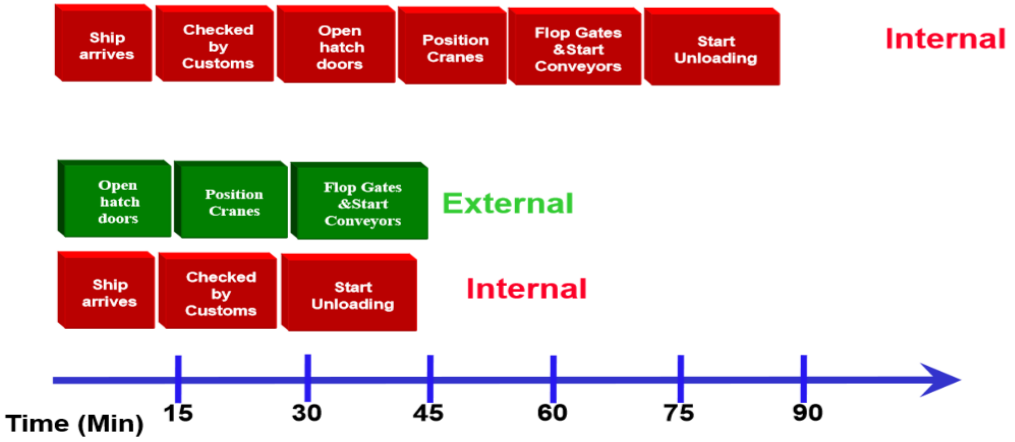


Figure 17: SMED Principles Internal vs. External (Source: Loyd, et al., 2009)

However, internal and external activities must be connected to avoid inefficiency. Checklist should be established for external stakeholders to reduce waste and improve process time. Lastly, standardized work analysis is developed for improving processes which can be used for effective training of employees involving standard operating procedures (SOP).

(c) Workplace Optimization Tools

This is the third layer of the optimized processes consisting of quality-at-the-source and total productive maintenance (TPM). Quality-at-the-source refers to being proactive instead of reactive. This process provides preventative measures to identify the shortcomings. This can be achieved through training of employees and developing SOPs for process improvements. Total productive maintenance is based on schedule maintenance of equipment to avoid unnecessary breakdowns.

(d) Continuous Improvement Culture

This consists of customer focus, teamwork and kaizen where every component corresponds to an action item in the VSM implemented plan to support the customer demand. Teamwork requires training of employees for greater flexibility when responding to customer demand. Kaizen is achieved by creating small teams to perform brainstorming exercise on waste elimination on a particular task. Kaizen approach provides employees with a forum for suggestions and participation in implementation process. This results in best practices for overall improvement of processes. Kaizen cycle approach is referred to as the PDCA cycle as seen in Figure 18.

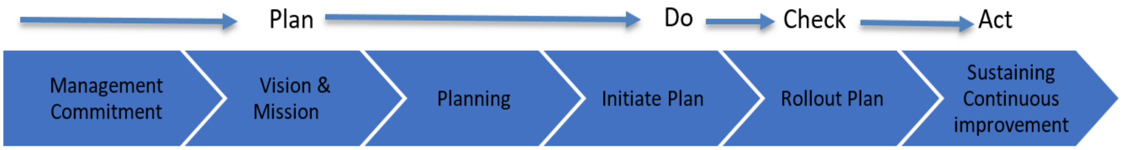


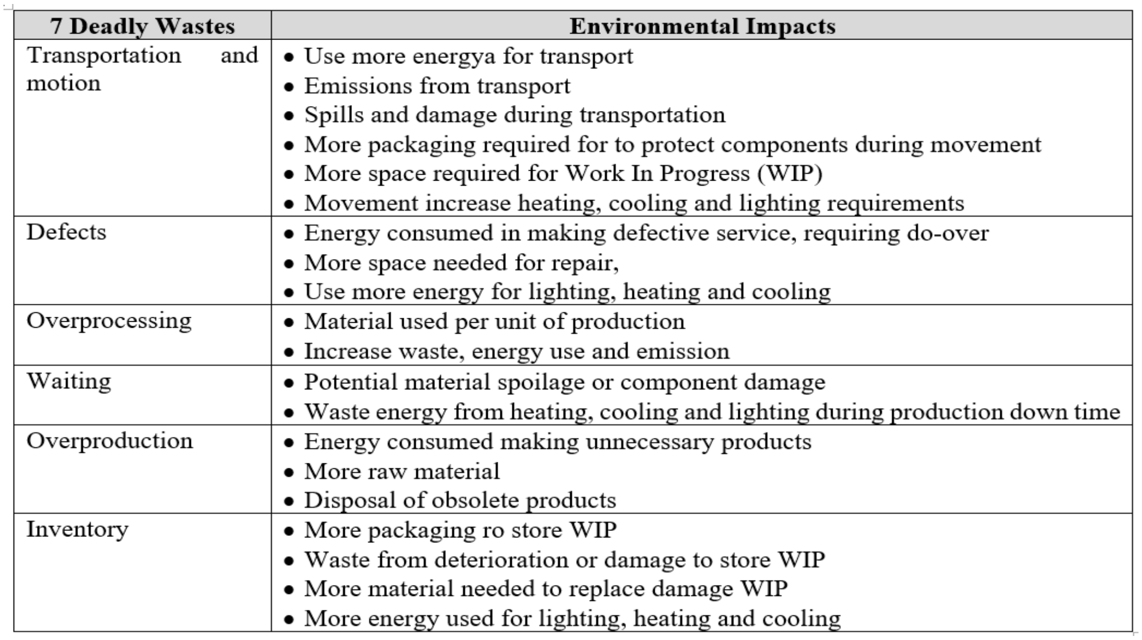
Figure 18: Kaizen/PDCA Cycle (Author, 2018)

3.4.5 Lean Environmental Performance

Energy efficiency and environmental performance can be evaluated by implementing Lean to eliminate environmental waste within the port operations process.

Environmental Waste and 7 Deadly Wastes

Environmental waste is defined as *“the utilization of any unnecessary resources or substances released into the air, land and water that are harmful to human health or environment”* (USEPA, 2017). Environmental waste does not add value but impacts negatively on service quality, time, flow and cost. It is important to identify these wastes to quantify the possible measure and impact. Lean implementation would demonstrate improvement in processes and safe working environment. Listed in Table 12 are environmental impacts associated with the 7-deadly wastes targeted by lean approach.



7 Deadly Wastes	Environmental Impacts
Transportation and motion	• Use more energya for transport • Emissions from transport • Spills and damage during transportation • More packaging required for to protect components during movement • More space required for Work In Progress (WIP) • Movement increase heating, cooling and lighting requirements
Defects	• Energy consumed in making defective service, requiring do-over • More space needed for repair, • Use more energy for lighting, heating and cooling
Overprocessing	• Material used per unit of production • Increase waste, energy use and emission
Waiting	• Potential material spoilage or component damage • Waste energy from heating, cooling and lighting during production down time
Overproduction	• Energy consumed making unnecessary products • More raw material • Disposal of obsolete products
Inventory	• More packaging ro store WIP • Waste from deterioration or damage to store WIP • More material needed to replace damage WIP • More energy used for lighting, heating and cooling

Table 11: Deadly waste impact on Environment (USEPA, 2017)

3.5 Renewable Energy Technologies – Saint Lucia

Table 13 indicates renewable sources in Saint Lucia with wind, geothermal and solar having the highest potential.

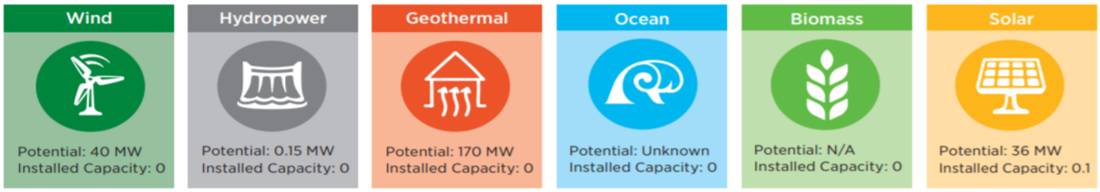
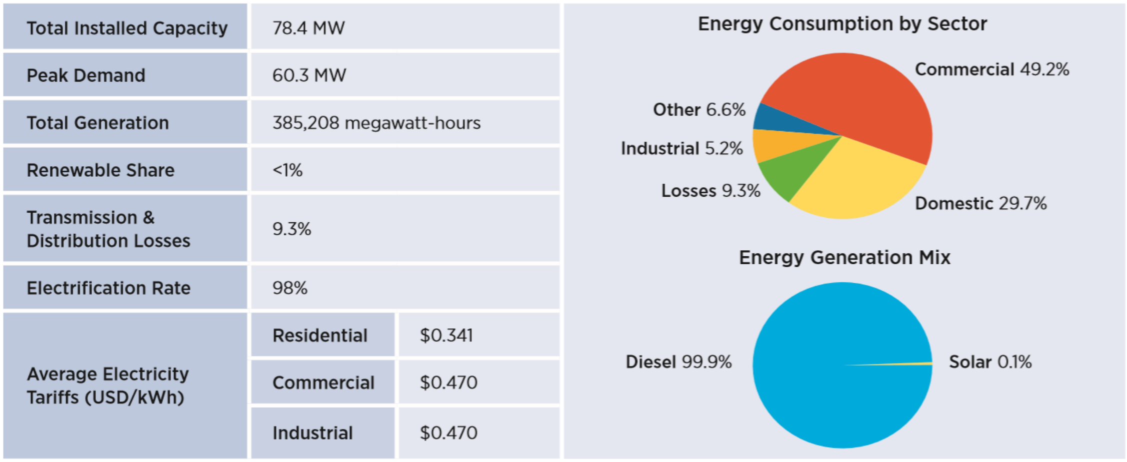


Table 12: Saint Lucia Renewable Energy Potential and Status (NREL, 2015)

Figure 19 gives an overview of electricity installation capacity and consumption according to sector. Currently, the fuel price as of August 2018 is US$0.28/kWh. However, the Government has introduced the modified market past-through petroleum pricing mechanism conducted every three weeks to provide relief to consumers when fuel price goes down on the global market (GoSL, 2015).



Total Installed Capacity	78.4 MW	
Peak Demand	60.3 MW	
Total Generation	385,208 megawatt-hours	
Renewable Share	<1%	
Transmission & Distribution Losses	9.3%	
Electrification Rate	98%	
Average Electricity Tariffs (USD/kWh)	**Residential**	$0.341
	Commercial	$0.470
	Industrial	$0.470

Figure 19: Saint Lucia Electricity Overview (NREL 2015)

Due to current legislation, it is illegal to install system to generate 100% electricity from renewable resources, hence, the project must include national grid. Currently, 25 kWp for Solar PV System is permitted for commercial customers and must be approved by National Utility Regulatory Commission (NURC, 2016).

3.6 Solar PV System Simulation

Solar PV system cost is determined by capital cost, variable costs, discount rate, level of solar irradiation and cells efficiency. The initial capital investment is substantial but provides long-term benefits. To simulate the least-cost option of suitable PV system for Port Castries, a feasibility study carried out utilizing Hybrid Optimization Model for Multiple Energy Resources (HOMER) software for optimization and sensitivity analysis of the data collected. HOMER was originally designed by NREL, is one of the most frequently use optimization software for hybrids simulation of residence, commercial, industry and community. This simulation model determines all possible combinations of the technologies input in time steps series from minute, hour, month or year. This was used to assess various possible combination of PV systems in a single run. The software sort and select suitable systems according to the optimization variable identifying least-cost options. This makes the process for finding the optimal system quickly with sensitivity results across a wide range of values. A sensitivity analysis or “what if” when performed is critical in understanding the robustness of the model and allow the understanding of how the changing input would affect the choice of least-cost system. The software analyses the viability of each system configuration, combined with costs estimations over the project lifetime consisting of initial cost of capital (ICC), operation and maintenance (O&M), replacement and salvage costs.

The input data consists of Saint Lucia’s annual temperature, solar global horizontal irradiance (GHI), solar PV prices, current fuel and electricity cost. Various scenarios were used as to solar PV system combined with battery bank on direct current (DC) side connecting to converter and national grid on alternating current (AC).

3.7 PV System Project Appraisal

Cost-benefit analysis (CBA) was used to evaluate and calculate the feasibility of the project namely Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI), payback period and other factors to assess all possible economic gains generated from this model.

3.7.1 Levelized Cost of Energy (LCOE)

Pawel (2013) defined LCOE as “*the total lifetime cost of an investment divided by the cumulated generated energy by this investment*.” LCOE method is used to estimate the cost of lifetime generated energy and to benchmark the cost-effectiveness of the system (Ouyang & Lin, 2014). LCOE is calculated using both capital and recurring cost of the project to value per energy unit that must be collected, ensuring expenses are met and profits generated. The levelized cost is the total annualized cost divided by the annual energy output (Allen, 2013). It determines the price at which energy should be sold to obtain NPV of zero.

3.7.2 Social/Ecological Costs

(a) Cost of Emission

USEPA estimated social cost of carbon (SC-CO_2) as measured dollar amount of long-term impact of 1 ton of carbon dioxide (CO_2) emissions per year representing the value of damages avoided. The importance of reducing CO_2 emissions in ports are highly relevant to meeting energy targets and reducing carbon footprint. Furthermore, reducing CO_2 emission have placed tremendous pressure on governments to prioritized and developed eco-friendly initiates (Geerlings & van Duin, 2011). Using solar PV system to power the port would reduce CO_2 emission and therefore, achieving environmental goals.

(b) Ship's Waiting Cost

Ship's waiting cost represents combined waiting time before and during berthing. The costs of delayed ships are measured by the using fuel costs, waiting and service time and terminal costs. Vessel delay costs consist of cargo depreciation costs, lost vessel opportunity costs, and terminal handling penalties (Lang & Veenstra, 2009). This is essential for the case study as to the cost incurred for ships when delayed due to interruption in electricity supply from the national grid.

3.7.3 Payback Period

Payback period determines the time required to offset the amount invested for a project by net cash flow generated (Allen, 2013). Payback period offers investors an indication as to the project's risk and liquidity (Brigham & Houston, 2004). Payback period was calculated by use of simple payback which excludes taxes and discounted payback including taxes and time value of money (TVM). Investors prefer short payback periods because the risk would be for a shorter period of time. Payback method should not be the only criterion for acceptance of an investment, other appraisal methods such as IRR and NPV, should be taken into consideration for further assessment of the project's viability and overall profitability.

3.7.4 Net Present Value (NPV)

Allen (2013) defines NPV as the *"difference between benefits and expenses with everything discounted to present value."* NPV determines long-term profitability of projects consisting of the sum of the present value (PV) of cash inflows and outflows and must be greater than zero or positive to deemed as an acceptable investment (Brigham & Houston, 2004). However, any project that generates negative NPV should be rejected. NPV is used to calculate the time value of money (TVM) indicating how cash flow over the period of the solar project compares in today's dollar factoring inflation, interest and other costs. NPV theory would give assurance to the viability of the project to generate profits and aid in decision-making process on whether or not to investment.

3.7.5 Internal Rate of Return (IRR)

IRR measures the profitability of investments. The higher the IRR, the more attractive is the project to investors, and should be greater than weighted average cost of capital (WACC) and interest rate. IRR is the discount rate that forces the present value of inflows to equal to cost or NPV = 0 (Brigham & Houston, 2004). Most investors prefer IRR >15% to consider a viable project and to reap the benefit from the investment quickly. High IRR demonstrates that the rate of return on the project is greater than costs.

3.7.6 Return on Investment (ROI)

ROI indicates financial gains over the project period. ROI calculation for the project includes current utility rate per kWh, annual bill without solar, lifetime costs associated with the solar installation including inverter replacement, O&M cost. This will also highlight the payback period and total financial savings for using solar PV system.

3.8 Proposed Decision-making Framework

The implementation of the proposed model consists of three aspects (I) lean only, (II) solar PV system only and (III) combination. The decision-making framework usually consists of economic, environmental and technological based on alternatives versus criteria. Selecting the best solution among trade-off options can be challenging and require assessment of each alternative to each criterion, known as multiple attribute decision-making criteria (MADM), where trade-off solutions are assessed against economic and environmental merits (Ölçer & Ballini, 2015). However, Ren & Lützen (2017) research on alternative sustainable energy source for shipping, concluded that multi-criteria decision making is made under incomplete information where framework of prioritizing is subjective to decision-makers judgement and preferences. Implementation of solar PV system requiring significant investment using economic and sustainability assessment for criteria given in Figure 20.

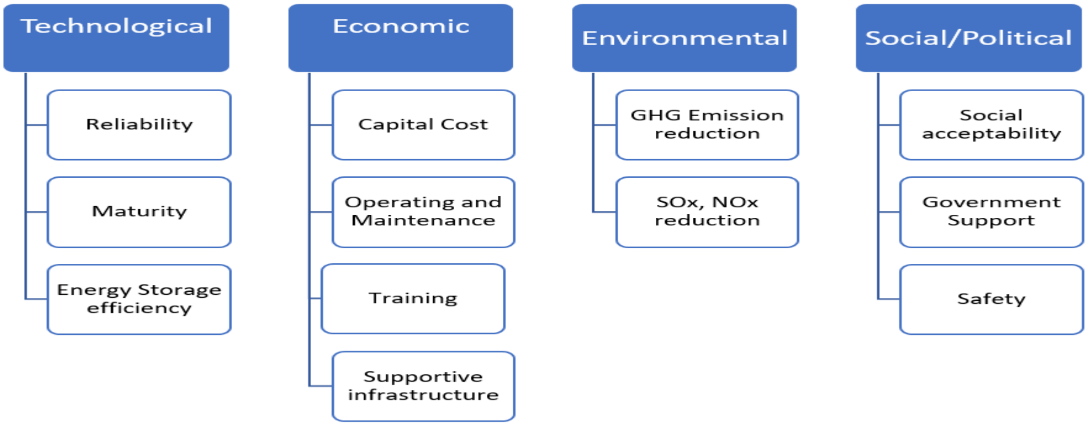


Figure 20: Decision-making Criteria for Projects (Author, 2018)

Technological aspect in decision-making is based on how extensive and profoundly PV system can be used in comparison to another alternative energy source, its resistance and robustness such as to weather. Economic aspects such as supportive infrastructure and cost. Environmental aspect gives details as to how eco-friendly is the system in reducing emission and social/political is based on government support in the adoption solar PV system with regulations and standard policies, safety of employees is also critical in the decision-making process (Ren & Lützen 2017). The decision-making approach for this model is based on single criterion namely cost due to Port Castries financial situation.

3.9 Conclusion

The conclusion summarizes and makes recommendations regarding the best solution for Port Castries as to the implementation of one or both pillars. Assessment of the pillars would assist in the decision-making process where criteria are based on cost, process improvement, environmental performance, energy security and efficiency. For continuous waste reduction and cost, a proposed energy policy would be developed based on ISO 50001 standard combined with the best practices of Lean Enterprise to assist management in the implementation process. The results of feasibility of the proposed model would be discussed in the following sequence as shown in Figure 21.

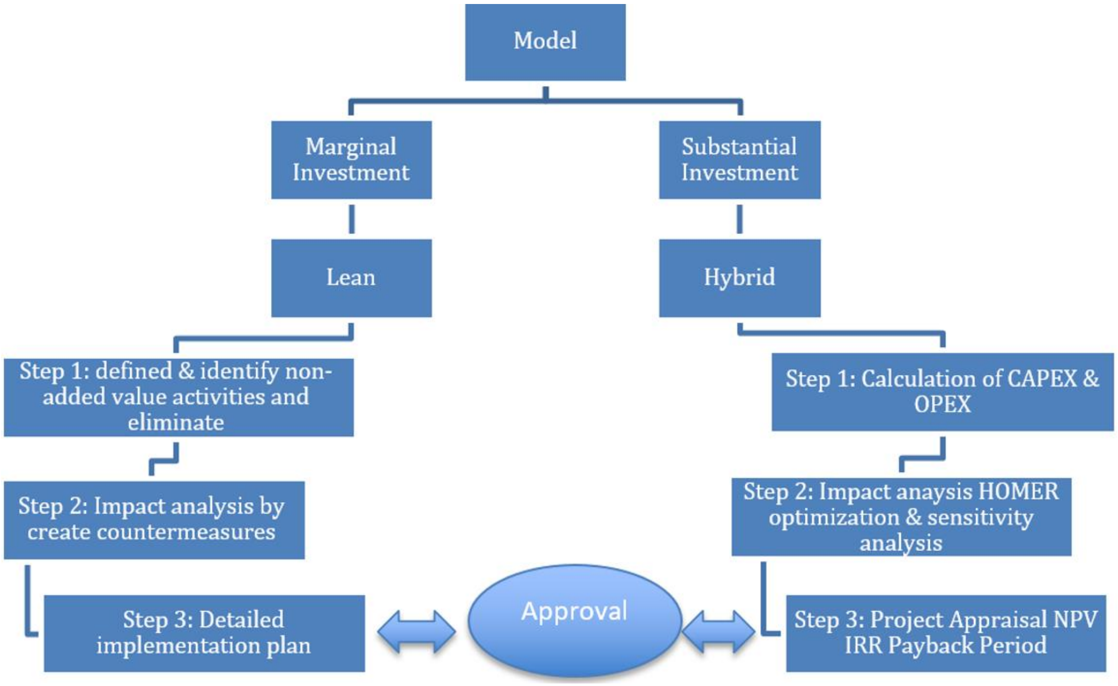


Figure 21:Step-wise Approach for Project (Author, 2018)

CHAPTER FOUR: FEASIBILITY STUDY DISCUSSION AND RESULTS

This chapter presents analysis and findings of a proposed implementation model consisting of Lean concepts and solar PV system. This chapter is divided into four sections:

(a) Section 4.1 comprises of the selection of applicable lean tools and principles in Port Castries. Operations processes would be assessed using VSM to identify and eliminate waste, increasing performance and efficiency according to customer demand.

(b) Section 4.2 explores the feasibility of Solar PV system utilizing HOMER software to determine the optimization and sensitivity analysis result. The model would be used for future energy savings, efficiency and security and environmental benefits.

(c) Section 4.3 is the project appraisal calculating NPV, IRR, payback period and other factors to determine project feasibility.

(d) Section 4.4 is the decision-making criteria based on finding the best available option for Port Castries.

4.1 LEAN IMPLEMENTATION - PORT CASTRIES, SAINT LUCIA

Port Castries, with financial constraints and high operating expenses, require a holistic approach to minimize expenses without substantial investment. Lean implementation in Port Castries is a strategic initiative to eliminate waste in operations processes while constantly adding value to the available resources, without compromising quality and efficiency. The realization of a successful lean approach requires an understanding of the key principles and waste identification and elimination from the processes. VSM is selected to identify waste in the current state to identify non-added value activities within the process. Countermeasures are then created to address these issues and evaluated for continuous improvement.

4.1.1 Value Stream Mapping (VSM)

VSM consist of current state, future state and detailed implementation plan to evaluate ship arrival, berth, yard and gate processes.

4.1.2 Understanding Waste

For proper VSM, a good understanding of what waste exist in Port Castries operation processes. To effectively reduce waste in the processes, the following transformation phases must be considered before implementation.

- The order in which the Seaports Operations would introduce lean improvement process such as berth/yard/gate.
- Develop strategic plan to meet objectives of continuous improvement program in support of mission and vision of the Port;
- Training of management for understanding of role in the lean process;
- Training of employees to meet required standard;
- Management appointment of lean leader for overseeing implementation, enforcing appropriate performance schemes to drive necessary behaviours among employees;
- Implementation of continuous improvement culture in performing day to day activities.

4.1.3 Assessment of Current State

The current state of operations in Port Castries was examined to identify where inefficiencies exist within the processes. The results indicate the need for standardized database and monitoring system in collaboration with Customs and other supporting government agencies such as Ministry of Health, for complete value flow from ship arrival to departure. Prior to ship arrival, advance notification from Ship Agent would assist Seaports Operations in the planning and preparation of berth to prevent unnecessary ship delays. Arrival and berthing of ships are dependent on experience of pilots, the availability of tugboat and mooring team. Frequent breakdown of pilot boat causes additional delay awaiting replacement vessel. Also, breakdown of cargo handling equipment, particularly harbour crane, due to age and damage to major parts, has the port utilizing ship's crane, and if not communicated may also cause delays in vessel unloading/loading cargo. Figure 22 gives Port Castries procedures for ship arrival and departure including stakeholders' involvement in processes.

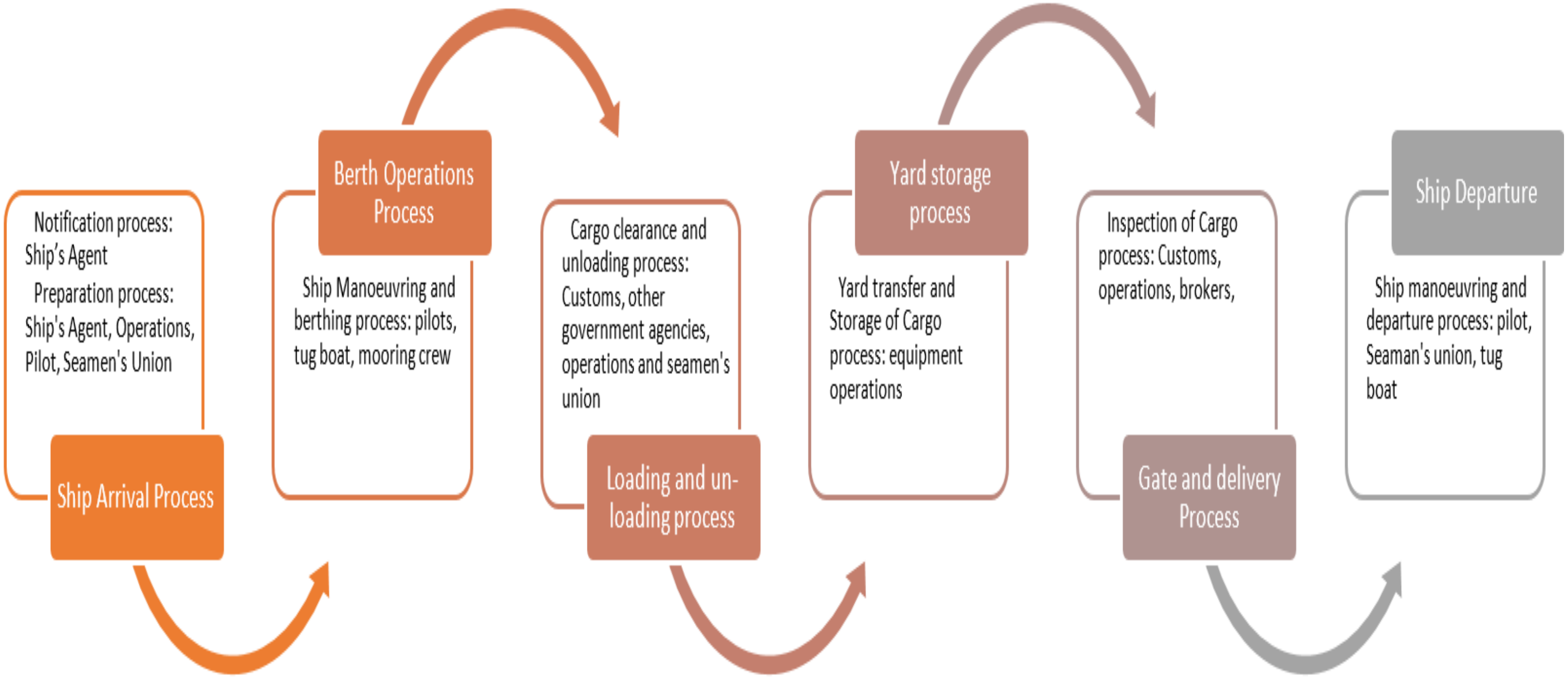
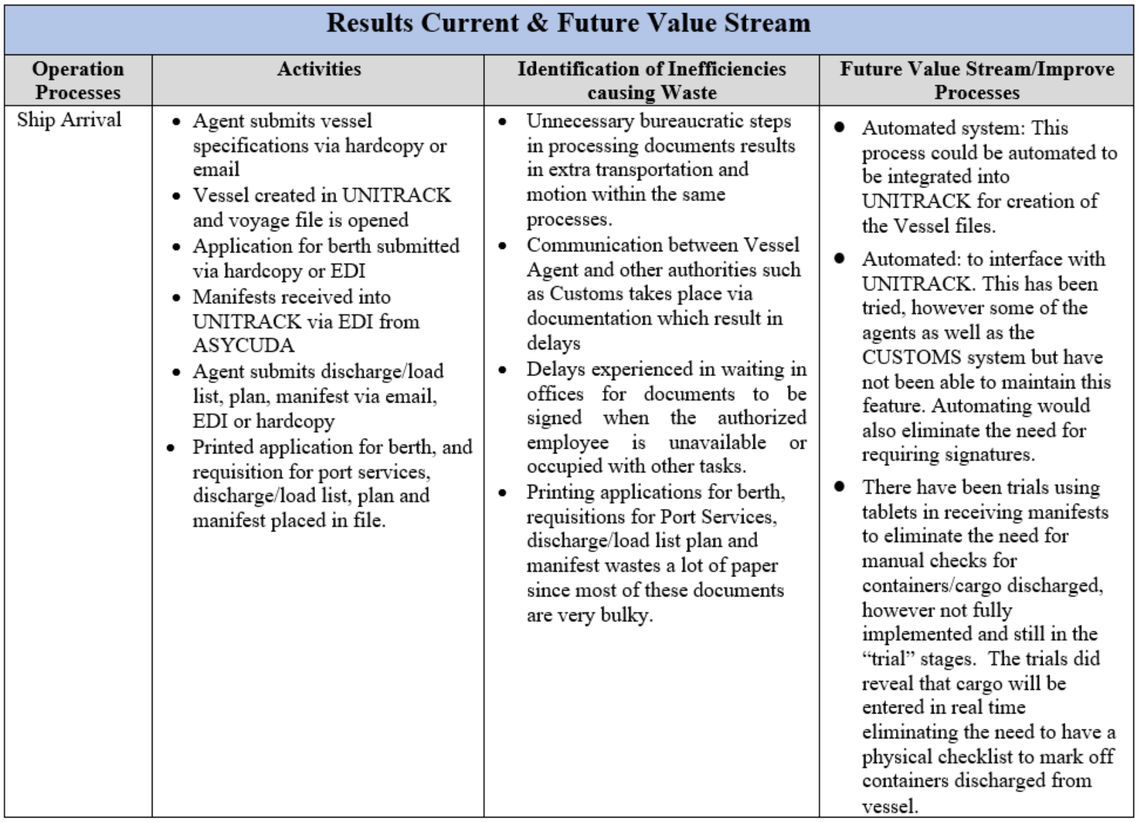


Figure 22: Current VSM Seaports Operations processes (Author, 2018)

Each commodity type requires different handling process, equipment, storage facilities, yard layout and staff requirement. Therefore, good communication and information flow between stakeholders and Seaport Operations would minimize waste within the cargo handling and clearing process. Port Castries offers five days' free storage to allow cargo suppliers to utilize the facilities and to reduce idle time and terminal congestion. The current storage capacity namely closed and open facilities is sufficient for cargo accommodation during normal operating conditions. Consequently, during peak season, the delivery process requires extra storage capacity to accommodate cargo, utilizing open facility near the ferry terminal where many of deadly waste such as transportation is evident due to distance and layout.

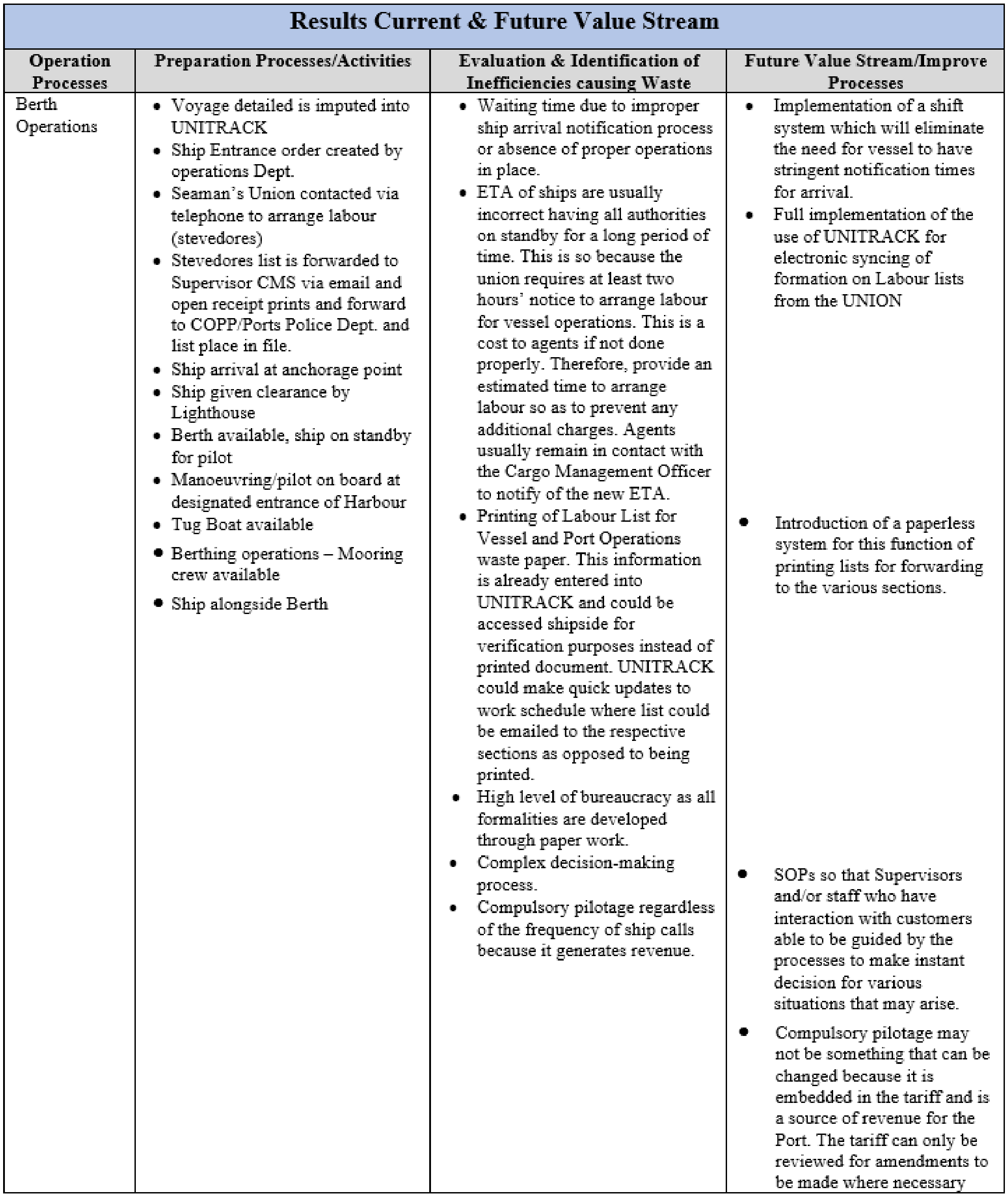
Furthermore, the cargo delivery process begins with the consignee making arrangement for cargo clearance by preparing the necessary documents to be presented to Customs. The results indicate the need for electronic copies to reduce paperwork. However, not all personnel involved, such as equipment operators, has access to EDI or Customs software, therefore hardcopies are necessary to ensure that labour and equipment are readily available to accommodate ship arrival.

The study has developed countermeasures to address the waste encountered during the current value stream process for future improvement. Table 14 provides the results by evaluating the wastes identified, giving detailed description as to causes of inefficiencies and improve processes.



Results Current & Future Value Stream			
Operation Processes	**Activities**	**Identification of Inefficiencies causing Waste**	**Future Value Stream/Improve Processes**
Ship Arrival	• Agent submits vessel specifications via hardcopy or email • Vessel created in UNITRACK and voyage file is opened • Application for berth submitted via hardcopy or EDI • Manifests received into UNITRACK via EDI from ASYCUDA • Agent submits discharge/load list, plan, manifest via email, EDI or hardcopy • Printed application for berth, and requisition for port services, discharge/load list, plan and manifest placed in file.	• Unnecessary bureaucratic steps in processing documents results in extra transportation and motion within the same processes. • Communication between Vessel Agent and other authorities such as Customs takes place via documentation which result in delays • Delays experienced in waiting in offices for documents to be signed when the authorized employee is unavailable or occupied with other tasks. • Printing applications for berth, requisitions for Port Services, discharge/load list plan and manifest wastes a lot of paper since most of these documents are very bulky.	● Automated system: This process could be automated to be integrated into UNITRACK for creation of the Vessel files. ● Automated: to interface with UNITRACK. This has been tried, however some of the agents as well as the CUSTOMS system but have not been able to maintain this feature. Automating would also eliminate the need for requiring signatures. ● There have been trials using tablets in receiving manifests to eliminate the need for manual checks for containers/cargo discharged, however not fully implemented and still in the “trial” stages. The trials did reveal that cargo will be entered in real time eliminating the need to have a physical checklist to mark off containers discharged from vessel.

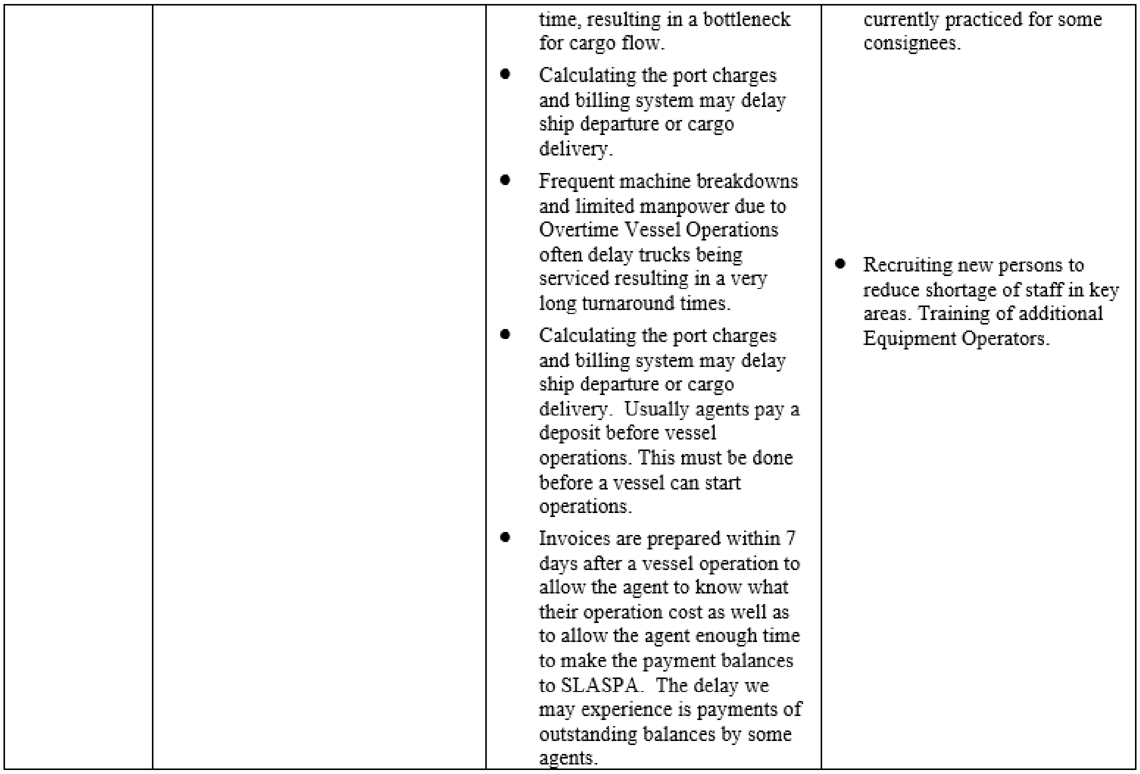
Table 13 Ship Arrival Current & Future State (Author, 2018)



Results Current & Future Value Stream			
Operation Processes	**Preparation Processes/Activities**	**Evaluation & Identification of Inefficiencies causing Waste**	**Future Value Stream/Improve Processes**
Berth Operations	• Voyage detailed is imputed into UNITRACK • Ship Entrance order created by operations Dept. • Seaman's Union contacted via telephone to arrange labour (stevedores) • Stevedores list is forwarded to Supervisor CMS via email and open receipt prints and forward to COPP/Ports Police Dept. and list place in file. • Ship arrival at anchorage point • Ship given clearance by Lighthouse • Berth available, ship on standby for pilot • Manoeuvring/pilot on board at designated entrance of Harbour • Tug Boat available • Berthing operations – Mooring crew available • Ship alongside Berth	• Waiting time due to improper ship arrival notification process or absence of proper operations in place. • ETA of ships are usually incorrect having all authorities on standby for a long period of time. This is so because the union requires at least two hours' notice to arrange labour for vessel operations. This is a cost to agents if not done properly. Therefore, provide an estimated time to arrange labour so as to prevent any additional charges. Agents usually remain in contact with the Cargo Management Officer to notify of the new ETA. • Printing of Labour List for Vessel and Port Operations waste paper. This information is already entered into UNITRACK and could be accessed shipside for verification purposes instead of printed document. UNITRACK could make quick updates to work schedule where list could be emailed to the respective sections as opposed to being printed. • High level of bureaucracy as all formalities are developed through paper work. • Complex decision-making process. • Compulsory pilotage regardless of the frequency of ship calls because it generates revenue.	• Implementation of a shift system which will eliminate the need for vessel to have stringent notification times for arrival. • Full implementation of the use of UNITRACK for electronic syncing of formation on Labour lists from the UNION • Introduction of a paperless system for this function of printing lists for forwarding to the various sections. • SOPs so that Supervisors and/or staff who have interaction with customers able to be guided by the processes to make instant decision for various situations that may arise. • Compulsory pilotage may not be something that can be changed because it is embedded in the tariff and is a source of revenue for the Port. The tariff can only be reviewed for amendments to be made where necessary

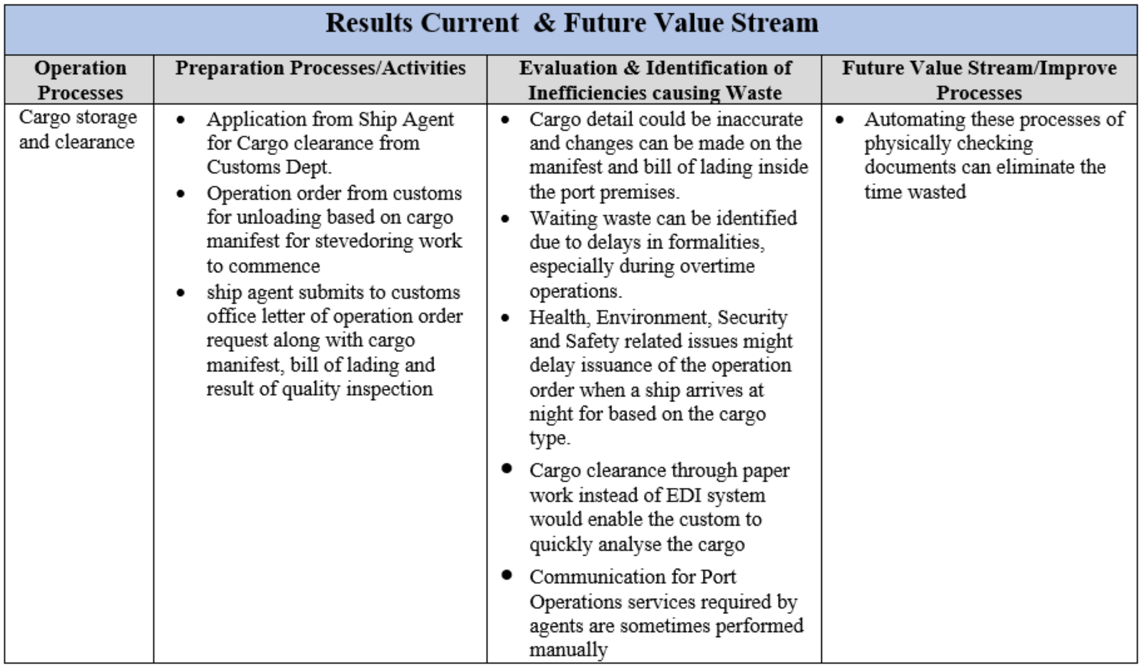
Table 14 Berth Operations Current & Future State (Author, 2018)

Results Current & Future Value Stream			
Operation Processes	Preparation Processes/Activities	Evaluation & Identification of Inefficiencies causing Waste	Future Value Stream/Improve Processes
Yard Transfer	• Clerks retrieve discharge/load lists, ship plan from file and proceeds to berth • Supervisor verifies stevedores list. • Crane Operator discharge and load vessel using Shore Crane. If the Shore Crane is unavailable, the Ship's Crane is utilized. • Equipment Operators retrieve containers from the stack to take to the vessel for loading as well as pick up containers from the quay to stack in the respective stacks according to line. • Reefer containers are trucked to reefer point for plugging. Reefers which have to be delivered immediately are picked up shipside. • Clerk tallies containers discharged and loaded • Clerks inputs vessel discharge/loading data into UNITRACK and reports are printed for the Shipping Section	• Long distance between the unloading, storage and delivery processes • Equipment age leads to frequent breakdown and failure during the cargo handling process. • Crane, yard and delivery productivity are unevenly performed which creates inefficiencies. • Crane breakdowns happen very frequently and causes revenue loss, particularly when operations use ship's crane which severely delays process, resulting in additional expenses for the Agents. • Complicated decision-making process in relation to cargo handling process resulting from complexity of management structure. • Cruise Vessels are given priority as such Cargo Operations must commence after Cruise Ships have left Port. • Storage space is limited the nature of the PORT being multipurpose. • Cargo locations may change with the constant shifting of cargo. Personnel usually do not record the change in location resulting in cargo being misplaced. This causes delays in cargo clearance. Cargo may be lost completely as well because of not being placed back in the location stated in UNITRACK or on the tallies. There is also the possibility of claims to the Port for lost cargo. • Gap in communications and knowledge sharing between the operation management and ground workers leads to underutilized employee. • Cargo inspection process delaying the cargo unloading process and cargo delivery process. • UNITRACK down turn causes the need to revert to the written delivery receipts. • Due to late clearance, trucks queue at the gate at the same	• Full implementation of the automation of these processes in UNITRACK can eliminate the manual labour required. • Training to enhance the skill sets of the staff so that greater efficiencies can be achieved. • Purchase of a new crane as the crane is very old and some parts are out of production. The lead time for the arrival of parts can further delay crane being down. • Standardization of procedures to allow greater autonomy and guided by the policies set in the procedures. • Possible relocation of the Cargo Services can make operations faster and more efficient. This would leave this sheltered harbour only for use of Cruise Vessels. • Implementing an RFID system to locate cargo maybe necessary to avoid this as manual interference causes the Port liabilities. • Documenting necessary information to ensure that there is always smooth continuity of operations. This also allows capable employees to read this document so that they can be fully appraised of what the various job entails. • This process is necessary but can be done randomly and not on all cargo type. This is



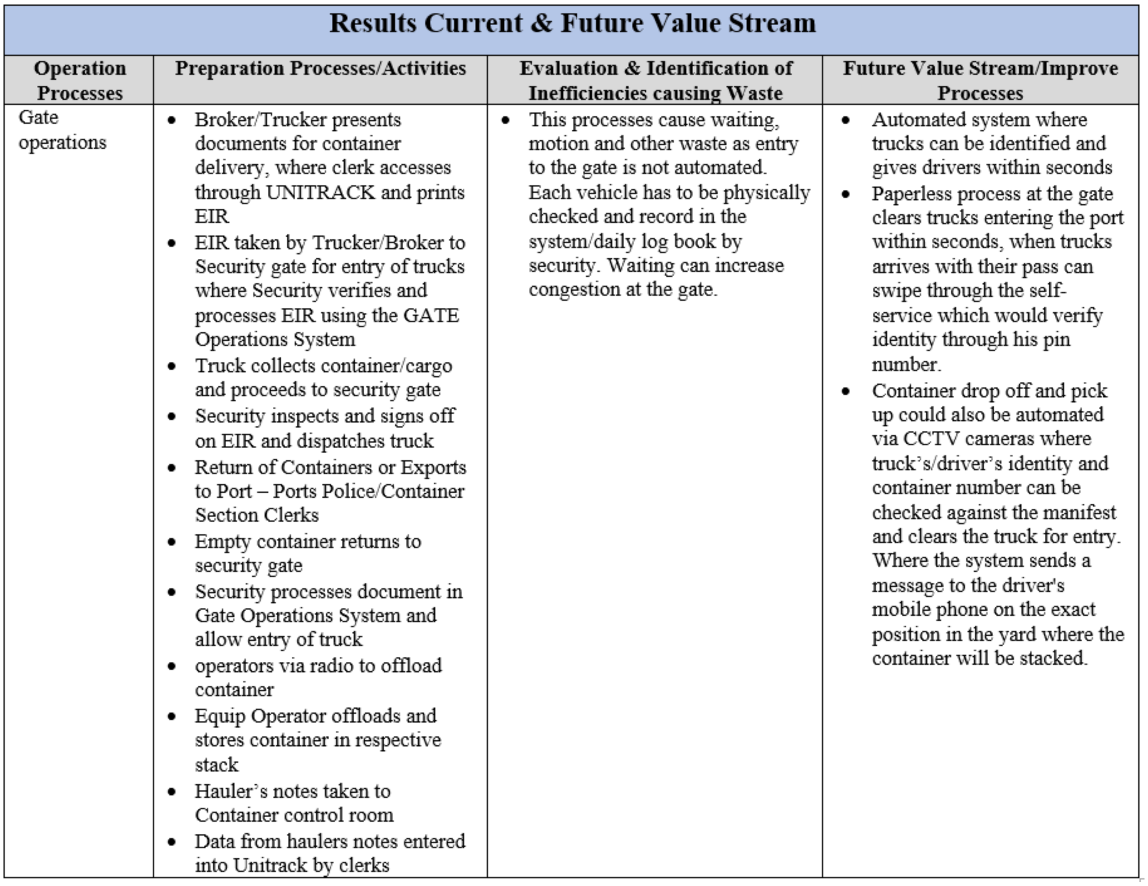
		time, resulting in a bottleneck for cargo flow. • Calculating the port charges and billing system may delay ship departure or cargo delivery. • Frequent machine breakdowns and limited manpower due to Overtime Vessel Operations often delay trucks being serviced resulting in a very long turnaround times. • Calculating the port charges and billing system may delay ship departure or cargo delivery. Usually agents pay a deposit before vessel operations. This must be done before a vessel can start operations. • Invoices are prepared within 7 days after a vessel operation to allow the agent to know what their operation cost as well as to allow the agent enough time to make the payment balances to SLASPA. The delay we may experience is payments of outstanding balances by some agents.	currently practiced for some consignees. • Recruiting new persons to reduce shortage of staff in key areas. Training of additional Equipment Operators.

Table 15 Yard Transfer Current and Future State (Author, 2018)



Results Current & Future Value Stream			
Operation Processes	**Preparation Processes/Activities**	**Evaluation & Identification of Inefficiencies causing Waste**	**Future Value Stream/Improve Processes**
Cargo storage and clearance	• Application from Ship Agent for Cargo clearance from Customs Dept. • Operation order from customs for unloading based on cargo manifest for stevedoring work to commence • ship agent submits to customs office letter of operation order request along with cargo manifest, bill of lading and result of quality inspection	• Cargo detail could be inaccurate and changes can be made on the manifest and bill of lading inside the port premises. • Waiting waste can be identified due to delays in formalities, especially during overtime operations. • Health, Environment, Security and Safety related issues might delay issuance of the operation order when a ship arrives at night for based on the cargo type. • Cargo clearance through paper work instead of EDI system would enable the custom to quickly analyse the cargo • Communication for Port Operations services required by agents are sometimes performed manually	• Automating these processes of physically checking documents can eliminate the time wasted

Table 16 Cargo Storage and Clearance Current and Future State (Author, 2018)



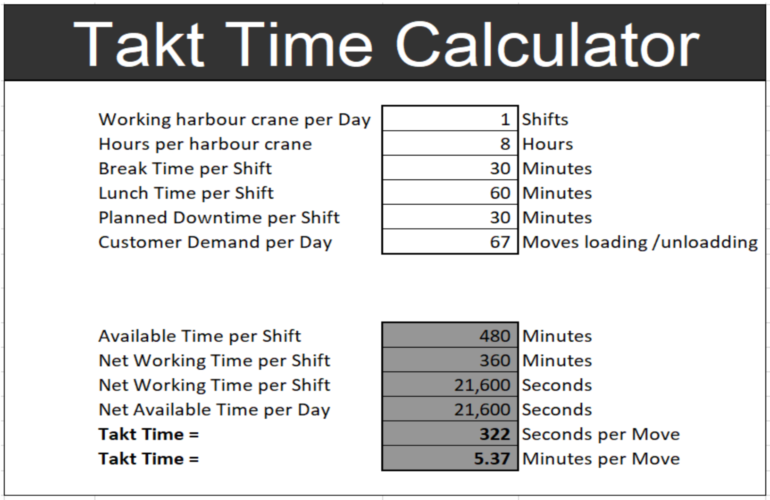
Results Current & Future Value Stream			
Operation Processes	**Preparation Processes/Activities**	**Evaluation & Identification of Inefficiencies causing Waste**	**Future Value Stream/Improve Processes**
Gate operations	• Broker/Trucker presents documents for container delivery, where clerk accesses through UNITRACK and prints EIR • EIR taken by Trucker/Broker to Security gate for entry of trucks where Security verifies and processes EIR using the GATE Operations System • Truck collects container/cargo and proceeds to security gate • Security inspects and signs off on EIR and dispatches truck • Return of Containers or Exports to Port – Ports Police/Container Section Clerks • Empty container returns to security gate • Security processes document in Gate Operations System and allow entry of truck • operators via radio to offload container • Equip Operator offloads and stores container in respective stack • Hauler's notes taken to Container control room • Data from haulers notes entered into Unitrack by clerks	• This processes cause waiting, motion and other waste as entry to the gate is not automated. Each vehicle has to be physically checked and record in the system/daily log book by security. Waiting can increase congestion at the gate.	• Automated system where trucks can be identified and gives drivers within seconds • Paperless process at the gate clears trucks entering the port within seconds, when trucks arrives with their pass can swipe through the self-service which would verify identity through his pin number. • Container drop off and pick up could also be automated via CCTV cameras where truck's/driver's identity and container number can be checked against the manifest and clears the truck for entry. Where the system sends a message to the driver's mobile phone on the exact position in the yard where the container will be stacked.

Table 17: Gate Operations Current and Future State (Author, 2018)

4.1.4 Future Value Stream Map

The future VSM is developed from the result of minimizing waste from existing processes. It is designed in setting specific timelines from the implementation of the improved processes by displaying countermeasures as highlighted in Table 14, 15, 16 and 17.

To satisfy customer demand, Takt time is calculated for crane productivity for unloading and loading of containers, general cargo and RORO (cars) operations as per customer demand per day, shown in Table 18, 19 and 20. Takt time is an important factor in port performance and beneficial to management for synchronizing and balancing the processes according to customer demand.

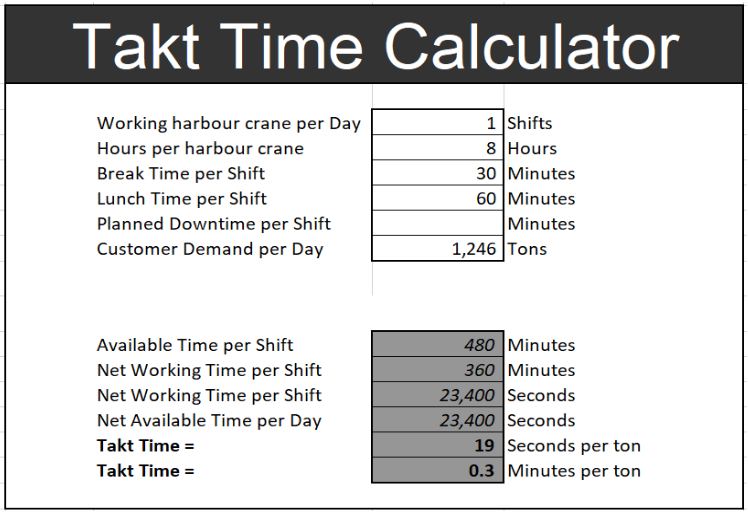


Takt Time Calculator

Working harbour crane per Day	1	Shifts
Hours per harbour crane	8	Hours
Break Time per Shift	30	Minutes
Lunch Time per Shift	60	Minutes
Planned Downtime per Shift	30	Minutes
Customer Demand per Day	67	Moves loading /unloadding
Available Time per Shift	480	Minutes
Net Working Time per Shift	360	Minutes
Net Working Time per Shift	21,600	Seconds
Net Available Time per Day	21,600	Seconds
Takt Time =	**322**	Seconds per Move
Takt Time =	**5.37**	Minutes per Move

Table 18: Takt Time Calculation for containers vessels in Port Castries (Author 2018)

The results indicate that 5.37 minutes is required to move one container from ship to shore or vice versa. This is relatively slow productivity time accounting for approximately 11 crane moves/hr. Port Castries only handles a yearly average of 35,000 TEUs. Large ports performance average 25–40 crane moves/hr with 110,000 TEUs annually per crane (UNCTAD, 2017). Investigations as to low productivity are required by management for proper equipment utilization. This could be influenced by equipment condition, age and variation in skills of operators. Some equipment operators are more efficient than others, therefore, additional training is recommended to enhance skills in order for all operators to perform at the same level.

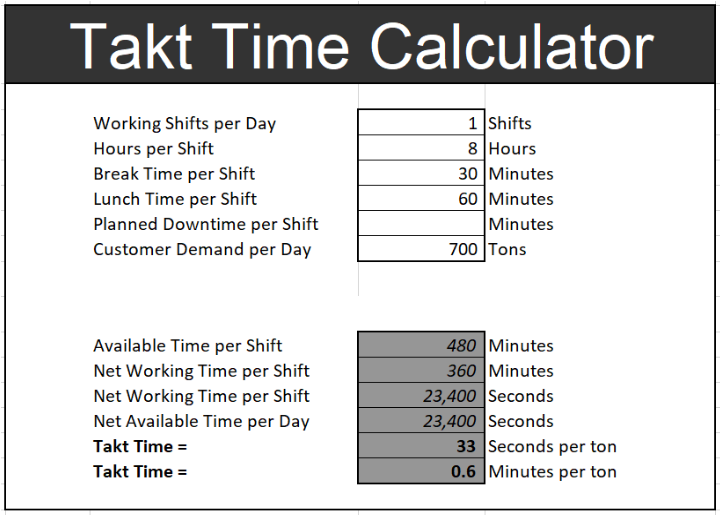


Takt Time Calculator

Working harbour crane per Day	1	Shifts
Hours per harbour crane	8	Hours
Break Time per Shift	30	Minutes
Lunch Time per Shift	60	Minutes
Planned Downtime per Shift		Minutes
Customer Demand per Day	1,246	Tons
Available Time per Shift	*480*	Minutes
Net Working Time per Shift	*360*	Minutes
Net Working Time per Shift	*23,400*	Seconds
Net Available Time per Day	*23,400*	Seconds
Takt Time =	**19**	Seconds per ton
Takt Time =	**0.3**	Minutes per ton

Table 19: Take time for General Cargo Operations (Author, 2018)

The results depend on the yard layout and distance between unloading from ship and cargo storage area. Some cargoes are loaded directly on trucks, therefore, reducing time.



Takt Time Calculator

Working Shifts per Day	1	Shifts
Hours per Shift	8	Hours
Break Time per Shift	30	Minutes
Lunch Time per Shift	60	Minutes
Planned Downtime per Shift		Minutes
Customer Demand per Day	700	Tons
Available Time per Shift	*480*	Minutes
Net Working Time per Shift	*360*	Minutes
Net Working Time per Shift	*23,400*	Seconds
Net Available Time per Day	*23,400*	Seconds
Takt Time =	**33**	Seconds per ton
Takt Time =	**0.6**	Minutes per ton

Table 20: Takt time for RORO (Cars) operations (Author, 2018)

The result is based on size and layout of the terminal where storage of cars is distance from the berth as shown in Figure 23. Also, being a multipurpose port, cars utilize the same traffic lane as handling equipment and trucks causing delays and inefficiency in the process. At present, the designated queueing area for trucks is directly to the front of the car storage zone.

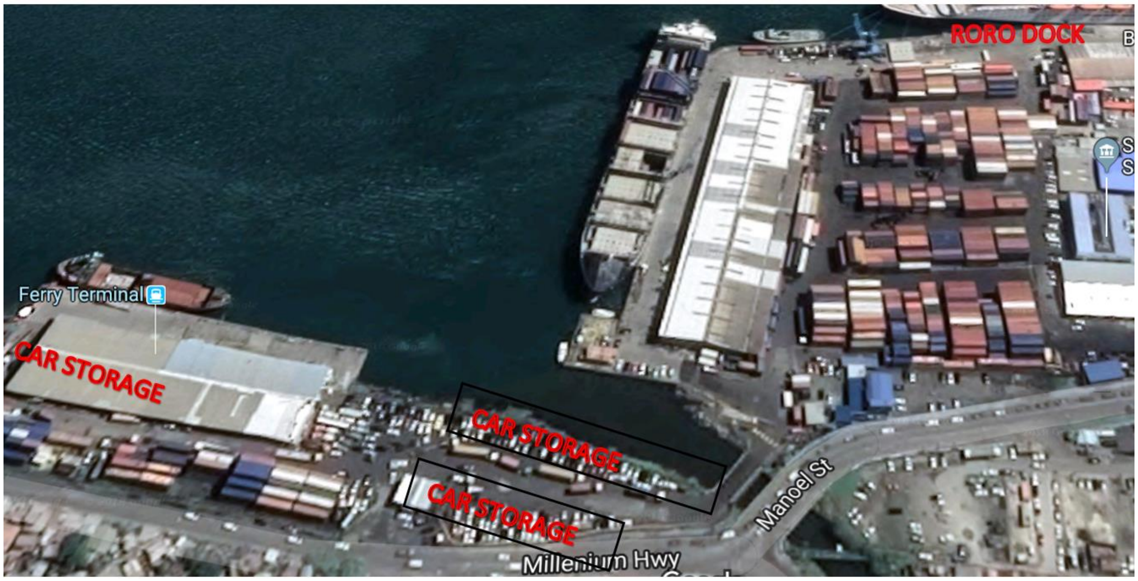


Figure 23: Car Storage Layout – Port Castries (Image courtesy Google Earth)

The Takt time result would assist management in setting real-time targets for quality and efficiency for establishing effective continuous improvement programs involving all employees to reduce the non-added value activities mentioned above. There are various assumptions as to the low productivity within the processes. The layout of the terminal hinders the free flow of cars and equipment. Such unbalanced makes it difficult for each process to maintain same takt time resulting inconsistent pull system from the customer side, where delivery of goods is delayed. Therefore, balancing operations processes is essential where all processes should function at the same takt time to eliminating waiting time and deadly wastes. Working at different takt time may cause delay and congestion. Moreover, there must be sufficient handling equipment, employees and yard storage at appropriate distances.

Additionally, the decision-making process hinders the port, causing unnecessary steps in the processes. Lean would provide fast and cost-effective way in the delivery of value to customer before and during vessel’s call, increasing productivity if properly implemented. This would depend on IT systems utilized by Seaports Operations and customs, to allow cargo release as soon as it is practical. Full automation of these processes in UNITRACK would minimize waste.

4.1.5 Implementation Plan

A successful lean transformation in Port Castries involves management, staff and stakeholders working together, having a common goal and using the necessary resources to reduce waste. Figure 24 gives details of organisational structure of Seaports Operations, number of employees and supporting departments.

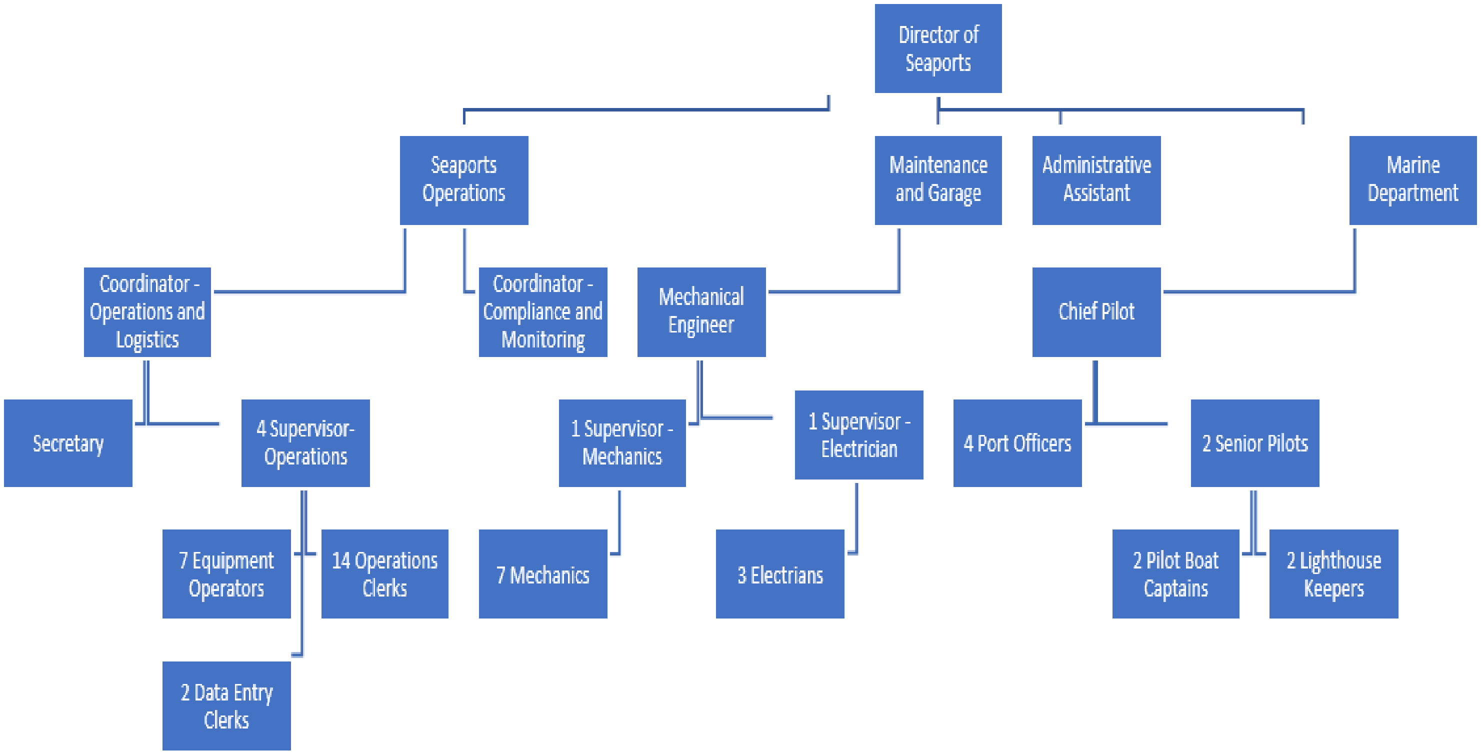


Figure 24: Organisational Structure of the Operations Department: Ports Castries (Author, 2018)

The proposed lean implementation plan for Port Castries is represented by the three tier house as discussed in the methodology.

(a) Workplace Organization Tools

5s system, visual workplace and point-of-use-storage (POUS) are the foundation which focuses on workplace organization involving clean, safe and organized work area for easy access eliminating wastes such as motion. The evaluation revealed that maintenance workshop, container yard and Shed#6 are highly recommended for implementation of 5s where organized work is essential to carry out maintenance work promptly and delivery of cargo/containers to the customer. Personal effects and container section, during peak time, the tendency of misplacing cargo, although it can found in UNITRACK, occurs through constant shifting and not replacing it in the right location, causing cargo to be lost and claims forwarded to SLASPA for compensation. Implementing the 5s would clearly identify designated location where resources if not present could be noticed. The maintenance workshop would benefit with clean and organized work space with visibility of tools, spare parts and storage of large item for better utilization of floor space. Establishing 5s score sheet would provide a standard for balancing areas that require improvements. Workplace organization would result in improved employees' morale and a safe working environment.

(b) Workplace analysis tools

This includes layout analysis, SMED principles, and standardized work where processes are examined to eliminate waste by reducing unnecessary steps. Layout analysis is critical for optimization of space such as the distance from berth to storage yard, location of containers for loading and stacking height. The empty container storage area is located after the ferry terminal. Ships often leave without loading empties due to additional delays and scheduled time for next port of call. Communicating to the ship and agent in advance as to loading of empties would decrease the high amount currently at the terminal. SMED analysis involves working with internal and external processes to avoid inefficiencies. Port planners need to set timeline such as notice of arrival of ships so that all agencies are available for free flow of resources. Standardized operations throughout the terminals through development of SOPs, documented to improve processes. Training of employees and reviewing job description to ensure that assigned duties are carried out effectively and to avoid underutilization of employees.

(c) Workplace Optimization Tools

This can be achieved through training and documented SOPs for key process areas including being proactive as to establishing preventative measures for each process. Total productive maintenance is based on schedule maintenance of equipment to avoid unnecessary breakdowns. Port Castries has implemented Facilities Management System for the maintenance workshop to strengthen asset management which provides scheduling, assigning and monitoring of engineering tasks for equipment. The software produces work orders for technicians for a better understanding of performance and maintenance. Therefore, maintenance of equipment would be carried out on a scheduled basis reducing the number of breakdowns.

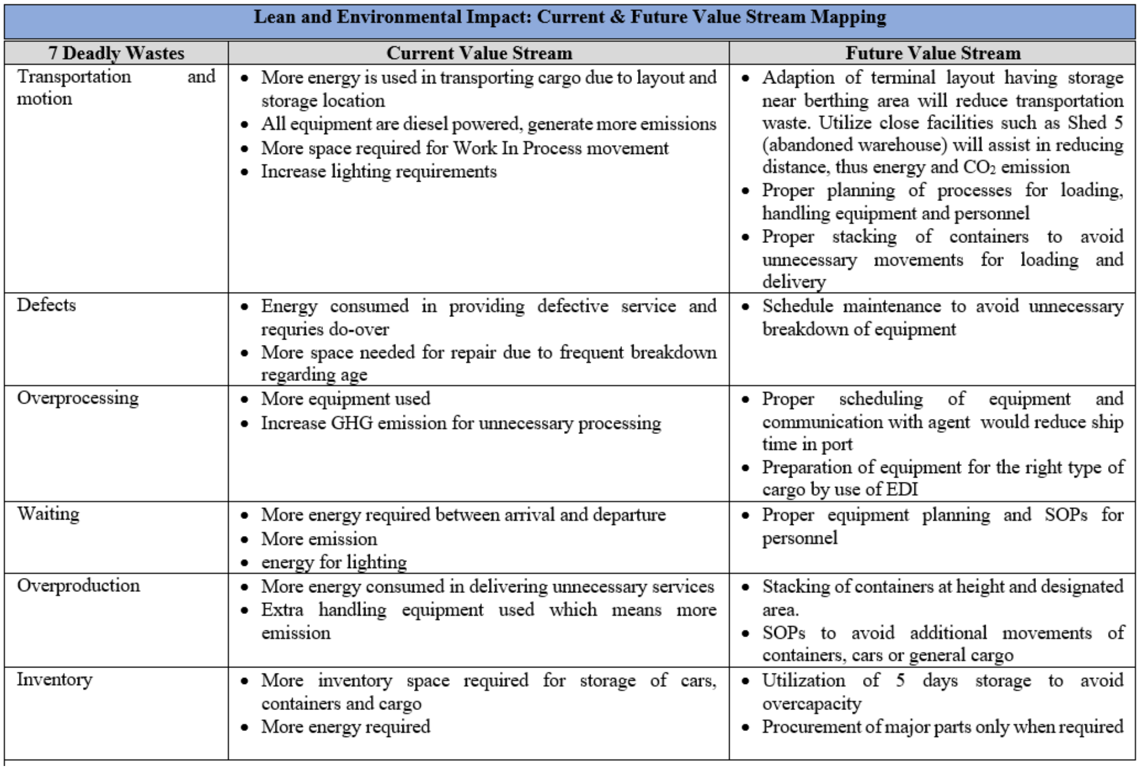
(d) Continuous improvement

- Teamwork requires training of employees with the necessary tools to respond to customer demand. During 2017, senior personnel received early retirement packages, leaving the port operating with inexperienced employees. The succession plans, cross-training or documented procedures were inadequate as to allow smooth transition, leaving a huge knowledge and competence gap. Succession plan should be created and documented for training of employees to avoid recurrence.
- Kaizen exercise for process improvement utilizing PDCA cycle of plan, do, check and act. Employees participation in the process would give a better understanding

and appreciation as to best practices and adapting to a culture of continuous improvement.

4.1.6 Lean Environmental Performance in Port Castries

Port Castries lacks the capacity or funding for sustainable development of port resources. All cargo handling equipment such as quay crane, reach stacker, forklifts are diesel powered. The research only focused on implementation of Lean to reduce energy consumption and CO_2 emission within berthing and cargo handling processes. For long-term planning, Port Castries would require more fuel-efficient equipment, however, in the interim, the need to reduce the distance equipment travels from berth to storage facility is important in energy and CO_2 emission reduction. Implementing Lean to reduce waste in the processes would reduce harm to the environment without substantial investment. Lean tools to target environmental impacts associated with the 7-deadly wastes highlighted in Table 21 combined with countermeasures for improve process.



Lean and Environmental Impact: Current & Future Value Stream Mapping		
7 Deadly Wastes	**Current Value Stream**	**Future Value Stream**
Transportation and motion	• More energy is used in transporting cargo due to layout and storage location • All equipment are diesel powered, generate more emissions • More space required for Work In Process movement • Increase lighting requirements	• Adaption of terminal layout having storage near berthing area will reduce transportation waste. Utilize close facilities such as Shed 5 (abandoned warehouse) will assist in reducing distance, thus energy and CO_2 emission • Proper planning of processes for loading, handling equipment and personnel • Proper stacking of containers to avoid unnecessary movements for loading and delivery
Defects	• Energy consumed in providing defective service and requries do-over • More space needed for repair due to frequent breakdown regarding age	• Schedule maintenance to avoid unnecessary breakdown of equipment
Overprocessing	• More equipment used • Increase GHG emission for unnecessary processing	• Proper scheduling of equipment and communication with agent would reduce ship time in port • Preparation of equipment for the right type of cargo by use of EDI
Waiting	• More energy required between arrival and departure • More emission • energy for lighting	• Proper equipment planning and SOPs for personnel
Overproduction	• More energy consumed in delivering unnecessary services • Extra handling equipment used which means more emission	• Stacking of containers at height and designated area. • SOPs to avoid additional movements of containers, cars or general cargo
Inventory	• More inventory space required for storage of cars, containers and cargo • More energy required	• Utilization of 5 days storage to avoid overcapacity • Procurement of major parts only when required

Table 21: Port Castries Environmental Deadly targeted by Lean (Author, 2018)

4.2 FEASIBILITY STUDY FOR HYBRID - SOLAR PV SYSTEM FOR PORT CASTRIES

This section presents a feasibility study on solar PV system to generate electricity in Port Castries to reduce electricity cost and consumption. The study utilized HOMER software for selection of the least-cost option. Sensitivity analysis and optimization would be performed using economic variables.

4.2.1 Port Castries Electricity Supply and Demand

Saint Lucia has the potential to generate electricity from renewable energy sources namely solar, wind and geothermal with the rest at smaller scale. However, due to the high cost associated with these technologies and SLASPA's financial situation, wind and geothermal were eliminated from the study. Furthermore, Port Castries, being a city port in close proximity to the GFLC Airport, onshore or offshore wind turbines would not be ideal.

SLASPA being state-owned, requires government intervention amending legislation to provide sustainable energy by use of 100% renewable energy to electrify the port and reduce operational and energy cost and carbon footprint. Currently, there is a cap as to solar PV system for electricity generation from commercial customer of 25 kWp. Port Castries has been experiencing high electrical bill and consumption particularly in critical areas such as storage and main administration building. Furthermore, power shortages are issues to be addressed since the country may experience storms/hurricane during the Atlantic hurricane season from June to November. During this time, the country requires the main port of entry to be functional for emergency purposes.

From data collected from 2015-2017, results show that Port Castries average monthly electricity bill is approximately US$21,000 and consumption of 62,000 kWh. This is extremely high for a small port with limited capacity (400 TEU). Furthermore, Port Castries energy base load is estimated at 2033 kWh per day whilst electricity is sold to commercial customers at US$0.28 kWh.

4.2.2 Data collection and analysis

The Study utilizes data from Port Castries for both qualitative and quantitative analysis. For quantitative analysis, historical data from 2015-2017 consist of electricity bill and consumption, container throughput, capital and operating expenditure and other data relevant for the project such as solar GHI, temperature, cost of electricity. Temperature and solar GHI for Saint Lucia was collect to appraise the potential of solar energy.

4.2.3 Model Description and Configuration

The project is based on only solar PV system installation to provide 75% power to Port Castries. The author utilized HOMER software to perform economic comparison and feasibility of undertaking the project. Since HOMER software is designed for hybrids, the author has considered the following technologies for simulation:

- Solar PV
- Grid
- Converter, and
- Battery storage

Hybrid

Solar PV system is simulated as the primary power source with battery bank where excess electricity is fed to the grid. The converter connects direct current (DC) and alternating current (AC), converting PV system and battery power output to AC to supply the load.

Grid energy delivers to AC bus, whereas PV system and battery supply DC bus as shown in Figure 25.

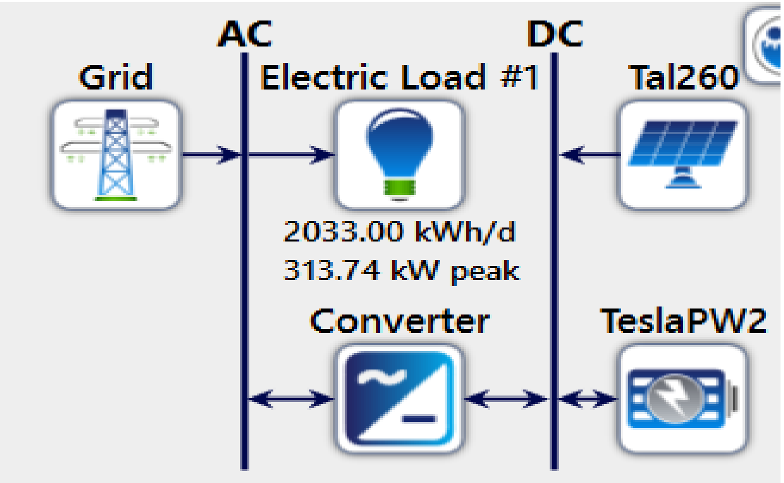


Figure 25: System Architecture (HOMER, 2018)

4.2.4 System Modelling

Commercial design was selected for daily profile and simulated where the port's peak period is between 8-5pm and for seasonal profile, July was selected as peak month as shown in Figure 26. The average hourly peak load was average at 313.74 kW as seen in Figure 25.

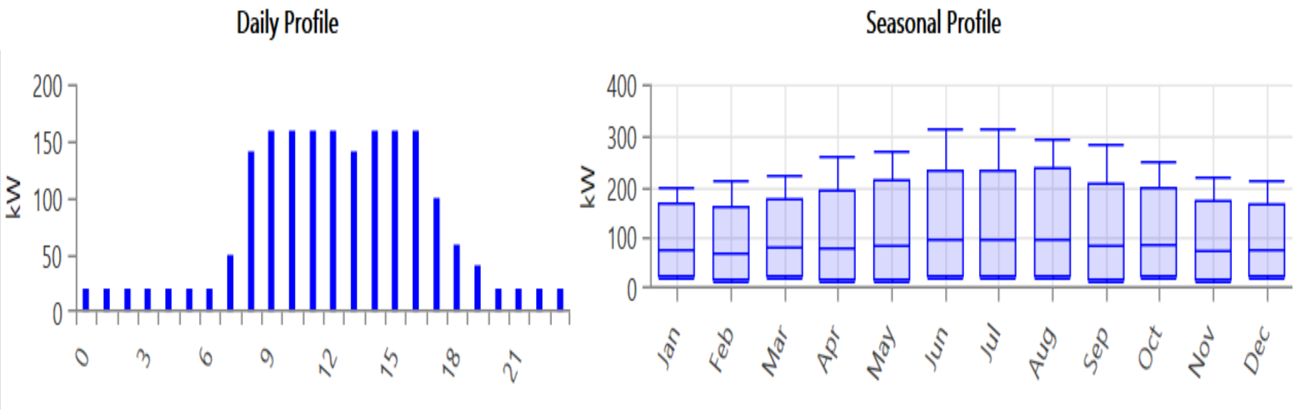


Figure 26: Hourly load and peak month profile (HOMER, 2018)

The solar radiation and temperature for Saint Lucia were analysed as per NASA Surface Meteorological and Solar Energy database, with annual average of 6.08 kWh/m^2/day and temperature of 26.27^o Celsius, as shown in Figure 27 and 28, respectively.

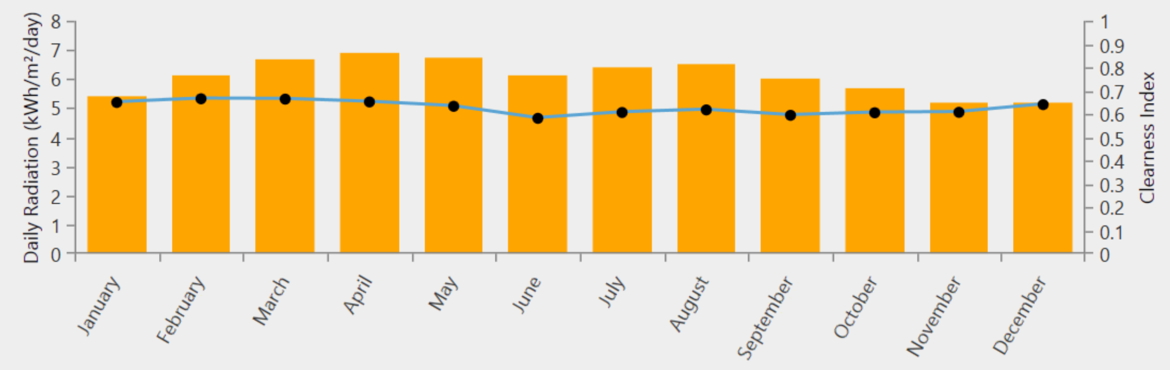


Figure 27: Annual Solar GHI for Saint Lucia (NASA, 2018)

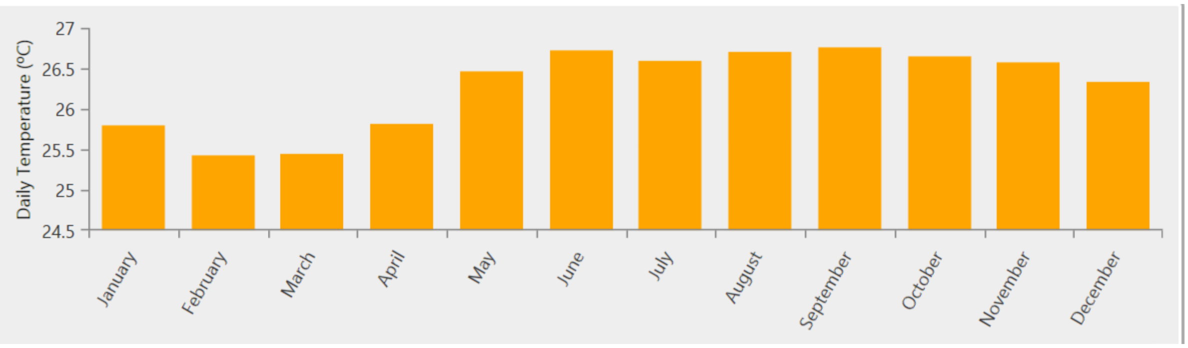


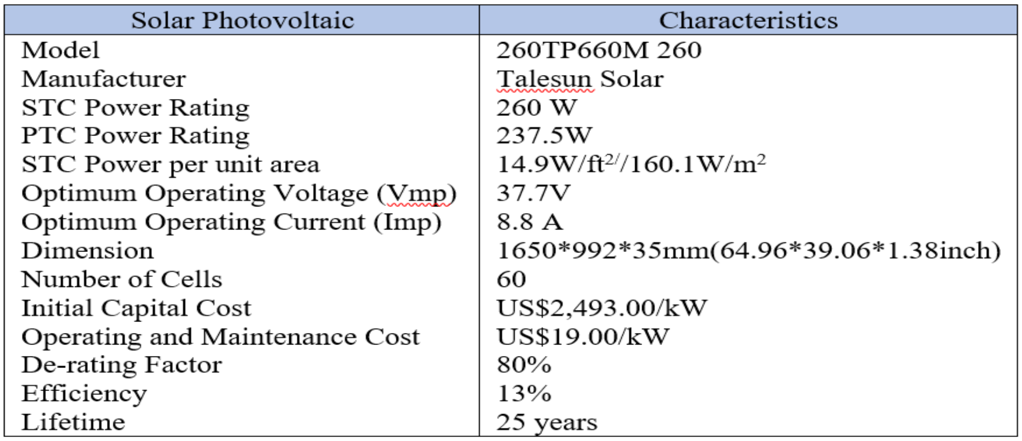
Figure 28: Saint Lucia Temperature (NASA, 2018)

The sensitivity analysis values simulated diesel fuel price of US$1.00 per litre and nominal discount rate of 8%, based on Saint Lucia's present fuel price and interest rate.

4.2.5 Solar PV module

Talesun Solar 260TP660M 260 was selected for this study based on availability in Saint Lucia and capacity. The module has a capacity rate of 400-k, power of 246w voltage, 37.70 volts and current of 8.8A. The technology associated are commercial-scale flat-plate system, mono-crystalline, mono-c-Si, with stand test condition (STC) of 13% efficiency. Capital cost was estimated at US$2,393/kW and operating and maintenance cost (O&M)

of US$19/kW annually based on NREL cost for electric generating technologies. The characteristics and dimension of the module are shown in Table 22.

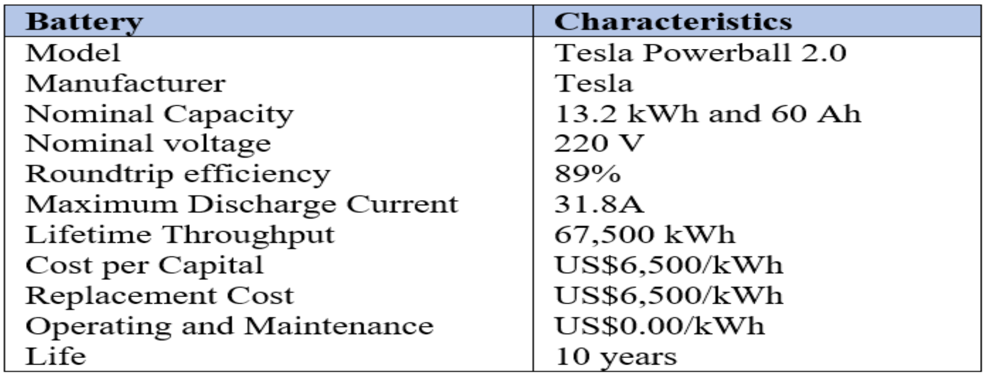


Solar Photovoltaic	Characteristics
Model	260TP660M 260
Manufacturer	Talesun Solar
STC Power Rating	260 W
PTC Power Rating	237.5W
STC Power per unit area	14.9W/ft$^{2/}$/160.1W/m^{2}
Optimum Operating Voltage (Vmp)	37.7V
Optimum Operating Current (Imp)	8.8 A
Dimension	1650*992*35mm(64.96*39.06*1.38inch)
Number of Cells	60
Initial Capital Cost	US$2,493.00/kW
Operating and Maintenance Cost	US$19.00/kW
De-rating Factor	80%
Efficiency	13%
Lifetime	25 years

Table 22: PV Characteristics (Author, 2018)

4.2.6 Battery Bank

Tesla Powerwall 2.0 battery serves as energy storage for the system. This is a Lithium-ion battery of 13.5kWh, throughput of 67,500 kWh, with initial cost of capital (ICC) and replacement cost of US$6,500 and expected lifetime of 10 years. The characteristics are highlighted in Table 23. The battery consists of an inverter that produces AC bus, however, to model a DC-output battery within HOMER, a converter must be included.



Battery	**Characteristics**
Model	Tesla Powerball 2.0
Manufacturer	Tesla
Nominal Capacity	13.2 kWh and 60 Ah
Nominal voltage	220 V
Roundtrip efficiency	89%
Maximum Discharge Current	31.8A
Lifetime Throughput	67,500 kWh
Cost per Capital	US$6,500/kWh
Replacement Cost	US$6,500/kWh
Operating and Maintenance	US$0.00/kWh
Life	10 years

Table 23: Battery Bank Description (Author, 2018)

The number of batteries and strings required for the project were calculated. Figure 30 shows the monthly state of charge for the Battery Bank.

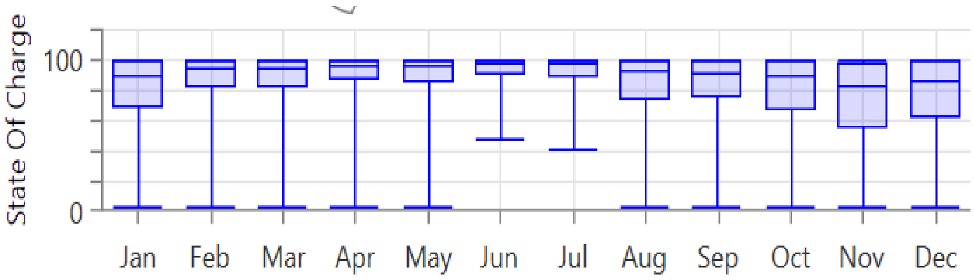


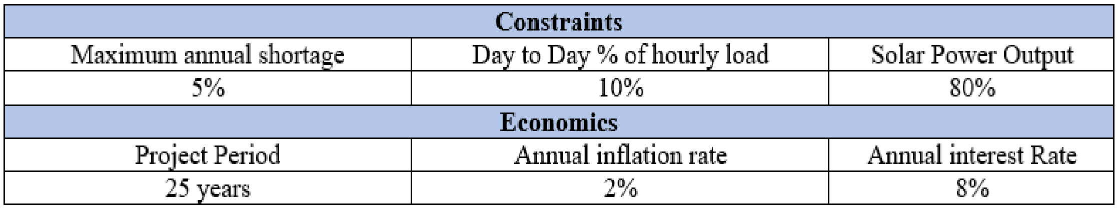
Figure 29 Batteries Annual state of charge

4.2.7 Power Converter

A generic system converter from the software was selected as interface between AC and DC bus. The author decided to use this option in determining the most suitable converter for the system. The converter selected by the software has an inverter input efficiency of 95%, lifetime of 15 years and rectifier input of relative capacity of 100% and 95% efficiency. The ICC and replacement are estimated at US$300/kW with O&M of zero.

4.2.8 Configuration results analysis

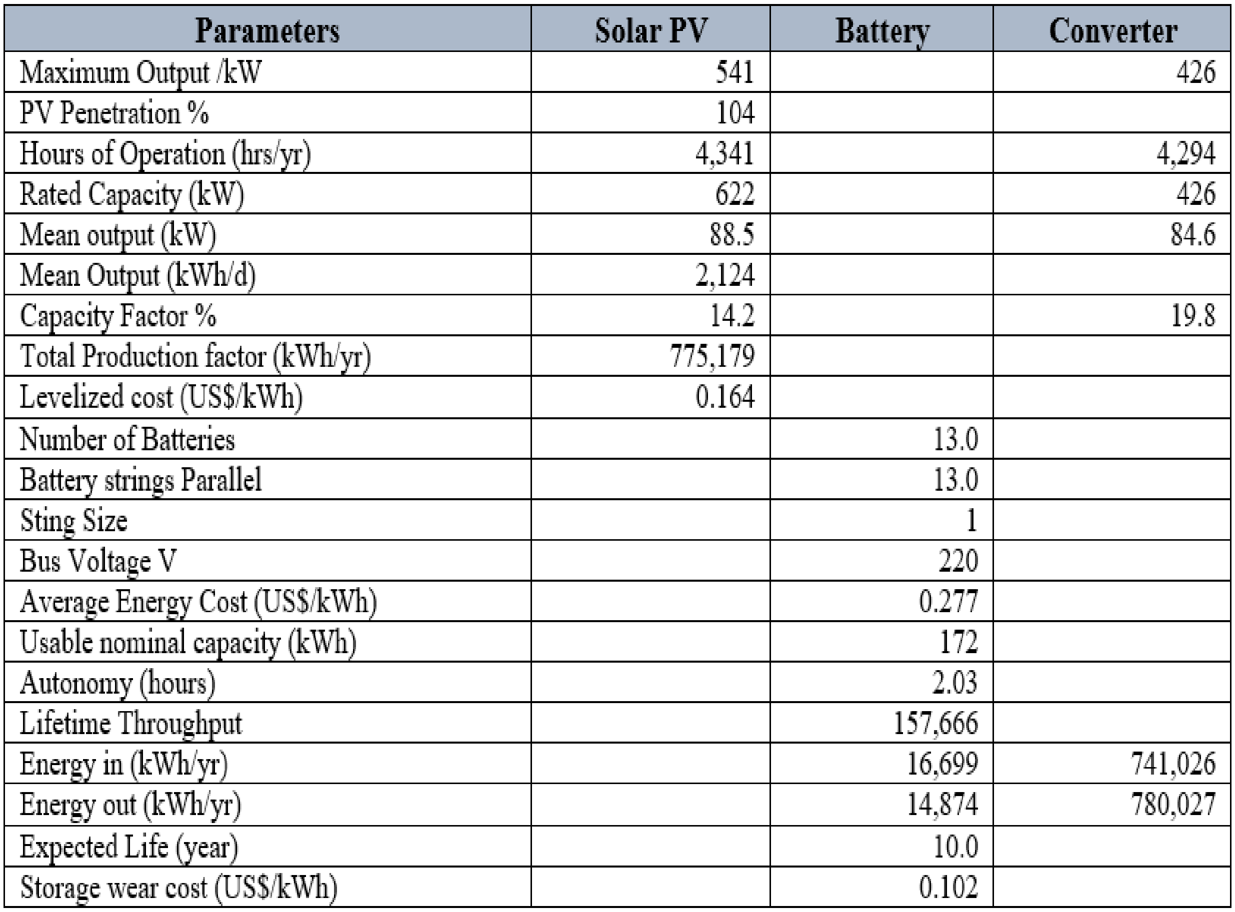
Economic variable and constraints were simulated to create various scenarios to find the optimal configuration for the system as illustrated in Table 21.



Constraints		
Maximum annual shortage	Day to Day % of hourly load	Solar Power Output
5%	10%	80%
Economics		
Project Period	Annual inflation rate	Annual interest Rate
25 years	2%	8%

Table 24: Model Constraints and Economic variables (Author, 2018)

The results revealed an optimal system comprised of Solar PV system with a total capacity of 622 kWh with battery bank of 13 strings comprising of 13 batteries to create the nominal voltage of DC bus of 220V and converter capacity of 426 kW. Tables 25 gives the electrical summary and statistical result of the PV System.



Parameters	Solar PV	Battery	Converter
Maximum Output /kW	541		426
PV Penetration %	104		
Hours of Operation (hrs/yr)	4,341		4,294
Rated Capacity (kW)	622		426
Mean output (kW)	88.5		84.6
Mean Output (kWh/d)	2,124		
Capacity Factor %	14.2		19.8
Total Production factor (kWh/yr)	775,179		
Levelized cost (US$/kWh)	0.164		
Number of Batteries		13.0	
Battery strings Parallel		13.0	
Sting Size		1	
Bus Voltage V		220	
Average Energy Cost (US$/kWh)		0.277	
Usable nominal capacity (kWh)		172	
Autonomy (hours)		2.03	
Lifetime Throughput		157,666	
Energy in (kWh/yr)		16,699	741,026
Energy out (kWh/yr)		14,874	780,027
Expected Life (year)		10.0	
Storage wear cost (US$/kWh)		0.102	

Table 25: Simulation results (Author, 2018)

At 8% discounted rate and fuel price of US$1/L, the project initial cost of capital (ICC) is US$1.701,091.83, net present cost (NPC) of $2,094,962.00, levelized cost US$0.164/kWh with operating cost of US$30,467.60. Whereas, the average energy cost of the battery US$0.277 with a wear cost of US$0.102. PV accounts for 75% of the total electricity production whilst 25% purchased from national grid. This is based on the current legislation and 6 hours of daylight. Figure 30 illustrates the mix of electrical production by component type and month.

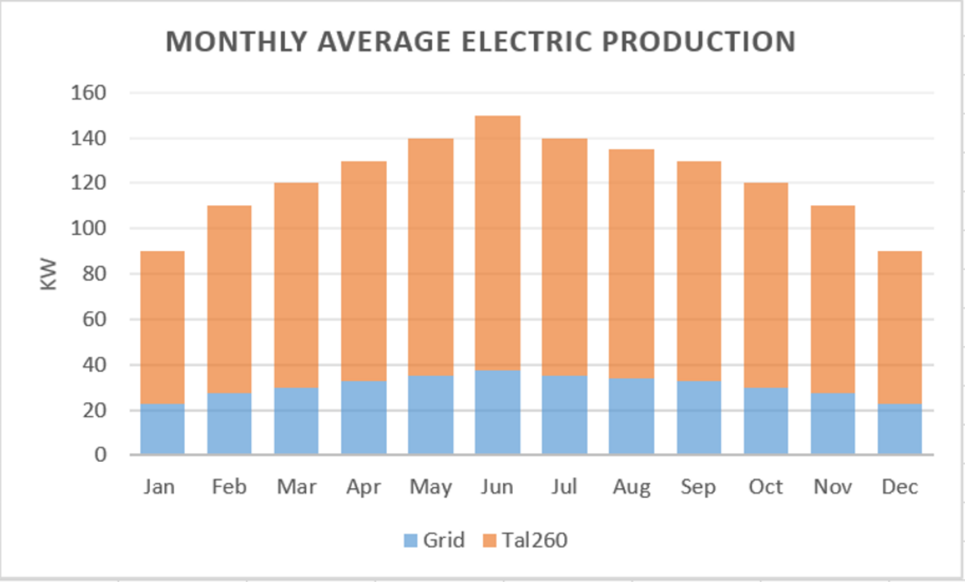


Figure 30: Average Monthly Electricity Production (Author, 2018)

Figure 31 shows daily battery State of Charge where red is fully charged and green is empty. In this case, it is fully charged most of the time.

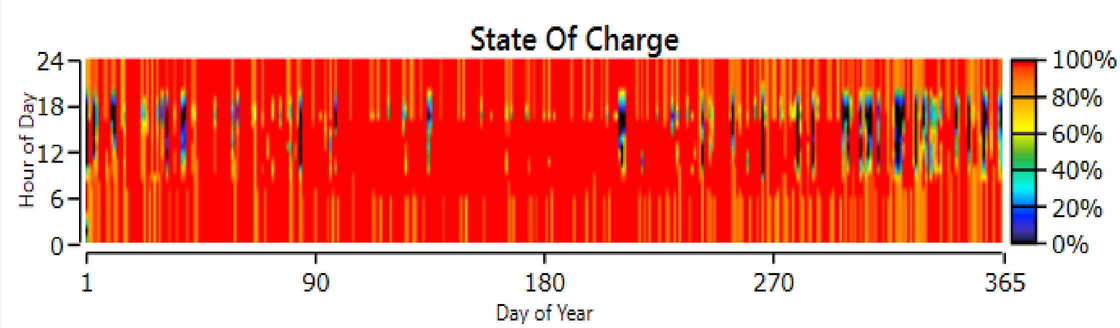


Figure 31: Battery State of Charge

HOMER state of charge parameters applies to the cycle state of charging strategy where the system begins to charge the storage bank until reaches the set-point state of charge. This assist in reduction of the amount of time the storage bank spends at a low state of charge and also number of charge-discharge cycle occurring throughout the year. HOMER calculates the battery fixed storage cost at zero whilst the marginal cost to be equal to storage wear cost of US0.102. Figure 32 shows the frequency of charge histogram depicting battery state of charge value to be fully charged 72.81% of time whilst 80-95% between 4-6%.

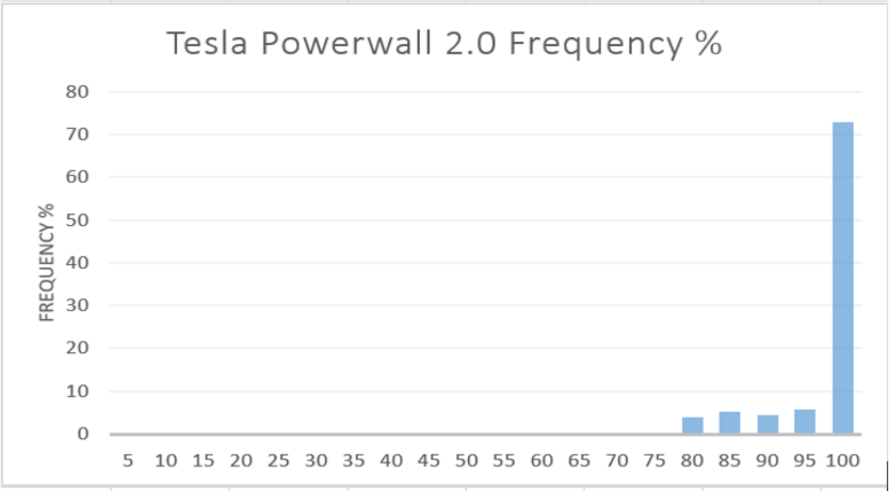


Figure 32: Frequency histogram (Author, 2018)

4.2.9 System Cost Structure

Table 26 gives a summary of the project cash flow. The project was simulated for a lifetime of 25 years, whilst the battery and converter, 10 and 15 years respectively. This explains the replacement cost for battery and converter during the project period. However, some components would extend beyond the project period which is deducted from the total cost representing savings indicated as salvage.

Component	Capital	O&M	Replacement	Salvage	Total
Solar PV	$1,488,651.02	$152,798.00	-	-	$1,641,449.02
Battery	$84,500.00	-	$74,650.48	$-10,121.32	$149,029.16
Converter	$127,941.81	-	$54,281.94	$-10,216.41	$172,007.34
System	**$1,701,092.83**	**$152,798.00**	**$128,932.42**	**$-20,337.73**	**$1,962,485.52**

Table 26: Cost Summary of system (Author, 2018)

4.3 PROJECT APPRAISAL

Project appraisal performed to establish whether the project is a worthwhile investment by conducting an economic evaluation comprises of NPV, IRR, ROI, payback period and LCOE. The benefits are calculated “With-Project” and “Without-Project” scenarios along with the associated costs throughout the project period.

4.3.1 Levelized Cost of Energy (LCOE)

The result shows the project yield LCOE of US$0.164 kWh. The electrical energy price sold from the national grid, as of August 2018, for commercial customers were US$0.280/kWh. The PV system in comparison with the grid shows a difference of US$0.116kWh. This indicates that installation of the PV systems has the potential of approximated 60% cost savings on the electrical bill where expenses would be met and profits generated.

4.3.2 Annual Electricity Bill

The electricity for Port Castries is procured from the national grid at US$0.28/kWh with power load of 735,663 kWh/yr. The unsatisfied demand is 251,130 kWh/yr., representing an annual power grid production of 25%. The cost is as follows:

- Cost of Electricity = 735,663*0.28 =US$205,985.64
- Cost of unmet electrical load/Grid Sales = 251,130*0.28= US$70,316.40

4.3.3 Social/Ecological Costs

(a) Cost of Emission

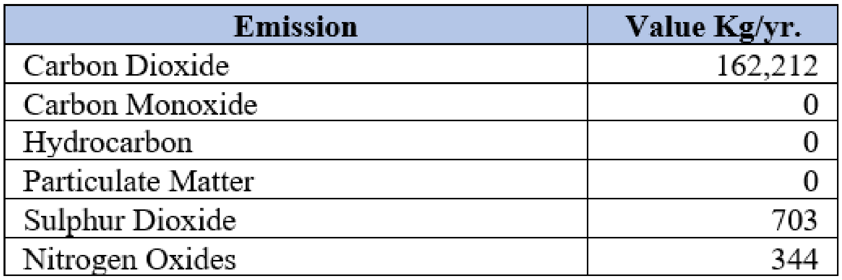
As previously mentioned, most of Saint Lucia’s electricity is generated from diesel-powered generators with solar accounting for 1.3%. To calculate CO_2 currently emitted from Port Castries electricity consumption, Corona Energy (2015) formula was used.

CO_2 = consumption (kWh)*0.537

Port Castries year 2017 = 729,502*0.537

Port Castries current emission =391,743 kg/yr.

The result of emission calculation from HOMER is highlighted in Table 27, indicating CO_2 emission of 162,212 kg/yr. would be emitting from the system. This emission amount is due to the 25% generation from grid which can be further reduced if the system was fully renewables.

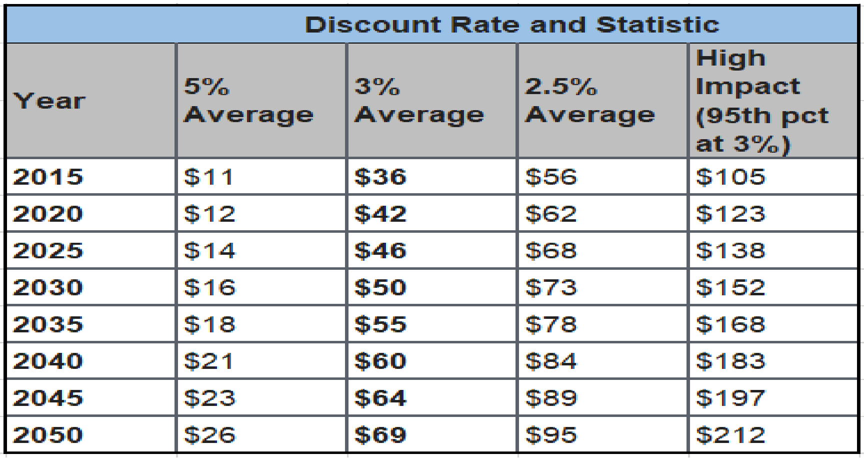


Emission	Value Kg/yr.
Carbon Dioxide	162,212
Carbon Monoxide	0
Hydrocarbon	0
Particulate Matter	0
Sulphur Dioxide	703
Nitrogen Oxides	344

Table 27: Project emission quantity in Kg/yr. (HOMER, 2018)

In comparison to the existing emission, the project CO_2 emission would be reduced by 41% which is double the amount targeted by the port of 20%. However, Port Castries can further reduce emissions but requires government intervention in amending legislation to enable the port to generate electricity from renewables at a higher scale.

To calculate the social cost of CO_2 emission in dollars, the author utilized USEPA recommended rate given in Table 28. The social cost is measured in metric tons. Using 2020-dollar amount of US$123, the result shows Port Castries current CO_2 emission cost is US$48,184.39, with the proposed PV system installation would be US$19,952.08, a difference of US$28,232.31.



	Discount Rate and Statistic			
Year	**5% Average**	**3% Average**	**2.5% Average**	**High Impact (95th pct at 3%)**
2015	$11	**$36**	$56	$105
2020	$12	**$42**	$62	$123
2025	$14	**$46**	$68	$138
2030	$16	**$50**	$73	$152
2035	$18	**$55**	$78	$168
2040	$21	**$60**	$84	$183
2045	$23	**$64**	$89	$197
2050	$26	**$69**	$95	$212

Table 28: USEPA 2015-2050 SC-CO_2 (USEPA, 2015)

(b) Ships Waiting Cost

Port Castries handles on average 35000 TEU, 280 vessel calls and operates 260 days per year. Assumptions were made as to power interruption at 5% as simulated in HOMER. Clarkson database was utilized for the calculation of ship waiting cost using daily charter rate for container feeder vessels of 1000 TEU in relation to similar vessels berthing in Port Castries. The rate of US$7,250 as of August 2018 was used (Clarkson, 2018). The result shows that the annual ship waiting cost is estimated at US$362,500. However, ships prefer to be served on arrival, hence reducing the ship waiting time would create competitive advantage for Port Castries.

4.3.4 Excess Electricity

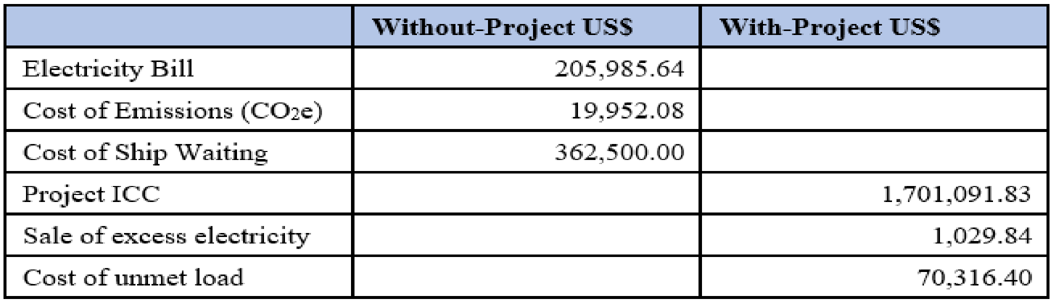
The project produces excess electricity of 3,678kWh/y. The reason for producing this low figure is associated based on the 25% grid purchase, battery storage capacity and working hours of the port.

The excess fed to the national grid as per simulation at US$0.280kWh/yr.

- Sale of excess electricity = 3,678*0.280= US$1,029.84

4.3.5 Economic Comparison: "Without-Project" and "With-Project" Scenarios

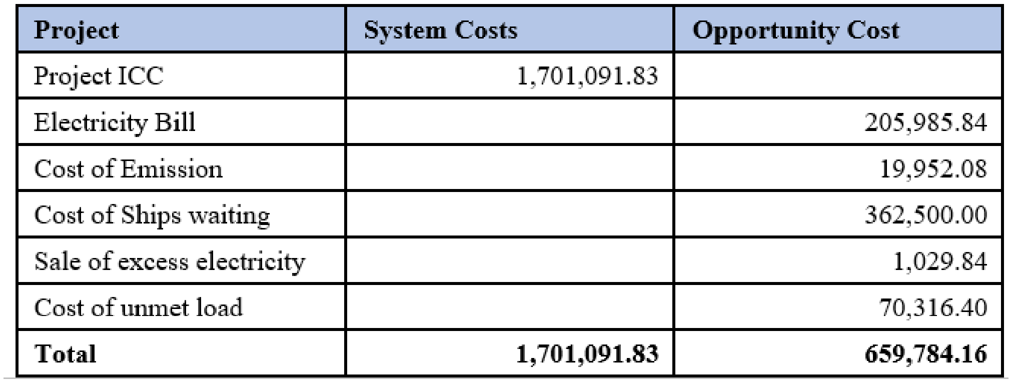
The cost associated with "Without-Project" is considered to be the current operating cost if not implement and "With-Project" vice versa. Table 29 shows the cost and benefits of the project.



	Without-Project US$	With-Project US$
Electricity Bill	205,985.64	
Cost of Emissions (CO_2e)	19,952.08	
Cost of Ship Waiting	362,500.00	
Project ICC		1,701,091.83
Sale of excess electricity		1,029.84
Cost of unmet load		70,316.40

Table 29: Economic Comparison Without and With Project (Author, 2018)

The project cost summary is divided into system costs and opportunity costs indicating cash inflows and outflows for undertaking the project as shown in Table 30. This is carried out to analyse the viability of the project to generate income if implemented.



Project	System Costs	Opportunity Cost
Project ICC	1,701,091.83	
Electricity Bill		205,985.84
Cost of Emission		19,952.08
Cost of Ships waiting		362,500.00
Sale of excess electricity		1,029.84
Cost of unmet load		70,316.40
Total	**1,701,091.83**	**659,784.16**

Table 30: Economic comparison (Author, 2018)

The results indicate that the project would procure a net benefit of $659,784.16 constituting the annual cash flow. Cash flow analysis is an important step in the decision-making process regarding project's acceptability. Cash flows analysis projections provides a balance of capital income and expenses associated with the project. Most importantly, the project must yield more cash inflow than outflow.

4.3.6 Payback Period

Payback period was calculated using both simple and discounted methods for the project lifetime of 25 years. The results show that the project payback period for simple and discounted payback is 5.80 and 7.30 years respectively. The discounted payback period inclusive of taxes would be considered for this project. This concludes that the project would be generating income in a short period, therefore, is acceptable.

4.3.7 Net Present Value (NPV)

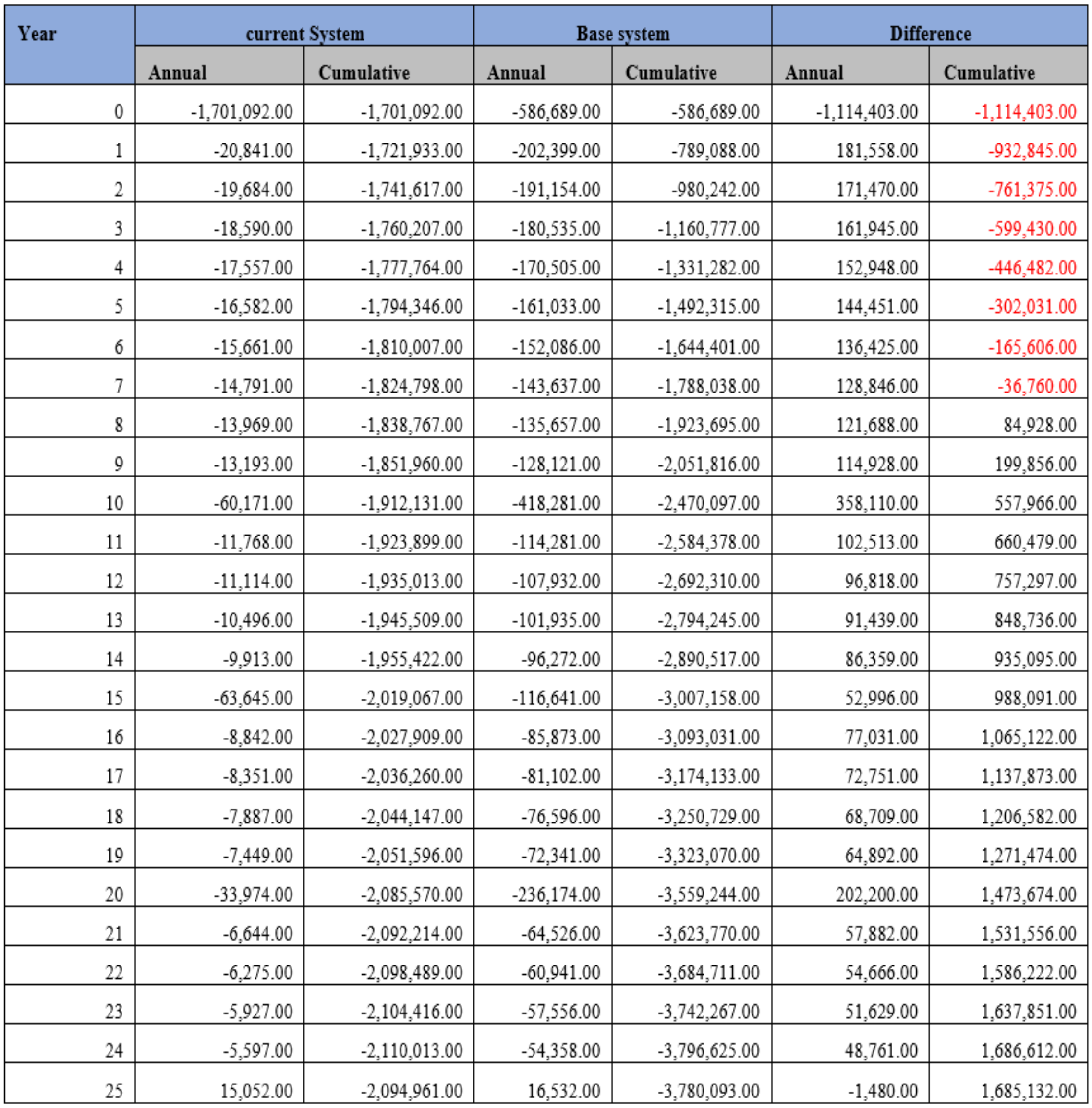
The project yield NPV of $495,431.74 which indicate an acceptable investment. NPV analysis results indicate the comparison between present value of cash inflows and outflows in relation to the project investment. Positive NPV values are acceptable by investors as a viable project.

4.3.8 Internal Rate of Return (IRR)

The project yield IRR of 18.5% over the 25-year period which makes the project an acceptable investment. Most investors prefer IRR greater than 15% to be considered as viable, therefore, higher IRR means greater the rate of return.

4.3.9 Return on Investment (ROI)

The project yield ROI of 15.5%. Analysing the cash flow in Table 31, shows between year 7- 8, the payment for the project has been made and the project starts accumulating income which confirms payback period. This will also highlight the payback period and total financial savings for using solar PV system.



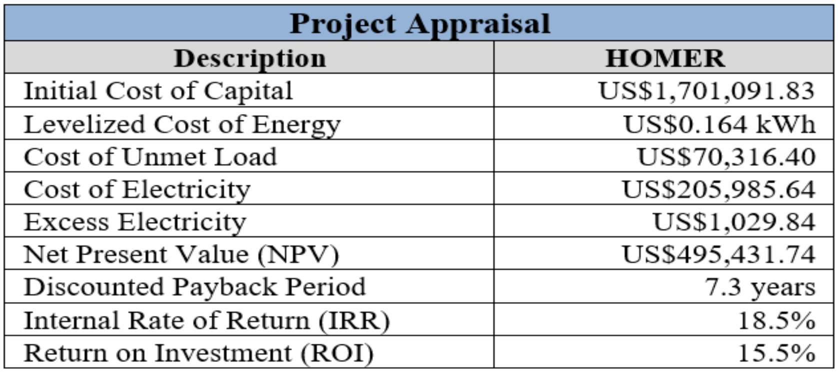
Year	current System		Base system		Difference	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
0	-1,701,092.00	-1,701,092.00	-586,689.00	-586,689.00	-1,114,403.00	-1,114,403.00
1	-20,841.00	-1,721,933.00	-202,399.00	-789,088.00	181,558.00	-932,845.00
2	-19,684.00	-1,741,617.00	-191,154.00	-980,242.00	171,470.00	-761,375.00
3	-18,590.00	-1,760,207.00	-180,535.00	-1,160,777.00	161,945.00	-599,430.00
4	-17,557.00	-1,777,764.00	-170,505.00	-1,331,282.00	152,948.00	-446,482.00
5	-16,582.00	-1,794,346.00	-161,033.00	-1,492,315.00	144,451.00	-302,031.00
6	-15,661.00	-1,810,007.00	-152,086.00	-1,644,401.00	136,425.00	-165,606.00
7	-14,791.00	-1,824,798.00	-143,637.00	-1,788,038.00	128,846.00	-36,760.00
8	-13,969.00	-1,838,767.00	-135,657.00	-1,923,695.00	121,688.00	84,928.00
9	-13,193.00	-1,851,960.00	-128,121.00	-2,051,816.00	114,928.00	199,856.00
10	-60,171.00	-1,912,131.00	-418,281.00	-2,470,097.00	358,110.00	557,966.00
11	-11,768.00	-1,923,899.00	-114,281.00	-2,584,378.00	102,513.00	660,479.00
12	-11,114.00	-1,935,013.00	-107,932.00	-2,692,310.00	96,818.00	757,297.00
13	-10,496.00	-1,945,509.00	-101,935.00	-2,794,245.00	91,439.00	848,736.00
14	-9,913.00	-1,955,422.00	-96,272.00	-2,890,517.00	86,359.00	935,095.00
15	-63,645.00	-2,019,067.00	-116,641.00	-3,007,158.00	52,996.00	988,091.00
16	-8,842.00	-2,027,909.00	-85,873.00	-3,093,031.00	77,031.00	1,065,122.00
17	-8,351.00	-2,036,260.00	-81,102.00	-3,174,133.00	72,751.00	1,137,873.00
18	-7,887.00	-2,044,147.00	-76,596.00	-3,250,729.00	68,709.00	1,206,582.00
19	-7,449.00	-2,051,596.00	-72,341.00	-3,323,070.00	64,892.00	1,271,474.00
20	-33,974.00	-2,085,570.00	-236,174.00	-3,559,244.00	202,200.00	1,473,674.00
21	-6,644.00	-2,092,214.00	-64,526.00	-3,623,770.00	57,882.00	1,531,556.00
22	-6,275.00	-2,098,489.00	-60,941.00	-3,684,711.00	54,666.00	1,586,222.00
23	-5,927.00	-2,104,416.00	-57,556.00	-3,742,267.00	51,629.00	1,637,851.00
24	-5,597.00	-2,110,013.00	-54,358.00	-3,796,625.00	48,761.00	1,686,612.00
25	15,052.00	-2,094,961.00	16,532.00	-3,780,093.00	-1,480.00	1,685,132.00

Table 31: 25 year Cash Flow Projection

4.4 Port Castries Investment Decision

The project provides both qualitative and quantitative methods of appraising the proposed model for management decision. The model consists of two cases, lean enterprise/solar

PV system only or combination where investment decision would be based on cost. Table 32 summarizes the project appraisal for solar PV system.



Project Appraisal

Description	HOMER
Initial Cost of Capital	US$1,701,091.83
Levelized Cost of Energy	US$0.164 kWh
Cost of Unmet Load	US$70,316.40
Cost of Electricity	US$205,985.64
Excess Electricity	US$1,029.84
Net Present Value (NPV)	US$495,431.74
Discounted Payback Period	7.3 years
Internal Rate of Return (IRR)	18.5%
Return on Investment (ROI)	15.5%

Table 32:Summary of Project Appraisal (Author, 2018)

Lean value stream mapping was used for workplace optimization to identify wastes and subsequent elimination for process improvements. HOMER software was utilized providing sensitivity analysis and optimization for solar PV system appraisal using NPV, IRR and payback period. The results indicated a viable project with IRR >15%, positive NPV or >0 and payback period of 7.3 years combined with other decision factors. Due to financial constraints and cost of solar PV system, Lean would be the preferred option for Port Castries. Lean implementation demonstrates improvements in operations processes to provide value to customers with cost savings benefit that is realized in short-term and long-term planning. Therefore, this investment decision is based on cost and does not require multiple attributes decision-making process as related to trade-offs. With one model consisting of two unique components combined would be sufficient in providing management with the necessary information for investment decision.

CHAPTER SIX: CONCLUSION AND FURTHER RESEARCH

This chapter presents a summary of the proposed model for Port Castries consisting of Lean approach and solar PV system. Both pillars if implemented would achieve cost benefits, improve processes, reduce environmental impact and increase energy efficiency and security. Recommendation would be made on the two scenarios as to implementation procedures, development of energy policy and future research.

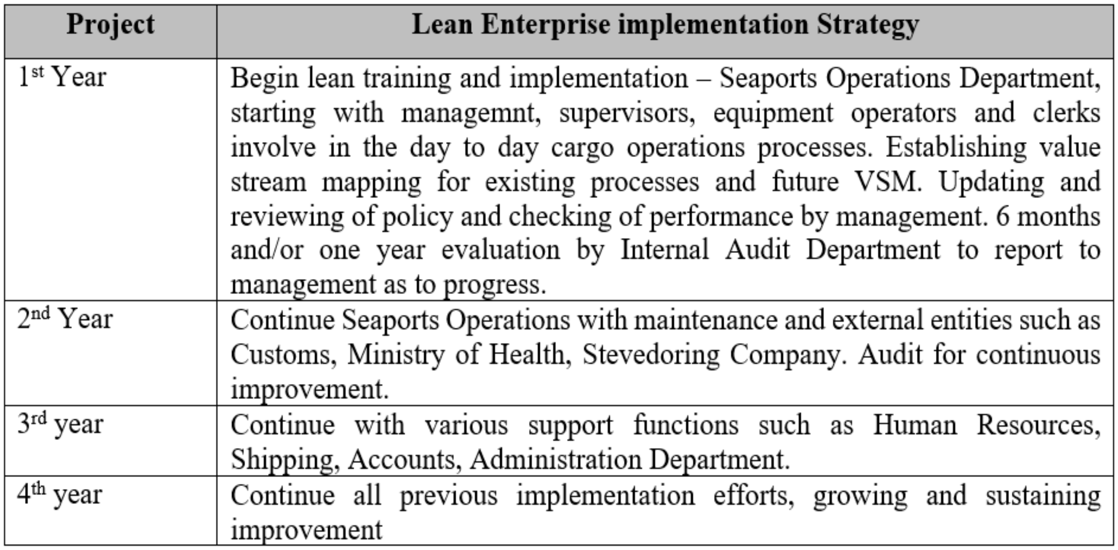
5.1 CONCLUSION

Saint Lucia is highly dependent on the importation of fossil fuels for electricity generation which makes the country vulnerable to fuel price volatility. Saint Lucia has the potential to generate electricity from renewable energy sources such as wind, solar and geothermal. However, this research is focused on the installation of only solar PV technology in Port Castries for energy efficiency and security. Wind and geothermal was not included due cost and location of the port. The second aspect of the model is to improve Port Castries competitiveness by implementing lean concepts for workplace optimization. Combining of the two requires financial investment where lean requires marginal investment for training of employees whilst solar PV requires substantial up-front investment. The competitiveness of ports no longer depends on price but on the quality of service based on speed, reliability, flexibility, efficiency and availability. Therefore, having a lean and green port, where customer satisfaction is paramount is a tool for gaining competitive advantage.

Firstly, lean approach was used to assess workplace optimization level by identifying wastes in the existing processes for continuous improvement and just-in-time service delivery to accommodate customers’ demand. VSM were selected as the applicable tool to evaluate ship arrival, berthing, yard and gate operations processes. The inefficiencies were identified within each process, outlined in the objectives. VSM was conducted on current state consisting of step by step flow of the processes to identify waste and subsequently eliminate, where countermeasures were developed. The results show that wastes were found in all areas from handling equipment to capacity and competencies of employees. Future value streams created where standard operating procedure would be developed for activities and resource efficiency. Takt time was calculated regarding customer demand per day on container, general cargo and RORO operations to identify the pace across the different processes. The result indicated low productivity and under-utilization of equipment, example 5.37 minute per move for container which is relatively low for a small port with capacity of 400TEUs. Furthermore, the result indicated the capabilities of the equipment operators, layout of terminal in relation to distance from berth to storage yard and number of equipment also cause delays and inefficiencies in the process. However, lack of process flow hinders decision, thus, having processes taking more time and steps to reach the ultimate goal of satisfying the customer. Therefore, calculating takt time would assist management to determine training needs of employees to reach the required standard to carry out their duties effectively.

Management adopting lean would encourage smooth process flows, providing quality of service to the customer. Management needs to set the pace as to training, motivating and encouraging employees regarding the big picture by setting real-time targets. Moreover, lean tool “kaizen” would provide the activities for employees’ participation and feedback in the implementation process for a culture of continuous improvement. This would assist management in creating SOPs and appointment of lean leaders for each process. Review of lean implementation plan is essential to ensure objectives are attainable by use of internal and/or external audit to ensure effectiveness of operations. Management adopting lean would result in smooth flows of processes throughout the entire operations. Implementing lean not only improve processes but creates a culture of understanding necessary in being responsive to customers' needs and further elimination of process waste.

Table 30 provided a strategy for Lean Enterprise implementation in Port Castries for a 4-year period. The proposed strategic plan should not be considered as the destination point but long-term initiative for continuous improvement in processes to meet customer demand.



Project	Lean Enterprise implementation Strategy
1st Year	Begin lean training and implementation – Seaports Operations Department, starting with managemnt, supervisors, equipment operators and clerks involve in the day to day cargo operations processes. Establishing value stream mapping for existing processes and future VSM. Updating and reviewing of policy and checking of performance by management. 6 months and/or one year evaluation by Internal Audit Department to report to management as to progress.
2nd Year	Continue Seaports Operations with maintenance and external entities such as Customs, Ministry of Health, Stevedoring Company. Audit for continuous improvement.
3rd year	Continue with various support functions such as Human Resources, Shipping, Accounts, Administration Department.
4th year	Continue all previous implementation efforts, growing and sustaining improvement

Table 33 Recommendation for Lean Implementation (Author, 2018)

Secondly, the research demonstrates installation of solar PV system for electricity generation in Port Castries to partially meet the energy demand and to reduce electricity bill and consumption. The selected optimal hybrid system with stand test condition (STC) power rating of 260W combined with supporting battery bank and converter. The LCOE is US$0.164 kWh which is less than grid of US$0.28 kWh. The project yields positive NPV or >0 and IRR of 18.5%, >15%, indicating a viable investment. Furthermore, payback period of 7.3 years shows potential savings to be realized in the near future. The unmet and excess electricity figures of 231,130 kWh/y and 3678 kWh/y is an indication of solar PV system generating only 75% power to the port whilst 25% is purchased from the grid. Since the port is state-owned, government intervention is required by amending legislation for higher percentage of electricity generation from renewables. Meanwhile, the port needs to provide an eco-friendly environment conducive to all port customers by creating and implementing energy policy based on ISO 50001 EnMS standard. This policy would serve as a guide for future energy needs and focus on the port target to reduce emission by 20% in line with Saint Lucia's commitment for 2030. The energy demand would be satisfied with marginal investment whilst awaiting finance for the PV system. A policy that encourages energy efficiency combined with lean techniques would ensure a successful port with improve processes, reduce environmental impacts and increase energy security and efficiency.

Implementation process of the proposed model is based on affordability versus performance improvement. At this point, the port faces financial difficulties where cost is the main factor in the selection lean over solar PV system. The implementation of lean enterprise is the best available option for short-term strategic planning. However, for the growth and development of the port and competitive advantage, further reduction is required for future investment in equipment, upgrade IT system and expansion. For long-term investment plan, Port Castries should invest in the combination case in two phases with lean enterprise implemented first, followed by solar PV system with financial backup from Saint Lucia Government and agencies that support green initiatives such as U.S. Department of Energy and Rocky Mountain Institute-Carbon War Room.

5.2 FURTHER RESEARCH

The research focused on two aspects namely proposed implementation of lean enterprise techniques and installation of solar PV system. The study examined lean technique of value stream mapping for optimization of seaports' operations processes to eliminate waste and finding optimal solutions for improvements. In-depth study of other lean tools mentioned in the methodology can be used or combined with lean tools gearing towards more efficient operations. Also, further investigations are required in lean enterprise in the support functions such as maintenance, accounts and IT department. This is critical in being proactive in scheduling maintenance of handling equipment to avoid breakdown and for easy flow of information and material resources. Expanding this study, to integrate lean techniques throughout the entire seaports processes and functions would be fruitful in providing value to customers and future benefits to the ports. Furthermore, cost saving associated with implementation of lean techniques were not dealt with in this study and would be essential in providing management with financial benefits for decision-making and acceptance of the investment. The research focused on ship arrival, berth, yard and gate processes and did not include hinterland connectivity. Stakeholders' involvement was briefly mentioned but require a more in-depth analysis for smooth flow of processes and finding optimal solutions for providing value to customers.

Furthermore, the researchers assessed the potential of solar PV systems with battery bank and converter to generate electricity in Port Castries. This can be expanded by investigating other renewable energy sources available in Saint Lucia such as wind and geothermal. Other analysis could be carried out on hybrid systems with or without national grid focusing on the removal of barriers by amending legislation for future cost savings, energy efficiency and security and reduction of environmental impact.

References

Acciaro, M., Ghiara, H., & Cusano, M. I. (2014). Energy management in seaports: A new role for port authorities. *Energy Policy*, *71*, 4-12.

Allen, J. S., (2013). Principles of Energy Conservation: Part 4 Energy Economics, 2-24.

Bicheno, J., & Holweg, M. (2016): The Lean Toolbox, 5th edition. A handbook for lean transformation. Retrieved from https://www.researchgate.net/publication/309012216

Bortolotti, T., Boscari, S., & Danese, P. (2015). *Successful lean implementation: Organizational culture and soft lean practices* doi://doi.org/10.1016/j.ijpe.2014.10.013

Boyle, G. (2004). Renewable energy. *Renewable Energy, by Edited by Godfrey Boyle, pp. 456. Oxford University Press, May 2004. ISBN-10: 0199261784. ISBN-13: 9780199261789*, 456.

Brigham, E. F., & Houston, J. F. (2004). *Fundamentals of Financial Management, 10th ed., United States: South-Western Thomson Learning*.

Caribbean Development Bank (2016). Transforming The Caribbean Port Services Industry: Towards the Efficiency Frontier. Retrieved from http://www.caribank.org/wp-content/uploads/2016/05/Study_Transformation-of-Caribbean-Maritime-Port-Services-Industry.pdf

Clarkson (2018): Shipping Intelligence Network Time Series. Retrieved from https://sin.clarksons.net/Timeseries?h=979&p=118

Ciolkosz, D. (2017): Penn State Extension, Renewable Energy. Retrieved from https://extension.psu.edu/what-is-renewable-energy

Corona Energy (2015). How to Calculate your CO_2 Emission: Electricity. Retrieve from https://www.coronaenergy.co.uk/how-to-calculate-co2-emissions/

Devabhaktuni, V., Alam, M., Shekara Sreenadh Reddy Depuru, Soma, Green, R. C., Nims, D., & Near, C. (2013a). *Solar energy: Trends and enabling technologies* doi://doi.org/10.1016/j.rser.2012.11.024

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). *Renewable energy resources: Current status, future prospects and their enabling technology* doi://doi.org/10.1016/j.rser.2014.07.113

Emanuel, E., Gomes, C. (2014). An assessment of mechanisms to improve energy efficiency in the transport sector in Grenada, Saint Lucia and Saint Vincent and the Grenadines. Retrieved from http://200.9.3.98/bitstream/handle/11362/37257/S1420560_en.pdf?sequence=1&isAllowed=y

Franzen, S., & Streling L. (2017). Value Stream Mapping of Container Flows at Seaports - A case study of four seaport container terminals Report No. E 2017:013. Retrieved from http://publications.lib.chalmers.se/records/fulltext/251033/251033.pdf

Frazer, K. (2015). Using lean principles to drive operational improvements in intermodal container facilities A conceptual framework. Retrieved from https://www.researchgate.net/publication/279181942

Fullerton, R. R., Kennedy, F. A., & Widener, S. K. (2014). *Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices* doi://doi.org/10.1016/j.jom.2014.09.002

Geerlings, H., & van Duin, R. (2011). *A new method for assessing CO2-emissions from container terminals: A promising approach applied in Rotterdam* doi://doi.org/10.1016/j.jclepro.2010.10.012

Government of Saint Lucia, (2017) Saint Lucia Energy Transition Strategy and Integrated Resource Plan. Retrieved from http://www.govt.lc/media.govt.lc/www/resources/publications/saint-lucia-nets-executive-summary-final.pdf

Haraksingh, I., & Koon, R. (2011). A Conceptual Model for Geothermal Energy Investigation with Emphasis on the Caribbean. Retrieved from https://www.researchgate.net/publication/228894854/download

Hentschel, M., Ketter, W., & Collins, J. (2018). *Renewable energy cooperatives: Facilitating the energy transition at the port of Rotterdam* doi://doi.org/10.1016/j.enpol.2018.06.014

Herzog, A. V., Lipman, T. E., & Kammen, D. M. (2001). Renewable energy sources. *Encyclopaedia of Life Support Systems (EOLSS). Forerunner Volume: 'Perspectives and Overview of Life Support Systems and Sustainable Development*.

Howell, M. T. (2014). *Effective implementation of an ISO 50001 energy management* *system (EnMS)*. ASQ Quality Press.

International Energy Agency (2017): Renewables Retrieved from https://www.iea.org/renewables/

International Energy Agency (2014): Technology Roadmap Solar Photovoltaic Energy, 2014 Edition. Retrieved from https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

International Energy Agency (2013): Technology Roadmap Wind Energy. Retrieved from https://webstore.iea.org/technology-roadmap-wind-energy-2013

International Energy Agency (2007): Contribution of Renewables to Energy Security: Information Paper. Retrieved from https://www.iea.org/publications/freepublications/publication/so_contribution.pdf

International Maritime Organization (2014). GHG3 Executive Summary and Report. Retrieved from http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf

International Renewable Energy Agency (IRENA) (2017). Electricity Storage and Renewables: Cost and Market 2030. Retrieved from http://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets

International Renewable Energy Agency (IRENA) (2017). Planning for the Renewable Future: Long-term Modelling and Tools to Expand Variable Renewable Power in Emerging Economies. Retrieved from http://biblioteca.olade.org/opac-tmpl/Documentos/cg00543.pdf

International Standard Organisation (2018). ISO 50001 Energy Management; ISO 14001 Environmental Management. Retrieved from https://www.iso.org/home.html

Joselin Herbert, G. M., Iniyan, S., Sreevalsan, E., & Rajapandian, S. (2007). *A review of wind energy technologies* doi://doi.org/10.1016/j.rser.2005.08.004

Kaldellis, J. K., & Zafirakis, D. (2011). *The wind energy (r)evolution: A short review of a long history* doi://doi.org/10.1016/j.renene.2011.01.002

Kuang, Y., Zhang, Y., Zhou, B., Li, C., Cao, Y., Li, L., & Zeng, L. (2016). A review of renewable energy utilization in islands. *Renewable and Sustainable Energy Reviews*, *59*, 504-513. Retrieved from http://www.reegle.info/policy-and-regulatory-overviews/LC

Kumar, Y., Ringenberg, J., Depuru, S., Devabhaktuni, V. K., Lee, J., Nikolaidis, E., Afjeh, A. (2016). *Wind energy: Trends and enabling technologies* doi://doi.org/10.1016/j.rser.2015.07.200

Lang N., Veenstra A., (2009). A quantitative analysis of container vessel arrival planning strategies Retrieved from https://link.springer.com/content/pdf/10.1007/s00291-009-0186-3.pdf

Low-Carbon Communities in the Caribbean(LCCC) (2012). Energy Policy and Sector Analysis in the Caribbean 2010-2011. Retrieved from http://www.oas.org/en/sedi/dsd/energy/doc/lccc_report.pdf

Loyd, N. (2007). Application of Lean Enterprise and Six Sigma as an Amalgamated Improvement Strategy. *Lean Management: Concepts and Industry Perspectives*, 23-48.

Loyd, N., Jennings, L. C., Siniard, J., Spayd, M. L., Holden, A., & Rittenhouse, G. (2009). Application of Lean Enterprise to Improve Seaport Operations. Transportation Research Record: Journal of the Transportation Research Board, 2100(-1), 29-37. doi: 10.3141/2100-04.

Loyd, N., & Siniard, J., (2009). Modern Continuous Improvement Methods to Improve Seaport Velocity and Productivity. Retrieved from http://aapa.files.cms-plus.com/PDFs/09MTMT_Loyd_Siniard.pdf

Lovelle, J. (2001). Mapping the value stream. *IIE solutions*, *33*(2), 26-33.

Lund, J. W., & Boyd, T. L. (2016). Direct utilization of geothermal energy 2015 worldwide review. *Geothermics*, *60*, 66-93.

Marlow, P. B., & Paixão Casaca, A. C. (2003). *Measuring lean ports performance* doi://doi.org/10.1016/j.ijtm.2003.12.002

Mahesh, A., & Sandhu, K. S. (2015). Hybrid wind/photovoltaic energy system developments: Critical review and findings. *Renewable and Sustainable Energy Reviews*, *52*, 1135-1147.

Moon, D. (2018). Port Management 2018 Lecture notes, World Maritime University.

Mostafa, S., Dumrak, J., & Soltan, H. (2015). *Lean maintenance roadmap*doi://doi.org/10.1016/j.promfg.2015.07.076

National Renewable Energy Laboratory (NREL), (2015). Energy transition Initiative: Island Energy Snapshot St. Lucia (Fact Sheet). https://www.nrel.gov/docs/fy15osti/62688.pdf

National Utility Regulatory Commission (2016). Application Procedure for Solar PV Generation. Retrieved from http://nurc.org.lc/

Och, A., Konold, M., Auth, K., Musolino, E., & Killeen P. (2015). Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS) Baseline Report and Assessment. Retrieved from http://www.worldwatch.org/system/files/C-SERMS_Full_PDF.pdf

Ölçer, A., & Ballini, F. (2015). *The development of a decision making framework for evaluating the trade-off solutions of cleaner seaborne transportation* doi://doi.org/10.1016/j.trd.2015.04.023

Ölçer, A. I., Kitada, M., Dalaklis, D., & Ballini, F. (Eds.). (2018). *Trends and Challenges in Maritime Energy Management* (Vol. 6). Springer.

O'Shaughnessy, E., Cutler, D., Ardani, K., & Margolis, R. (2018). *Solar plus: Optimization of distributed solar PV through battery storage and dispatchable load in residential buildings* doi://doi.org/10.1016/j.apenergy.2017.12.118

Ouyang, X., & Lin, B. (2014). *Levelized cost of electricity (LCOE) of renewable energies and required subsidies in china* doi://doi.org/10.1016/j.enpol.2014.03.030

Painuly, J. P. (2001a). *Barriers to renewable energy penetration; a framework for analysis*doi://doi.org/10.1016/S0960-1481(00)00186-5

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011b). *Role of renewable energy sources in environmental protection: A review* doi://doi.org/10.1016/j.rser.2010.11.037

Park, R., & De, P. (2015). An alternative approach to efficiency measurement of seaports. *Port management* (pp. 273-292) Springer.

Pawel, I. (2014). *The cost of storage – how to calculate the levelized cost of stored energy (LCOE) and applications to renewable energy generation* doi://doi.org/10.1016/j.egypro.2014.01.159

Pereira, R. (2008). Takt Time Calculation. Retrieved from https://blog.gembaacademy.com/2008/09/28/free-takt-time-video-and-calculator/

Rehman, S., Bader, M. A., & Al-Moallem, S. A. (2007). *Cost of solar energy generated using PV panels* doi://doi.org/10.1016/j.rser.2006.03.005

Ren, J., & Lützen, M. (2017). *Selection of sustainable alternative energy source for shipping: Multi-criteria decision making under incomplete information* doi://doi.org/10.1016/j.rser.2017.03.057

Renewable Energy Caribbean (2017). The Latest Industry News and Analysis on Clean Energy in the Caribbean. Retrieved from https://renewableenergycaribbean.com/2017/08/07/recent-initiatives-on-saint-lucia/

REN21 (2017). Advancing The Global Renewable Energy Transition. Retrieved from http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_-Highlights.pdf

Saint Lucia Air and Sea Ports Authority (SLASPA) Act (2001). Chapter 8.13 Revised Edition showing law as at 31 December 2001.

Saint Lucia Air and Sea Ports Authority (SLASPA), (2017): Background. http://www.slaspa.com/contentPages/view/background

Saint Lucia Air and Sea Ports Authority (SLASPA), (2015): Handbook and Directory 2013 – 2015: http://www.meridian-ebooks.com/stluciabook/files/assets/common/downloads/publication.pdf

Saint Lucia Electricity Company Ltd. (LUCELEC), (2018). 3 MW Solar Farm Now Feeding LUCELEC Grid. Retrieved from http://www.lucelec.com/content/3-mw-solar-farm-now-feeding-lucelec-grid

Saint Lucia National Energy Policy (2010). Retrieved from http://www.oas.org/en/sedi/dsd/Energy/Doc/NEP_StLucia_web.pdf

Sani Hassan, A., Cipcigan, L., & Jenkins, N. (2017). *Optimal battery storage operation for PV systems with tariff incentives* doi://doi.org/10.1016/j.apenergy.2017.06.043

Siemens Annual Report (2017). Innovative Power Distribution for Ports & Harbours: Concept for Profitable and Safe Electric Power Distribution. Retrieved from https://w3.siemens.com/powerdistribution/global/EN/consultant-support/download-center/tabcardpages/Documents/Planning-Manuals/Innovative-Power-Distribution-for-Ports-and-Harbors.pdf

Sullivan, W. G., McDonald, T. N., & Van Aken, E. M. (2002). *Equipment replacement decisions and lean manufacturing* oi://doi.org/10.1016/S0736-5845(02)00016-9

Talesun (2018). Talesun Solar 260TP660M 260 Retrieved from https://www.talesun-eu.com/products/

UNCTAD (2017). Review of Maritime Transport 2017: Ports Retrieved from http://unctad.org/en/PublicationsLibrary/rmt2017_en.pdf

US EPA (2017). The Social Cost of Carbon. Retrieved from https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

US EPA (2017). The Lean and Environment Toolkit. Retrieved from https://www.epa.gov/sites/production/files/2013-10/documents/leanenvirotoolkit.pdf

Verbruggen, A., Fischedick, M., Moomaw, W., Weir, T., Nadaï, A., Nilsson, L. J., Sathaye, J. (2010). *Renewable energy costs, potentials, barriers: Conceptual issues* doi://doi.org/10.1016/j.enpol.2009.10.03

Womack, J., & Jones, D. (2003). Lean Thinking, Banish Waste and Create Wealth in Your Corporation (rev.). Free Press.

World Bank (2018). Saint Lucia. Retrieved from https://data.worldbank.org/country/st-lucia

World Population Review (2018). Saint Lucia Population 2018. Retrieved August 5, 2018 from http://worldpopulationreview.com/countries/saint-lucia-population/

Yang, M. G. (., Hong, P., & Modi, S. B. (2011). *Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms* doi://doi.org/10.1016/j.ijpe.2010.10.017