



**A STUDY OF THE IMPACT OF PORT AUTOMATION IN SINGAPORE FOR
INCREASING COMPETITIVENESS.**

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International Shipping and Logistics Group
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Module:	MAR328
Submitted by:	Tan Jia Qi
Student number:	10564289
Supervisor:	Dr. Irina Neaga
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Abstract

In this new era of maritime trends and practices, innovative solutions of fusing information and communications technology such as optimizations with engineering solutions like robotics and automation in container handling operations are the trend. Even though the global economic has slowdown, there is a longer-term growth potential for Port of Singapore through mitigating its current challenges. Singapore will take the business forward for greater success and competitiveness with digital and automation transformation of the Tuas mega port in preparation for the future.

This research will analyse the current challenges faced by Port of Singapore. Secondary data are collected from academic journals, government databases and technology publications. Codes are identified and classified under different themes for thematic analysis. The benefits and drawbacks of automation is examined based on the factors affecting port competitiveness to evaluate the feasibility of automation in Singapore.

The conclusion of this research will give an emphasis on the importance of automation for boosting the competitiveness of Port of Singapore through addressing its challenges. As technology is gradually but constantly infused into daily lives and businesses, Singapore has to create a mindset and culture that embraces new innovations which will raise productivity, safety, environmental sustainability, service quality and reduce labour intensity. Hence, Singapore's automation investment will produce beneficial results and not lose out to competition when Tuas mega port is finalized.

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List of Abbreviations

Maritime and Port Authority of Singapore	MPA
Twenty-foot equivalent units	TEU
Automated Guided Vehicles	AGV
Port of Tanjung Pelepas	PTP
Automated Stacking Crane	ASC
Rubber Tyred Gantry	RTG
Rail Mounted Gantry	RMG
Electric Rail Mounted Gantry	E-RTG
Pasir Panjang Terminal	PPT
Shuttle Carrier	SC
Computer Integrated Terminal Operation System	CITOS
International Marine Centre	IMC

1. Introduction

Port of Singapore is the World's busiest container transshipment hub which is operated by PSA Corporation. In this new era of mega-sized vessels, powerful shipping alliances and intense regional competition, the port productivity of Singapore was lagging as compared to its rival competitors. There is a need to improve on the situation of large labour intensiveness and also the less automated terminals in Singapore (Tan, 2015).

To maintain Singapore's attractiveness as a global hub port, PSA continues to invest in terminal infrastructure, equipment and technology ahead of demand and ensures that Singapore Port remains highly efficient and competitive (PSA, 2017a). However, in 2014, Singapore's container port moved an average of 66 containers per hour per ship, while its geographically closest rival, the Port of Tanjung Pelepas (PTP) in south-western Johor in Malaysia, racked up an average of 81 (Tan, 2015). Therefore, Port of Singapore invested in Automated Guided Vehicle (AGV) in 2016, as a preparation to develop port technology solutions for the future automated Tuas terminal to increase competitiveness (PSA, 2016b).

Port automation provides three strategic needs which are, improvement in operational performance, increase of safety and security, and contribution to environmental sustainability (Martín-Soberón et al., 2014). It is important to improve efficiency and productivity to handle large amounts of cargo daily as well as to reduce operational cost to stay competitive (Yin et al., 2011). According to the Maritime and Port Authority of Singapore (MPA), Singapore's Tuas terminal is 20% completed and Phase 1 of development is estimated to be finished by 2020 (Loh, 2016).

Port of Singapore also faces challenges such as overcapacity, lacklustre trade, lack of manpower, competition from neighbouring ports and mega-alliances calling at Singapore port (The Business Times, 2016; PSA, 2016a). In 2015, container throughput declined to 30.9 million twenty-foot equivalent units (TEUs) of containers that passed through the port. It was the lowest container throughput volume since 2011, when 29.9 million TEUs passed through Singapore's port (The Economist, 2016).

Therefore, the purpose of this research is to analyse how Singapore strategically work with automation technologies to counter their challenges. It also aims to analyse how port automation increase the competitiveness of Port of Singapore through the future automated Tuas terminal.

1.1. Aim and Objectives

The study aims to analyse the impact of port automation for increasing Port of Singapore's competitiveness.

These are the following objectives:

1. To analyse the application of automation for ports and the features of Port of Singapore
2. To examine the advantages and disadvantages of port automation that influences the competitiveness of Port of Singapore
3. To investigate the present challenges faced by Singapore Port
4. To evaluate port automation as a solution for increasing Singapore's competitiveness against other competitors

1.2. Justification of Research

The handling of mega-ships is one of the key challenges faced by the shipping industry (Lim, 2015). Singapore is also facing the lack of land for development, port congestion as well as competition rising from neighbouring ports, in particular PTP (Cullinane et al., 2006). Since PTP has cost advantages over Singapore and also caused the overall container traffic to decrease in Singapore with Maersk moving over to PTP (Wright, 2008; Kleywegt et al., 2002).

Furthermore, investing in port technologies is a key element in Singapore port development in order to meet the challenges (PSA, 2016a). On top of that, PSA shows that they are planning forward through the Living Lab, which is to develop innovative and leading edge technology solutions for PSA's existing terminal operations in Singapore, as well as for the future Tuas terminal (Espina, 2016). Hence, the research would have a clearer view of the advantages and disadvantages of automation affecting Singapore's competitiveness.

1.3. Overview of Research

Chapter 2 contains a critical review of the relevant literature to create a better understanding of the topic. It highlights the concept of port automation, features of Singapore Port, levels of automation and the implications of automation for increasing competitiveness.

Chapter 3 identifies the methods and approaches used in this research which includes the research philosophy, approach, methodology choice, strategy, data collection and data analysis techniques, ethics and credibility of findings.

Chapter 4 presents the analysis and discussion on data collected. An analysis on the impacts of automation will be based on the factors affecting port competitiveness using thematic analysis. A discussion on how the research's objectives was met will be conducted.

Chapter 5 will give a conclusion to the research question and aim, the limitations of the research and identify any possible future studies.

2. Literature Review

A literature review gives a novel synthesis of existing work, which may lead to new ways of looking at a subject or identifying gaps in the literature (Easterby-Smith, 2008). For instance, very few published journal articles can be found on port automation of Singapore since it is a project in the future. Therefore, up-to-date information can be found mostly on news articles and news releases by corporates. PSA had foreseen the drop in their ranking and has been making changes by analysing challenges faced and thus the future Tuas port is armed with automation technology to counter them.

2.1. Concept of Port Automation

In this rapid changing society, the current trend of cargo handling in ports is to use increasingly specialized terminals that allow systematizing processes by utilizing massive automation devices for prosperity growth and well-being (Figueiredo, 2016). In shipping, navigation tasks can also be taken over by sophisticated systems (Konings et al., 2005). The increasing amount of intelligence used on both manned cranes and unmanned equipment is for improved safety, productivity and eco-efficiency (World Maritime News, 2016b). Fully automate container yards is one way of improving port efficiency as it reduces possible human mistakes that may occur (Yin et al., 2011). The level of efficiency in container handling procedures have profoundly affected the global economy (Peterson, 2015).

Port automation was first launched in Port of Rotterdam in 1993, it was equipped with Automated Stacking Crane (ASC) and Automated Guided Vehicles (AGV) which allowed the port to manage the handling of storage and interchange equipment respectively without operators (Martín-Soberón et al., 2014). Since then, there is a growing need for operators to invest in capabilities that reduce turnaround and waiting times for ships, and lessen cargo holding times (Kanno, 2014).

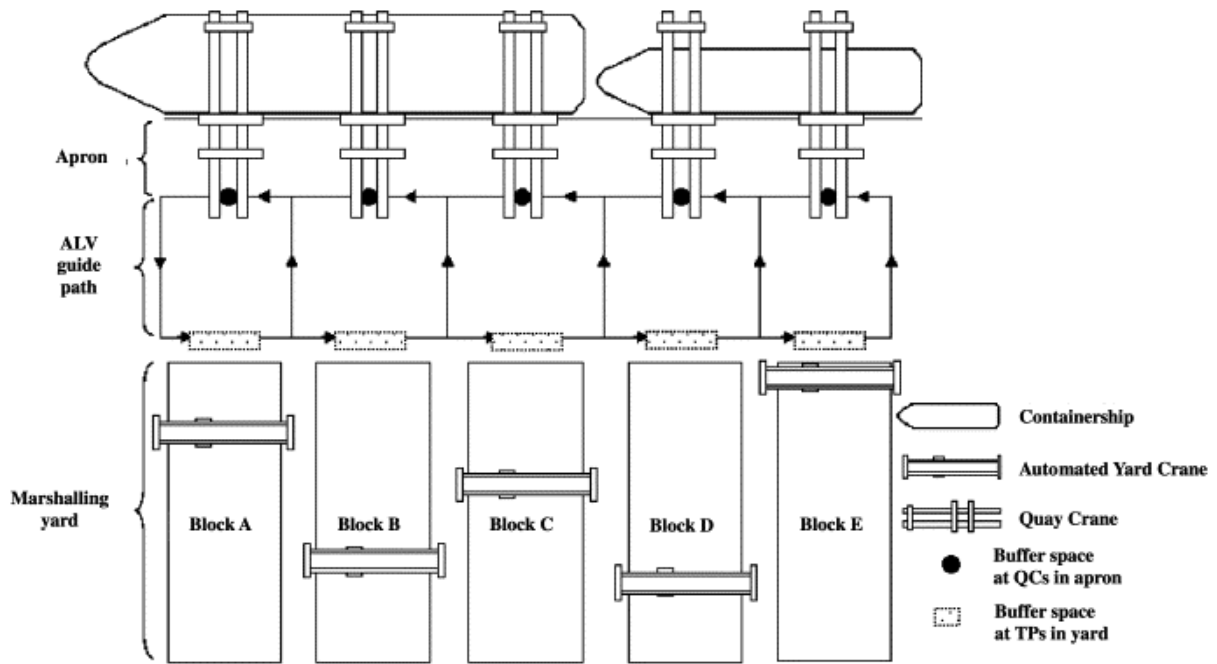


Figure 1: Layout of an automated terminal.

(Source: Nyugen and Kim, 2009)

In an automated terminal seen in Figure 1, the AGVs can start the journey with stroke and established operation, integrated with other equipment such as reach stackers, Rubber Tyred Gantry crane (RTG), Rail Mounted Gantry crane (RMG) transporters and quarry gantry cranes (Figueiredo, 2016).

2.2. Features of Port of Singapore

The reason for Singapore's existence is its port, hence it has to become more efficient, innovative and productive to stay ahead (Boh, 2016). Singapore moves towards consolidating all container operations at a new port in Tuas for maintaining its position as the world's top transshipment hub (Aggarwal, 2015). It also opens new opportunity for development of new technology to increase competitiveness. Due to the challenges of increasing in size of vessels, land constraints and competition from neighbouring ports, there is a need for the future Tuas port.

2.2.1. The future Tuas Port

MPA signed a S\$2.42 billion agreement for works on Tuas Terminal Phase 1 in 2015 (Channel NewsAsia, 2015). It will be developed in four phases over 30 years (Boh, 2016). This means that the terminals at Tanjong Pagar, Keppel and Brani, including

Pasir Panjang Terminal (PPT) 1 and 2 will be eventually merged at Tuas (BDP International, 2012). According to MPA, work had officially begun over half a year, the Phase 1 of Singapore's mega port terminal in Tuas is 20% completed and it will be finished on schedule by December 2020 seen in Figure 2 (Loh, 2016).



Figure 2: Design of the future Tuas Terminal.

(Source: The Maritime Executive, 2016)

Facilities at Tuas will allow 65 million standard-sized containers to be handled in a year (Woo, 2017). PSA, MPA, industry partners and institutes of higher learning are working closely to develop future technologies for Tuas Terminal (Aggarwal, 2015). The key features incorporated are to optimized land use, enhanced safety and security of port waters via advanced traffic management system and automated yard cranes (World Maritime News, 2016a). It is to raise productivity and reduce labour costs, also being able to cater to mega-vessels and the complex needs of shipping alliances. (Woo, 2017).

Operating 24/7, the AGVs invested by PSA will be used to transport containers between the quay side and the container yard completely without human drivers (PSA, 2016a). Traditional AGV systems use fixed guide-paths for vehicles whereas many modern AGVs are free-ranging, their preferred tracks are software programmed and can be changed relatively easily when new stations or flows are added (Le-Ahn and

De Koster, 2006). When completed, Tuas terminal will have a scale of operations larger than any port in the world, and AGVs will play a key part (Aggarwal, 2015).

2.2.2. Challenges faced by Singapore Port

2.2.2.1. Increasing in size of vessels

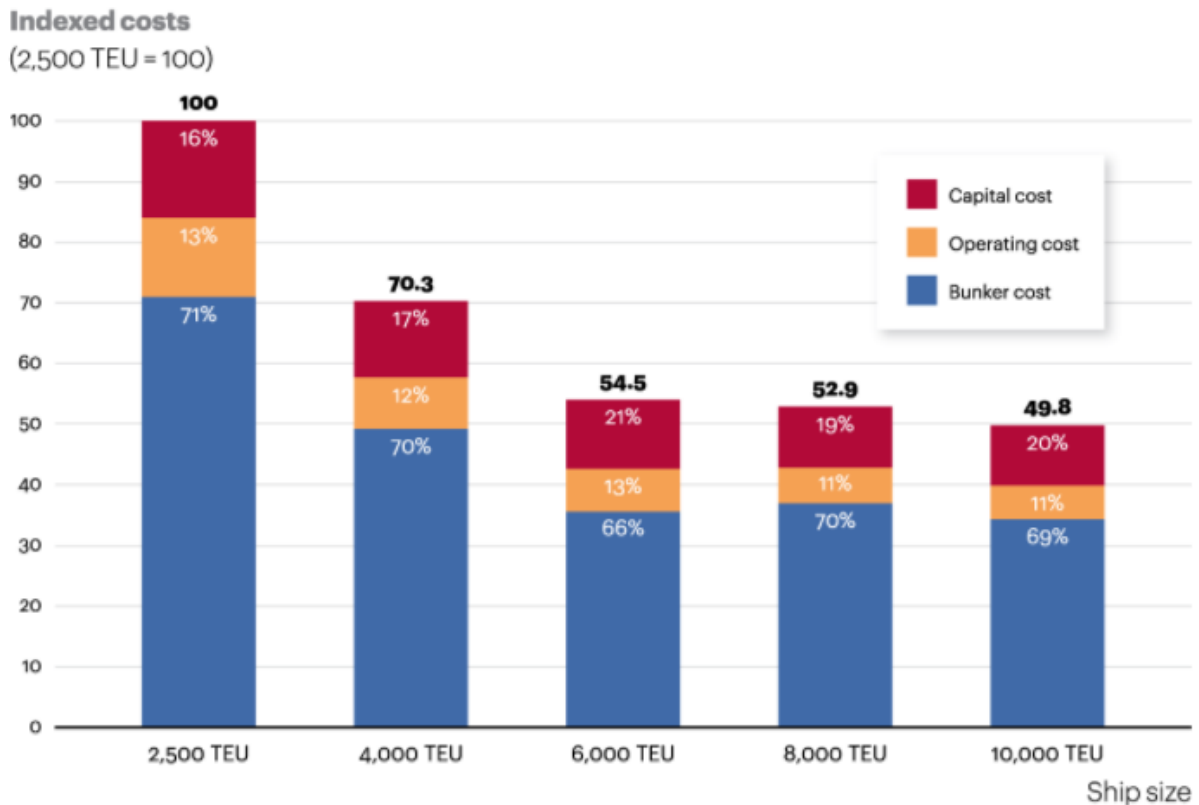


Figure 3: Bigger ships result in lower operating cost and higher capital cost

(Source: Drewry reports, 2012)

The recent developments in liner shipping is observed, productivity has been improved by using faster and larger ships as seen from the overall percentage decrease in operating and bunkering costs as size of ships increases in Figure 3 (Notteboom and Rodrigue, 2008). By deploying large container ships, the liner shipping companies can benefit from economies of scale in terms of ship size (Wang and Meng, 2012). Their efficient and speedy handling at the terminal directly influences the transit time and operational costs of mega ships (Stopford, 2009). Automation will speed up execution of container handling process, reducing errors and saving vessels' waiting time. Singapore Port has fully automated gantry cranes to handle mega ships with more precision (Hand, 2016). The average container handling time at port for a larger ship

may be lesser as compared to a smaller ship as more quay cranes can be deployed to serve larger ships (Wang and Meng, 2012).

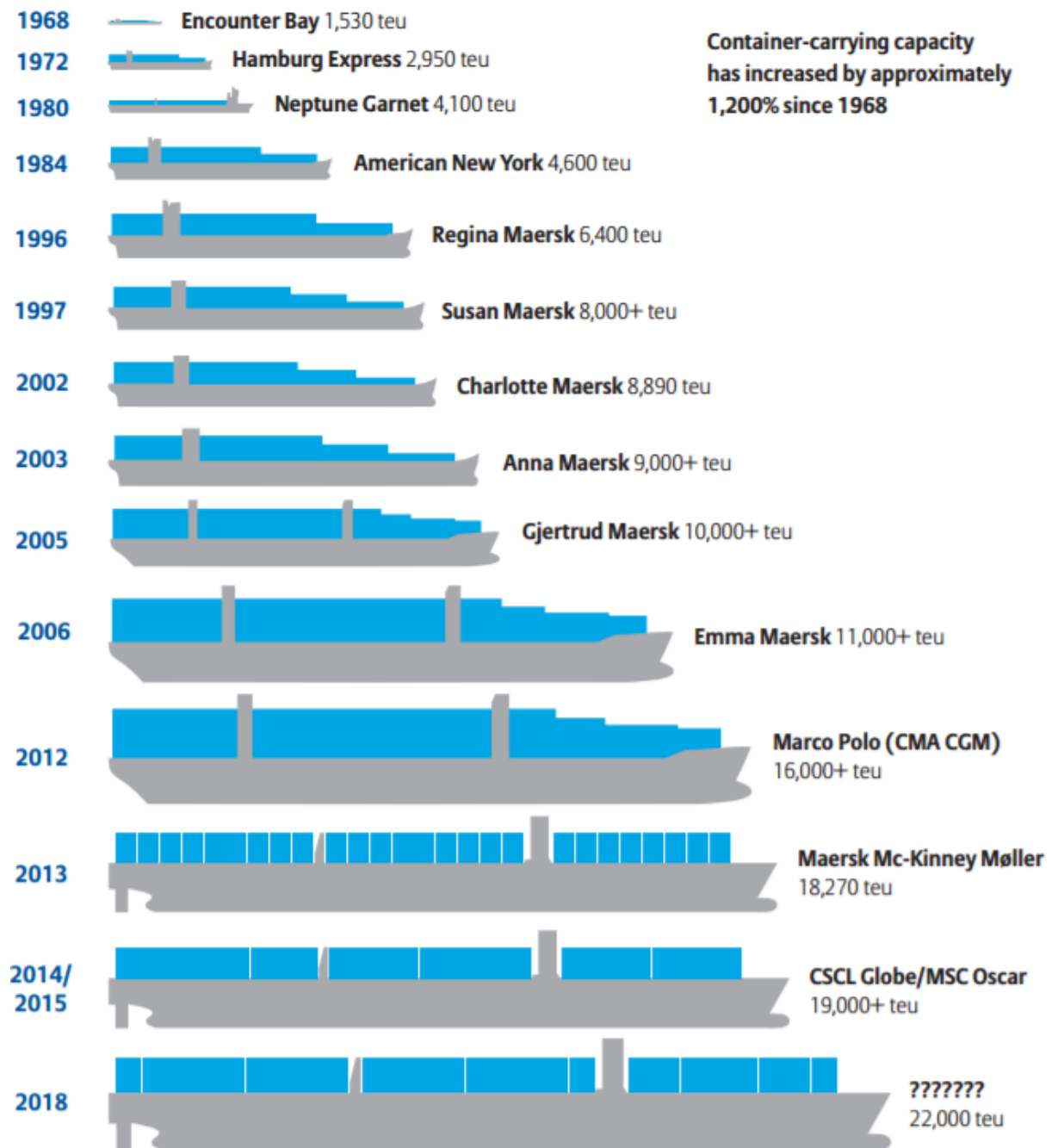


Figure 4: 50 years of container ship growth

(Source: Allianz Global Corporate & Specialty, 2015)

As seen in Figure 4, growth of ships is observed and ships as large as 22,000 TEU are expected to be in service as early as 2018 (Allianz, 2015). Mega ships discharge

huge loads at ports resulting in the need for larger port capacity, automated terminals serve as a solution since they get a boost in capacity (Schednet, 2017).

2.2.2.2. Land constraints

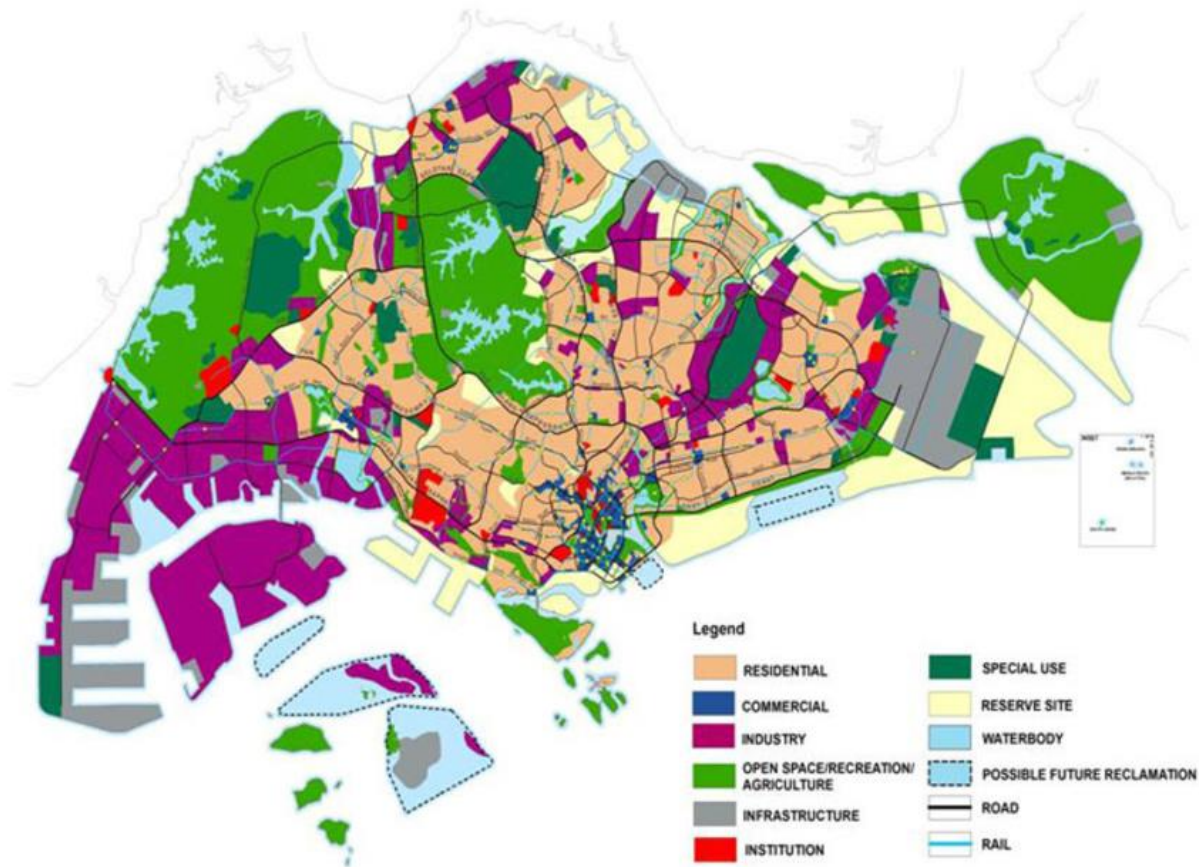


Figure 5: Singapore's possible land use allocation by 2030

(Source: MND Singapore, 2013)

Lack of land for expansion is one of the barriers faced by Singapore Port to increase competitiveness. In Figure 5, it shows the possible land use allocation by 2030, 19% will be used for transportation and global connectivity, the rest will be for residential uses and Singapore's defence needs (MND Singapore, 2013). There is an immense pressure to handle the surge of cargoes due to the increasing in size of vessels, however, many ports face land constraints making expansion not a feasible option to reduce the pressure (Yin et al. 2011).

Tuas mega port will be on reclaimed land and designated as a greenfield location (Wong, 2016; Tan, 2015). Singapore has to consider the cost of landfilling with sand, limited sea space and relations with neighbouring countries (LSH, 2011). So, to

increase land utilisation, Singapore is looking at the possibility of a two-tiered container terminal which will significantly increase the yard storage capacity and quay crane productivity (Hand, 2015). In addition, automated port equipment systems for yard storage would help to make space-efficient stacking of containers a reality (Tan, 2015).

2.2.2.3. Competition from neighbouring ports



Figure 6: Geographical location of Port of Singapore, PTP and Port Klang

(Source: Lam and Yap, 2017)

Container ports in Southeast Asia handled 64 million TEU in 2007, of which 63.3% was accounted for by the three largest container ports in the region, Singapore, Port Klang and PTP (Informa UK Ltd, 2008). Competition of container ports in Southeast Asia occurred between Singapore, Port Klang and PTP (Notteboom and Yap, 2012). PTP is located on the other side of the Straits of Johor from Tuas in Singapore's north-west as seen in Figure 6, has strengthened its position as a major container port and gradually developed into an attractive option for container shippers. In June, PTP announced a US\$2 billion investment plan aimed at increasing capacity over the next 15 years (The Economist, 2016). Port Klang, the largest in Malaysia, is reaching its

maximum capacity and thus is eager to build a new \$44 billion, 30m TEU capacity port complex on Pulau Carey in order to compete with their neighbouring competitor, Singapore Port (Leong, 2017; Port Strategy, 2017).

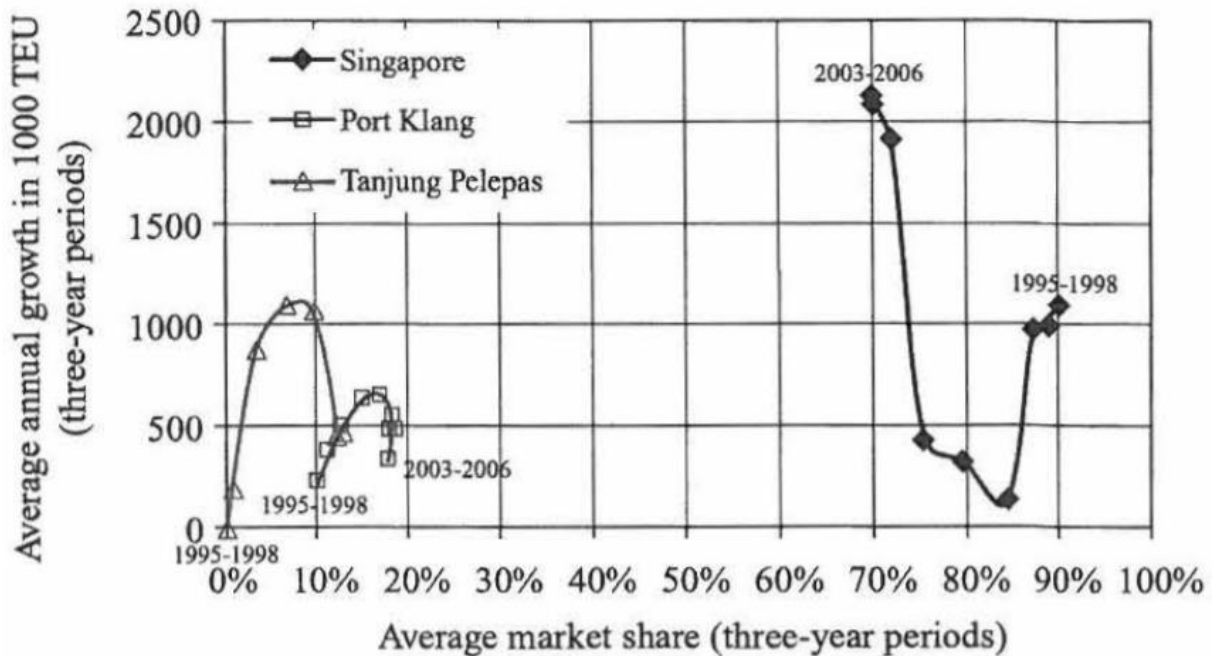


Figure 7: Evolution of market share and average annual growth based on annual throughput in TEU.

(Source: Notteboom and Yap, 2012)

The impact of the emergence of Port Klang and PTP as neighbouring competitors to Singapore is that they are able to grab the volume of container throughput from Singapore, especially transshipment cargoes. As observed in Figure 7, Singapore remains the market leader in the region since 1995, however, its market share decreased from 90% to around 70% in 2006, whereas for PTP and Port Klang have increased their joint market share (Notteboom and Yap, 2012) Thus, Port Klang and PTP are seen to be gaining competitiveness and becoming competitive alternatives for transshipment operations in the region (Lee and Lam, 2015).

2.2.3. Competitiveness as a Transshipment Hub

According to PSA (2015), about 85% of the containers handled in Singapore are transshipment cargo. Globally, with 33.9 million TEUs handled in 2014, Singapore is second only to Shanghai who handled 35.2 million TEUs in terms of container traffic and is the world's busiest in terms of transshipment cargo (Gill, 2015). Using its good

connectivity, many small feeder vessels tranship containers to large vessels that will carry the shipment to their final destination (MPA, 2017a). Transshipment is more cost efficient and time saving than vessels making a single direct voyage.

In the past, the transportation and distribution industry was led by the principles of point-to-point or direct-route operations. If each vessel sails direct to every port, the number of journeys made might be overlapped which in turn increases duration of voyage as seen in Figure 8, the Point-to-Point network.

Currently, Hub-and-Spoke model has been adopted by PSA to speed up deliveries and reduce costs. If each vessel tranships in Singapore, the number of journeys made will be significantly reduced as seen in Figure 8, the Hub-and-Spoke structure. Additionally, it improved shipment tracking (Delve, 2017).

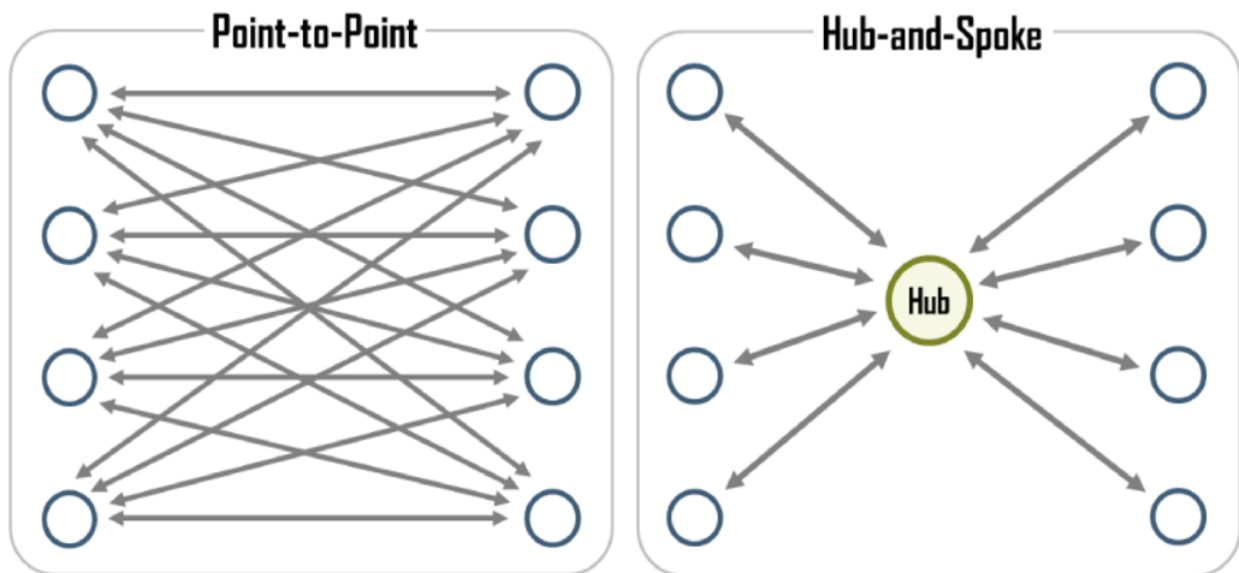


Figure 8: Network structure of transportation hub

(Source: Rodrigue, 2017)

2.3. Levels of Port Automation

In recent trend of automation, container terminals automate their storage equipment and the interchange between subsystems as seen in Figure 9 (Martín-Soberón et al., 2014). Automation can be applied to the entire range of operations of inland vessel fleets from the path following by a single vessel to the scheduling problems that

shipping companies have to deal with, and generally higher-levels of automation is adopted (Konnings et al., 2015).

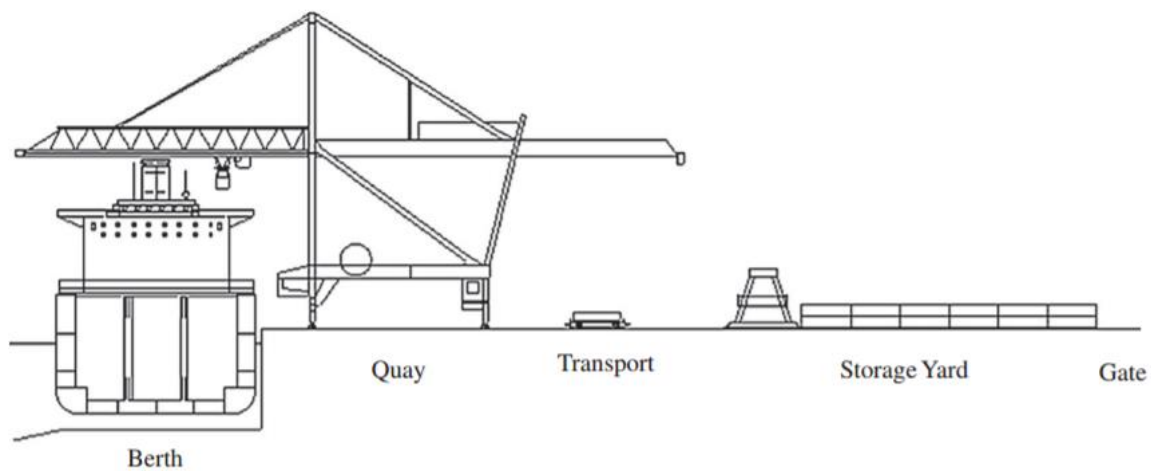


Figure 9: Container terminal main areas

(Source: Carlo et al., 2014)

In a conventional container terminal as shown in Figure 9, there are three types of equipment which are used to handle the containers (Bahnes et al., 2016):

1. Quay cranes → loading or unloading containers to or from the vessels
2. Stacking cranes → storing or retrieving containers at or from the stacking yard
3. Yard tractors → conveying containers between the quay and stacking cranes

In a semi-automated terminal, the use of equipment is controlled remotely or some functions are systematised for the equipment through minor or partial automations (Martín-Soberón et al., 2014). If only the yard stacking system is automated and the horizontal transfer remains with manually operated equipment, a terminal is described as semi-automated (Davidson, 2016). In a fully automated terminal, AGVs may be used for the transport of containers. Terminals are typically described as fully automated if both the horizontal transfer between quay and stack, and the yard stacking system are automated (Davidson, 2016). The stacking process can also be done automatically by ASCs or RTG cranes as seen in Figure 10 (Bahnes et al., 2016).

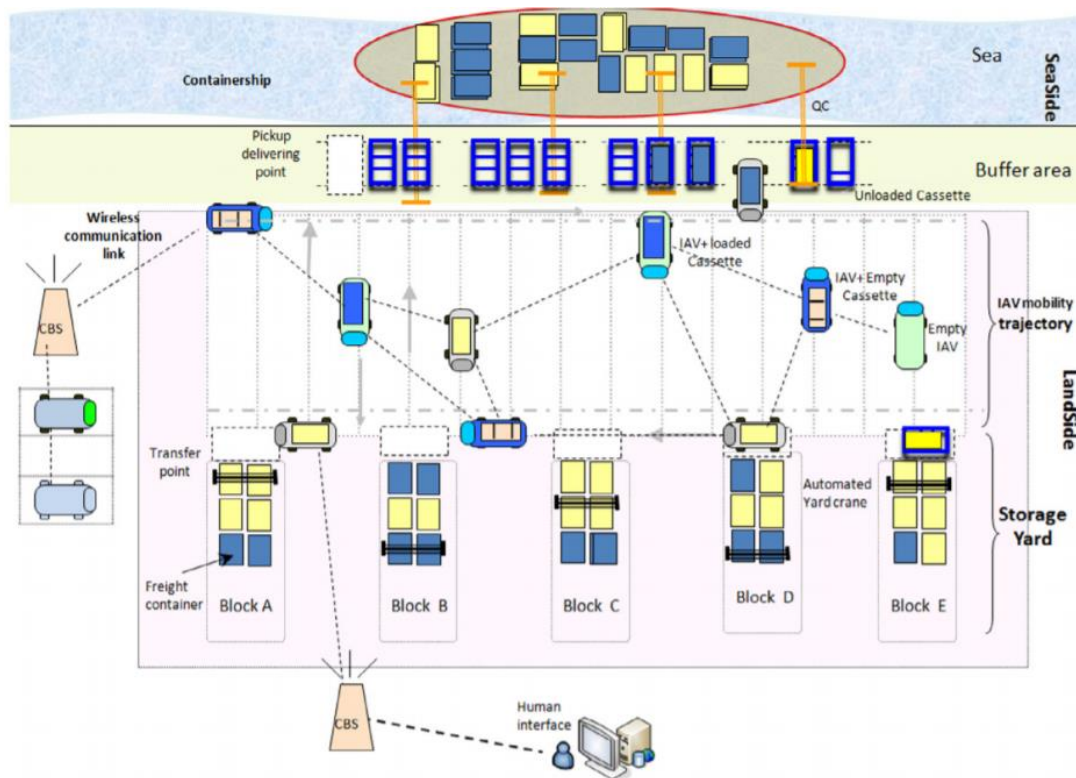


Figure 10: Overview of an automated container terminal

(Source: Bannes et al., 2016)

2.3.1. Singapore's Level of Automation

2.3.1.1. Current Level of Automation

Currently, Singapore's PPT Phases 3 and 4 are using semi-automation technologies. Some of the new port technologies, such as driverless or automated guided vehicles, are being tested and used at PPT (Woo, 2017). PPT boosts Singapore's total container handling capacity to 50 million TEUs per year (PSA, 2012). The term "semi-automated terminal" is used for terminals where, whilst yard movements are automated, dock-yard interchanges are carried out by conventional equipment, or inversely (Martín-Soberón et al., 2014). There is still semi-automation via double-trolley system, manual terminal tractor and shuttle carriers (SC) which are conventional technologies (Tan, 2013). In Figure 11, AGV is shown to have better and consistent results than manual SCs. As for the planning and execution within the port, CITOS (Computer Integrated Terminal Operations System) coordinates and integrates prime movers, yard cranes, quay cranes to containers and drivers in port (Gill, 2015). It also automatically generates ship stowage and yard layout plans with a

logical manner rather than in random, which maximizes asset utilization and optimizes retrievals (Gill, 2015).

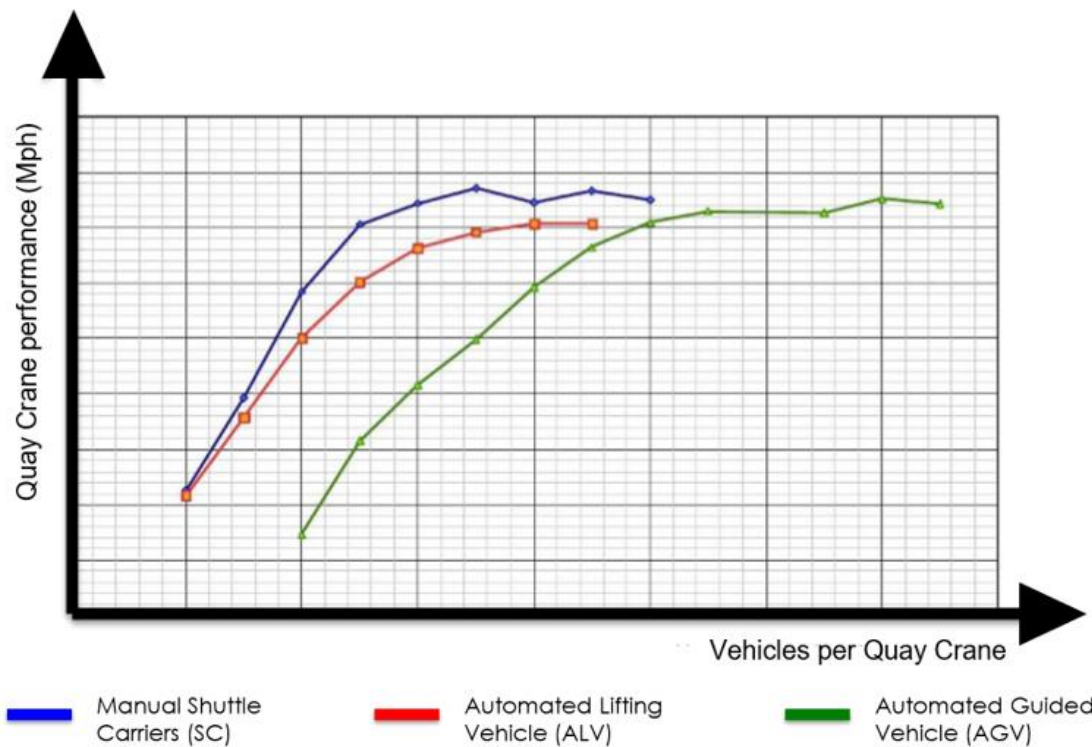


Figure 11: Performance of Manned and Automated systems at peak operations

(Source: PSA, 2013)

PPT being part of PSA Singapore's Living Lab program, utilises newest navigation systems, these AGVs will be seamlessly integrated with the existing AGV system as part of on-going initiatives to develop port technology solutions for the future automated Tuas Terminal (PSA, 2016c). At the equipment level, innovations like Flow-Through Gate, a fully automated system that identifies and security-clears incoming container trucks and provides drivers with drop-off location instructions within 25 seconds (Gill, 2015). Another is the remote-control crane operation system which allows operators to remotely monitor and control crane movements in a control room than on-crane, (Gill, 2015). Singapore's present capacity of 35 million TEUs is approaching its saturation point (Fwa, 2016), thus PPT serves as a proving ground for Tuas terminal which could handle 15 million more TEUs (Laursen, 2016).

2.3.1.2. Future Level of Automation

Tuas terminal will feature automated yard cranes and port equipment also together with the existing port technologies in PPT (Woo, 2017). Autonomous truck platooning

technology has also put to test in 2016 as seen in Figure 12, it can enable Singapore to make a quantum leap in productivity in the port sector, while addressing the shortage of drivers in the trucking industry and adding value to their jobs (Abdullah, 2017; Goh, 2015).

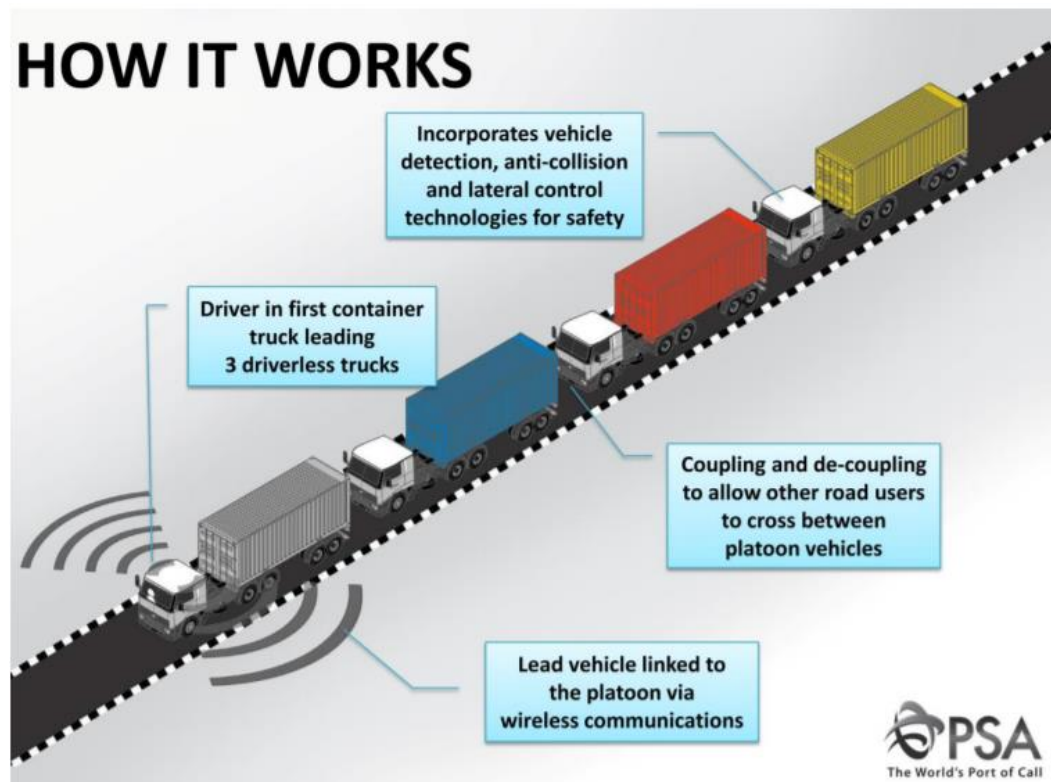


Figure 12: Illustration of Autonomous Truck Platooning Technology

(Source: PSA, 2017b)

Singapore port will be fully automated in the near future. The term “automated terminal” is used to refer to container ports which in reality have only automated the movements in the yard and dock-yard interchanges (Martín-Soberón et al., 2014). PSA will incorporate the latest automation systems, intelligent planning and control system into Tuas terminal (King, 2015). PSA is developing AGV prototypes that will operate on a 24/7 basis at its future container terminals, it aimed to eliminate human drivers and increase efficiency and reliability in transporting containers between the quay and the container yard (Port Financial International, 2012).

2.4. Implications of Automation for increasing competitiveness

A competitive port is a port that is chosen more regularly than other ports, along with facilitating the growth of its market share (OECD, 2014). Port competitiveness can be measured by the components listed in Table 1 below.

Table 1: Components of port competitiveness

(Source: Author's own based on Yeo et al., 2011; Roh et al., 2016)

Components	Factors affecting competitiveness
Port Service	• Prompt response • 24 hours a day, seven days a week service • Zero waiting time service Thus, when overall service quality provided to users of the port increases, port competitiveness increases.
Hinterland Condition	• Professionals and skilled labour in port operations • Volume of total container cargos
Availability	• Availability of a vessel berth on arrival in port • Port congestion
Green Practices	• Clean-burning low sulphur fuels • Environmental-friendly materials and equipment It will have positive impact on green performances and firm competitiveness
Logistics Cost	• Inland transportation cost • Costs related to vessels and cargoes entering port • Free dwell time on the terminal The lower the cost, the greater the level of competitiveness.
Regional centre	• Deviation from main trunk routes • Port accessibility Having a good location is deemed to render a port more competitive.
Connectivity	• Land distance and connectivity to major shippers • Efficient inland transport network

	The greater the connectivity, the higher the level of competitiveness.
--	--

By implementing automation, Singapore Port could fulfil the components for competitiveness so as to overcome challenges faced by the port and constantly improve customer satisfaction and loyalty in the long run. Several criteria should be met instead of just one when analysing automation's impact for affecting port competitiveness, it is important for port selection (OCED, 2014).

There are 5 elements most commonly highlighted that may affect the competitiveness of Singapore Port on the application of automation as elaborated below.

2.4.1. Operational Performance

The factors for measuring port operational performance commonly identified are container throughput, efficiency of container handling systems and the turnaround time of vessels (Beskovnik, 2008; Cullinane and Wang, 2010; Esmer, 2008). The main points for determining handling systems can be viewed in terms of cost and productivity (Nam and Ha, 2001). The basic elements of productivity in container terminals are the smooth and efficient handling of containers, handling systems and the level of automation (Yang and Shen, 2013). There are some aspects surrounding a particular terminal operation might affect the appropriateness of automated handling systems as seen in Table 2.

Table 2: Factors influencing automated handling systems

(Source: Nam and Ha, 2001)

Aspects	Factors
System characteristics	• Costs • Productivity • Flexibility • Reliability
Main goal for terminal operation	• Improving productivity • Saving cost • Improving level of service

	• Saving labour • Gaining automated technologies
Terminal characteristics	• Single or multiuser terminal • Small or large terminal • Usable land space
Social/Economic/Cultural aspects	• Labour cost • Skill of labour

In an automated terminal, automated stacking systems can provide the added boost to maintaining productivity at the quay, densifying terminal yards and improving utilization (Smith, 2015). There will be a boost in adapting to demand peaks and more organised and methodical operation which will reduce uncertainty in response times with automation (Martín-Soberón et al., 2014). Thus, resulting in a better use of available space and an increased facility capacity (Montfort et al., 2011), which is important for Singapore Port due to land constraint and as a fast-paced transshipment hub.

There is a downside for automation which is the lack of flexibility in operational planning and unpredictable situations (Martín-Soberón et al., 2014), such as the case of equipment breakdown in terminal operation (Brinkmann, 2011). Thus, ports should not rely heavily on automation and need to come up with backup plans to react swiftly. These are crucial challenges for Singapore Port as minor mistakes might lead to delayed schedules and increase in containers' dwell time, affecting competitiveness.

2.4.2. Economic Profitability

The goal of every terminal is to perform efficiently and remain competitive by providing low cost and high quality services to customers (Liu et al., 2002). Leeper (1998) concluded that advanced automated control technology is a necessary condition for the improvement of productivity and reduction in investment costs. Substitution of high labour costs with capital costs to achieve lower overall operating costs and also avoid the uncertainty that manual labour can bring, such as the potential for inflationary wage increases, the vagaries of negotiations on manning levels and conditions, and the possibility of disputes (Davidson, 2016).

The most common challenge for Singapore as a transshipment hub is the high land, operation and labour cost (Tan and Hilmola, 2012). The main driver for automation is to reduce the cost per handled container in the terminal (PEMA, 2012). Although the initial investment in an automated terminal is higher than for a traditional terminal, however, automation offers a wider range of advantages (PEMA, 2012). As automated equipment is more controlled and runs the operation more smoothly than a human operator, there is lesser wear and tear to the equipment which reduces maintenance and repair costs (Sisson, 2011).

2.4.3. Labour Force

In order to pursue increasing efficiency and reducing labour cost led container terminals to turn to automation options, however, there are still some container terminals that still prefer traditional operational concepts for their system reliability and labour flexibility issues (Michele and Patrizia, 2014). Singapore Port is reducing labour costs through the use of technology like automated yard cranes and port equipment (DEME, 2014). The reduction of man-hours, reduces the costs-per-move within terminals (Nichol, 2015), this cost savings is a tremendous incentive for automation (Edmonson, 2007).

Main advantages of automated operating systems are their high productivity in horizontal transfer and in lower labour costs as compared to traditional systems, conversely, they are rigidity in operations, high investment and well-trained workforce are needed (Michele and Patrizia, 2014). As automation substitutes for labour across the entire economy, the net displacement of workers by machines might worsen the gap between capital returns and labour returns, nonetheless there is still a possibility that displacement will result in an increase in safe and rewarding jobs in overall (Schwab, 2017).

Even though automation processes not only increase safety by reducing human errors in operation and potential accidents (Martín-Soberón et al., 2014). However, implementation of automation will cause low-skilled job losses but creates new job opportunities for high-skilled jobs. Automated equipment leads to a safer working environment, significantly lower accident rates and reduced insurance costs (Pettersson and Annala, 2015). Singapore Port will have to overcome the challenge of developing better technology to meet the new capacity required while creating better

jobs for the port works (Woo, 2017). Instead of retrenching workers, Singapore would have to provide trainings and education for them to take on the future automatized tasks and increase competitiveness (OCED, 2014).

2.4.4. Service Quality

Service quality is an important element as it positively impacts customer satisfaction, which in turn may have positive influence on customer loyalty (Chang and Thai, 2016). Ports must meet port users' needs or expectations (Kim et al., 2016). Fast service of inland transport modes becomes a strong competitive advantage for transshipment hub, if the peak of truck arrivals coincides with heavy workload periods for vessels, the performance and service quality of the entire terminal may decrease (Zehendner and Feillet, 2014). Efficient freight movement is critical to the competitiveness of Singapore port, thus development of an autonomous truck platooning system to transport containers between container terminals is crucial (Mooney, 2017).

Apart from the reputation for reliability, safe and environmentally responsible operations are also essential to a quality service in ports, operation performances can therefore influence customers' perception of the quality of a maritime transport service provider (Thai, 2015). Implementation of automation increases port safety. Furthermore, Singapore's comprehensive port facilities and services are unsurpassed in terms of quality, efficiency, competitiveness and reliability (MPA, 2017b). MPA (2016) highlighted that Singapore's effort was recognised and named "Best Seaport in Asia" for the 28th time at the 2016 Asian Freight, Logistics and Supply Chain Awards.

Positive influence of image and social responsibility-related dimension on customer satisfaction would justify port automation investments (Thai, 2015). Good service quality increases the reputation of the port and reliability of its services, thereby strengthening a port's competitiveness (Yeo et al., 2011; Cho et al., 2010).

2.4.5. Environmental Sustainability

Environmental sustainability has always been a growing concern for the port industry (Acciaro et al., 2014). In 2011, MPA became the world's first maritime administration to launch a comprehensive pro-environment initiative, known as the Maritime Singapore Green Initiative (MOT, 2014). Capital dredging is always carried out taking a sustainable view and often leads to the dredged material being used for the reclamation of new land such as the future Tuas terminal, moreover smart dredging

supports natural processes and uses river dynamics, ensuring that the environment comes first (Green Port, 2017).

Automation helps to optimise operations in all aspects, such as minimising travels made by equipment, empty runs, shuffling containers, and also directly prompting a decrease in energy use (Martín-Soberón et al., 2014). Additionally, in automated terminals most of the equipment are electric-powered, which are more efficient and reduce energy consumption, emissions and noise (Martín-Soberón et al., 2014, Pettersson and Annala, 2015). Remote monitoring technologies will also support the industry by improving the environmental and energy performance of its equipment, with real-time tracking of operational parameters, such as fuel consumption (Scott, 2012).

2.5. Summary

The concept of automation and features of Port of Singapore were discussed in the literature review to give a better understanding on the importance of automation. The components affecting port competitiveness were identified and the impacts of automation as well as the challenges faced by Singapore port were examined for further analysis on the influences of automation that may affect port competitiveness in the later chapter.

3. Research Methodology

Research methodology is a way to systematically solve the research problem and may be understood as a science of studying how research is done scientifically (Kothari, 2004). In order to show the relationship between automation and Singapore Port's competitiveness, the design of the research will be descriptive and explanatory (Saunders et al., 2016). The choice of research method chosen and justification will be further explained in the later chapters, as well as how will data be collected and analysed to answer to the research question (Collis and Hussey, 2013). The methods to be used will be based on the research onion as shown in Figure 13 (Saunders et al., 2016).

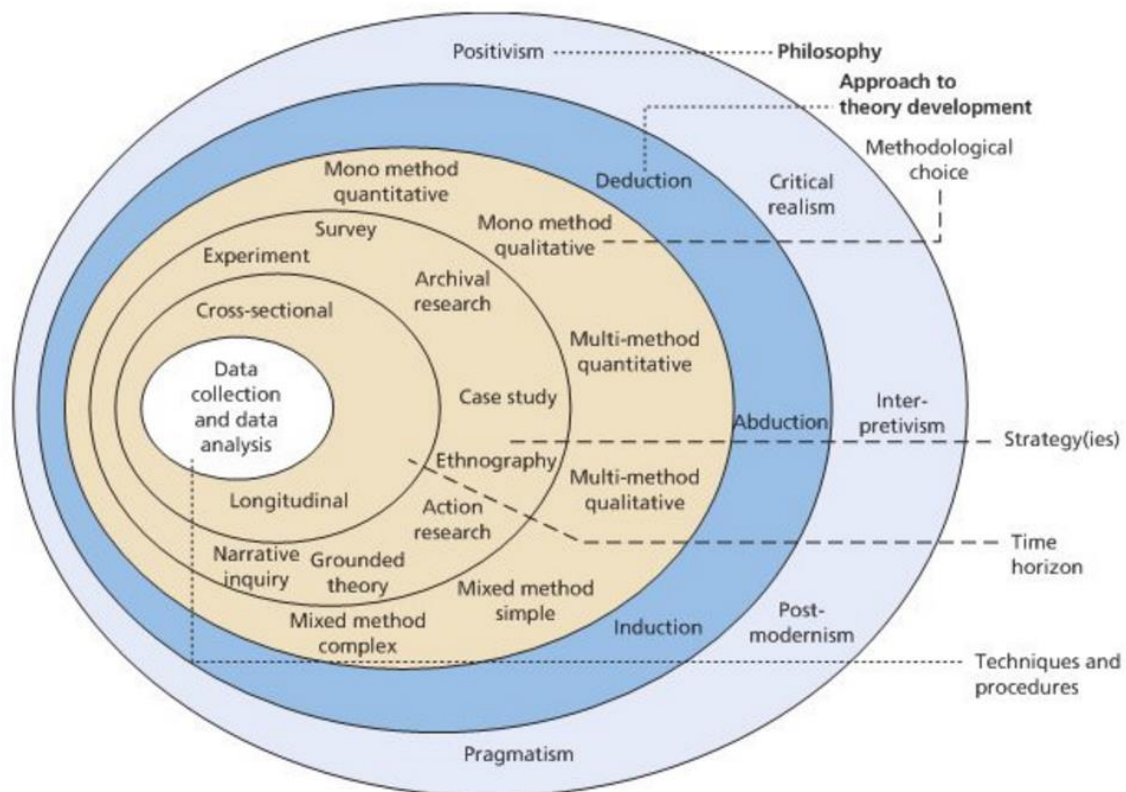


Figure 13: The Research Process

(Source: Saunders et al., 2016)

3.1. Research Philosophy

Research philosophy is important in underpinning the methodological choice, research strategy and data collection techniques and analysis procedures (Saunders et al., 2016). Pragmatism is chosen to be the most appropriate philosophy for this research. It provides a different way of thinking about objects of knowledge, and thus influences the choice of research methods (Biesta and Burbules, 2003). In pragmatism, both qualitative and quantitative approach is used and analysed to provide better understanding to the research problem (Creswell, 2014).

Qualitative approach allows the researcher to conduct data collection regarding the importance and effect of implementing port automation in Port of Singapore. For quantitative approach, the researcher will collect statistics on Port of Singapore and its neighbouring ports to emphasize the need to stay competitive with automation.

3.2. Research Approach

There are two types of research approach. Deductive approach is based on an existing theory and deduces a hypothesis that must then be subjected to empirical scrutiny seen in Figure 14, it is usually associated with quantitative research (Bryman, 2012).

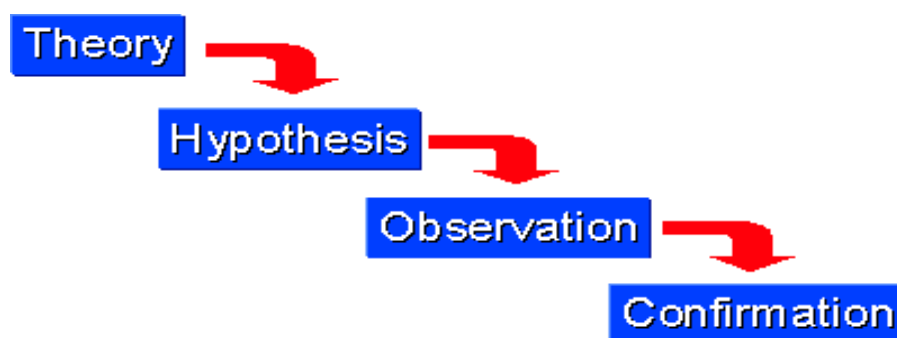


Figure 14: Deductive approach

(Source: Trochim, 2006a)

For inductive approach, theory is the outcome of research and the process of induction involves drawing generalizable inferences out of observations seen in Figure 15, it is usually associated with a qualitative research approach (Bryman, 2012).

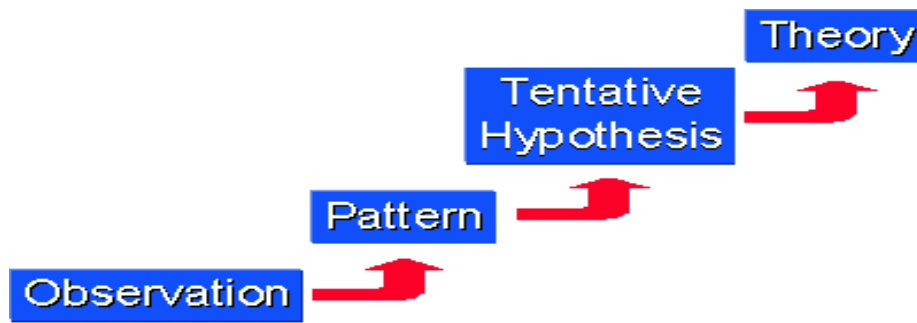


Figure 15: Inductive approach

(Source: Trochim, 2006a)

Inductive approach is chosen for this research as the importance of automation for increasing port's competitiveness will be determined by its advantages and disadvantages at the conclusion. There are many potential benefits to automation, however, terminal automation may or may not benefit every container terminal (Nichol, 2015). Furthermore, there are also some downsides to automation (Davidson, 2016). Therefore, system characteristics and terminal characteristic, social, economic and cultural aspect of Singapore Port have to be considered to conclude the theory (Nam and Ha, 2001).

3.3. Methodology Choice

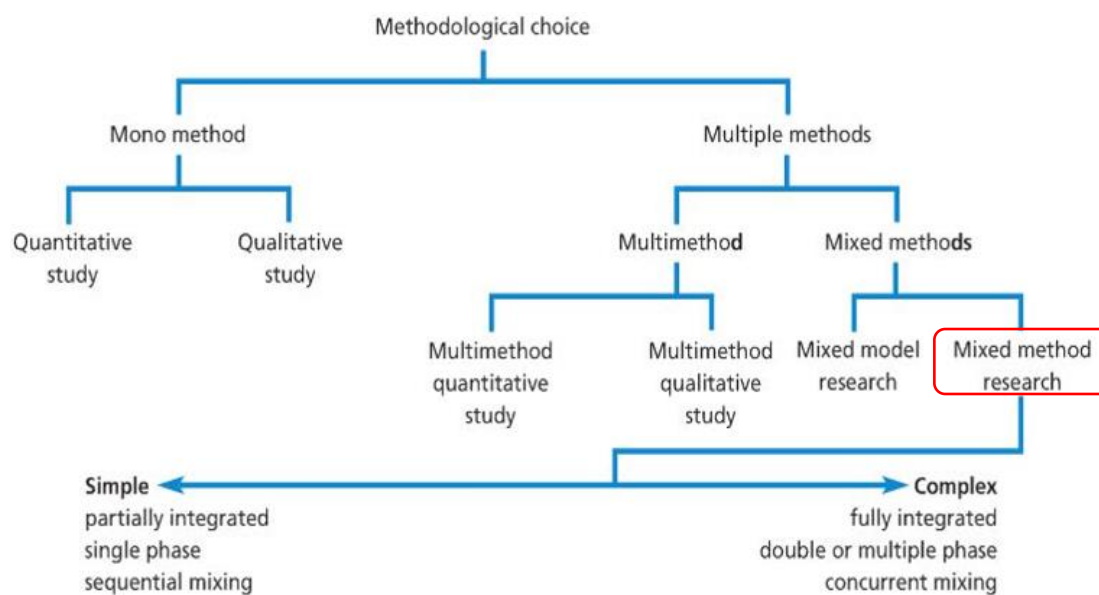


Figure 16: Methodological choice

(Source: Saunders et al, 2012)

Mixed methods research is the branch of multiple methods research that combines the use of quantitative and qualitative data collection techniques and analytical procedures (Saunders et al., 2016). Since pragmatist paradigm is not committed to any one system of philosophy and reality, it applies to mixed methods research which draws liberally from both quantitative and qualitative assumptions (Creswell, 2003). In other words, the methods are mixed in a way that has complementary strengths and no overlapping weakness (Onwuegbuzie and Teddlie, 2003).

The advantage of using mixed method research is that there is a possibility of triangulation, which allows the researcher to identify aspects of a phenomenon more accurately by approaching it from different viewpoints using different methods and techniques (FoodRisc, 2016).

The statistical quantitative data of container throughput from Port of Singapore and its neighbouring ports is used to further emphasize intense competitions. The need for automation in Singapore Port for increasing its competitiveness can be examined qualitatively.

3.4. Research Strategy

Research strategy is guided by the research aim and objectives, the extent of knowledge, the amount of time and resources available (Saunders et al., 2012). In this research, archival research and case study are chosen.

3.4.1. Archival Research

Archival research strategy allows the researcher to establish what data are available and designing the research to make most of it (Saunders et al., 2012). Archival research is analysing already collected data and applying statistical measures to describe the information in a simpler way (Kowalczyk, 2017). This research aims to collect statistical quantitative data of container throughput through companies' archives and also maritime news articles for the past few years and current year if possible to show increasing competitiveness between Singapore Port and its neighbouring ports. Concurrently, further emphasizing the importance of automation in increasing container throughput and to handle the future maritime industry.

3.4.2. Case Study

In this research, case study of Singapore and its neighbouring ports, Port Klang and PTP will be used. Case study is a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence (Saunders et al., 2012). This research will focus on mainly secondary data collection of port statistics, government publications and port developments for the case study.

In Figure 17, Singapore's container throughput had decreased while for its neighbouring port, Port Klang had increased by 12%. In Figure 18, the growth rate of PTP is observed to be much more than Port of Singapore over the years. Even though they have not caught up to Singapore but they are seen as potential competitors.

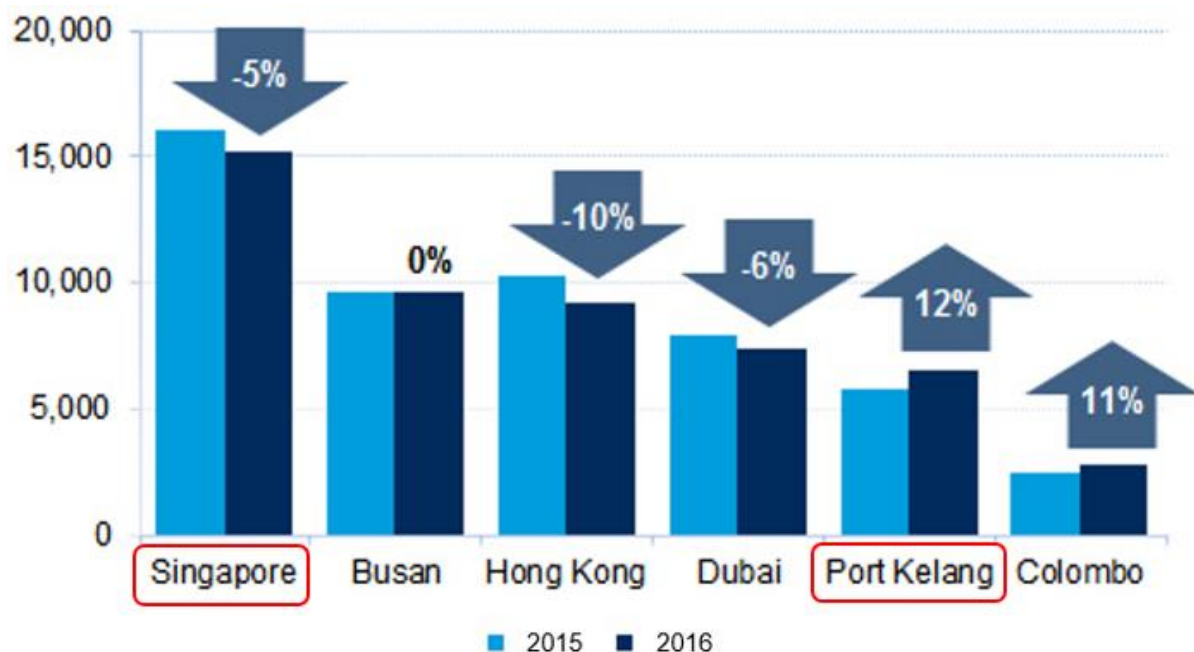


Figure 17: Container throughput at transshipment hubs, 6 months 2015-2016

(Source: Drewry Maritime Research, 2016)

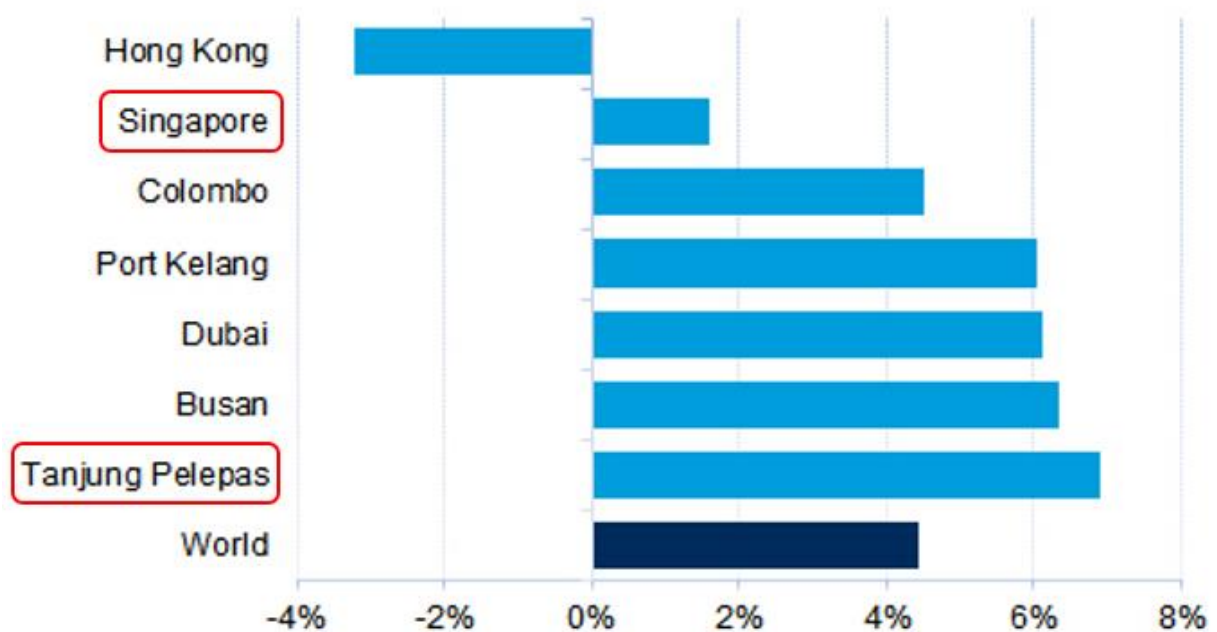


Figure 18: Container throughput compound annual growth rate from 2010-2015

(Source: Drewry Maritime Research, 2016)

PSA and MPA need to react to this situation, thus a large-scale investment was developed and plans to increase terminal capacity and implementing automation technology in the future Tuas port (Egan, 2014). Therefore, the objective of case study is to evaluate challenges faced by Singapore Port and the impacts of automation to Singapore.

3.5. Time Horizon

The time horizon chosen for this research will be cross-sectional study. Cross-sectional study involves a collection of multiple cases of quantitative and qualitative data at a single point of time, which are then examined to detect relationships between variables (Bryman, 2012). It provides a snapshot of research phenomena and it allows sufficient time and is inexpensive for the research (Collis and Hussey, 2013). Thus, cross-sectional study is the most suitable for the research, due to time constraint.

3.6. Data Collection and Data Analysis Techniques

3.6.1. Data Collection

In this research, documentary secondary data is chosen for this research shown in Figure 19 as it complements archival research strategy (Saunders et al., 2012). Data will be collected through platforms such as publications like Lloyd's List, academic journals from Plymouth University electronic database, port authority websites and news articles. The advantages of secondary data are the enormous saving in time and money, hence more time and effort can be spent on analysing and interpreting the data (Ghauri and Gronhaug, 2010).

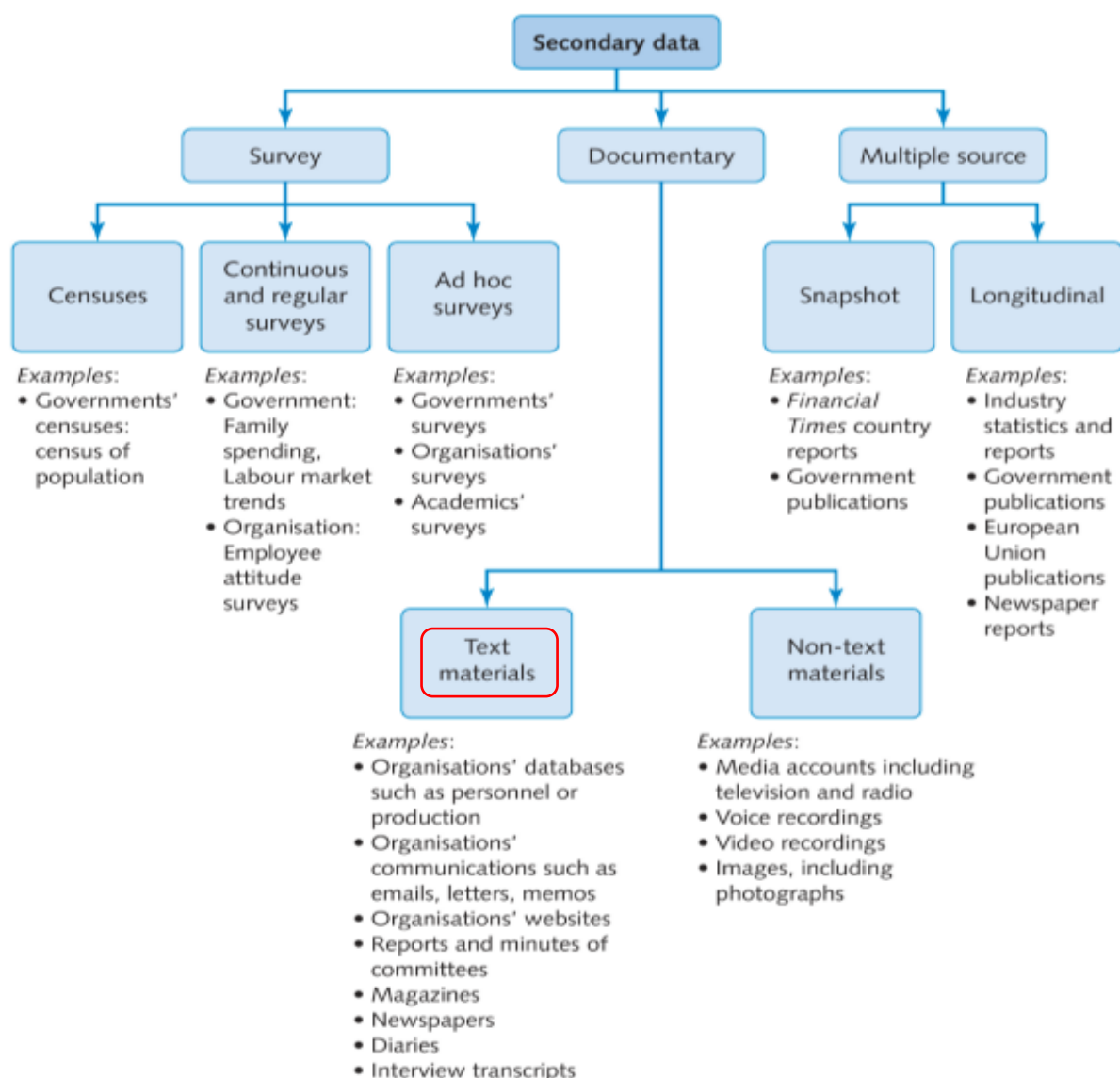


Figure 19: Types of secondary data

(Source: Saunders et al., 2016)

Some secondary data may cover the same general topic as the research, however, the definitions of data variables may not be most appropriate for the research objectives (Saunders et al., 2012). Thus, great care needs to be taken by the researcher to make sure the data have a consistent meaning throughout the research and ensure accuracy of data (Easterby-Smith, 2008). It is important that the researcher refers to sources which offer up-to-date information (Sekaran, 2003). Overall, secondary data is most suitable for this research as credible data can be obtained within the time frame of this project.

3.6.2. Data Analysis Techniques

Quantitative data are in the form of numbers that needs to be processed to make them useful, thus graphs, charts and statistics allows the research to describe and examine relationships and trends within the data (Saunders et al., 2012).

For qualitative data, which are non-numeric data that needs to be analysed and categorised into groups to further explain the research objectives through conceptualisation (Saunders et al., 2012). The research will adopt thematic analysis, which is defined as an independent qualitative descriptive approach for identifying, analysing and reporting themes within data (Braun and Clarke, 2006). It is to provide a description and understanding of answers (FoodRisc, 2016).

While quantitative analysis technique will be dealing with the evaluation of charts, graphs and statistics explore, present, describe and examine relationships within data (Saunders et al., 2012). Container throughput and statistics comparison of Singapore Port and its neighbouring ports, PTP and Port Klang, would be use for analysing competitiveness.

The researcher will categorise keywords such as productivity, manpower, cost, service quality and environment gathered in the literature review by grouping into themes. Subsequently, each theme will be further grouped under advantages and disadvantages. Secondary qualitative data in these contexts will refer to the views or opinions from port authorities and the archival research. The objective of the analysis is to identify the factors on the benefits of port automation and the barriers towards it.

3.7. Research Ethics

It is crucial is to be aware of the ethical principles involved and of the nature of the concerns about ethics in research so that the researcher can make accurate and righteous decisions, failure to do so may lead to false conclusions and incredibility of the research study (Bryman, 2012; Wilson, 2010). Ethical concerns can occur at all stages of the research like, while seeking access, during data collection, data analysing and discussions (Saunders et al., 2012). Thus, secondary data collected from various platform like journal articles, textbooks and websites must be properly cited to prevent plagiarism.

3.8. Credibility of Research Findings

The credibility criteria involve establishing that the results of qualitative research are credible or believable from the perspective of researcher (Trochim, 2006b). Thus, reliability, validity and triangulation have to be redefined to ensure credibility in a qualitative research (Golafshani, 2003).

3.8.1. Reliability

Reliability refers to the extent to which data collection techniques or analysis procedures will produce consistent findings (Saunders et al., 2012). It is a concept to evaluate quality in quantitative study with a “purpose of explaining” while in qualitative study, it has the purpose of “generating understanding” (Stenbacka, 2001). To ensure reliability in qualitative research, examination of trustworthiness is crucial (Golafshani, 2003). Patton (2001) point out that with regards to the researcher's ability and skill in any qualitative research also states that reliability is a consequence of the validity in a study.

There may be 4 threats to reliability, namely, subject or participant error, subject or participant bias, observer error and observer bias.

3.8.2. Validity

Validity is concerned with whether the findings are really about what they appear to be (Saunders et al., 2012). Researcher needs to construct validity test if the outcomes for the research have successfully served its purpose for the study (Creswell, 2014). It is not a fixed concept, but rather a contingent form, inescapably grounded in the

processes and intentions of particular research methodologies and projects (Winter, 2000). In case study research, internal validity can be established by use of cross case analysis, development of diagrams to demonstrate internal consistency of information collected, linking analysis to theories identified in literature review and analysis of pilot case studies (Yin, 1993).

There are also some threats to validity namely, history, testing, instrumentation, mortality, maturation and ambiguity about casual direction.

3.8.3. Triangulation

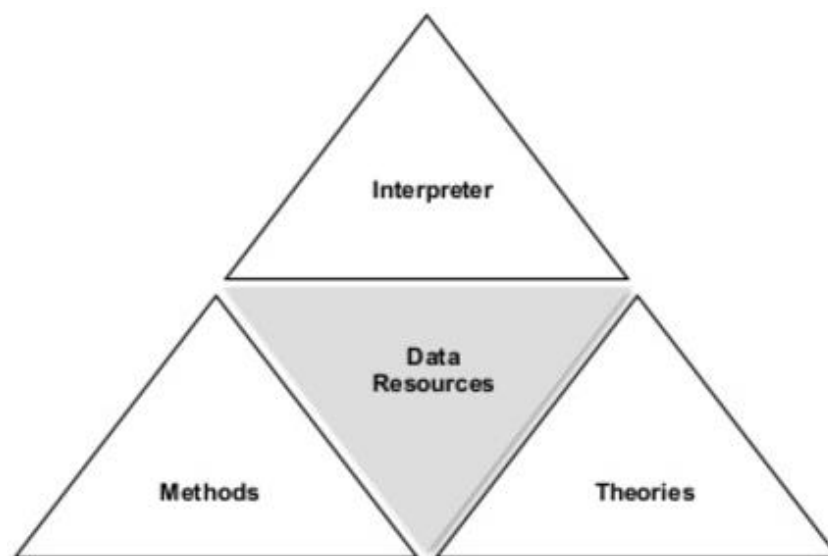


Figure 20: Triangulation overview

(Source: Tjitra, 2011)

Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena as seen in Figure 20 (Patton, 1999). Patton (2001) supports the use of triangulation by stating “triangulation strengthens a study by combining methods”. The researcher will compare findings from annual reports on Singapore port and its neighbouring ports, journal articles, textbooks, trade publications and newspaper articles to reach the final conclusion.

4. Analysis and Discussion

4.1. Overview

Based on the secondary data collected, this chapter will be classified into 6 main themes as seen in Figure 21 to examine whether automation contributes to increasing competitiveness for Singapore Port.

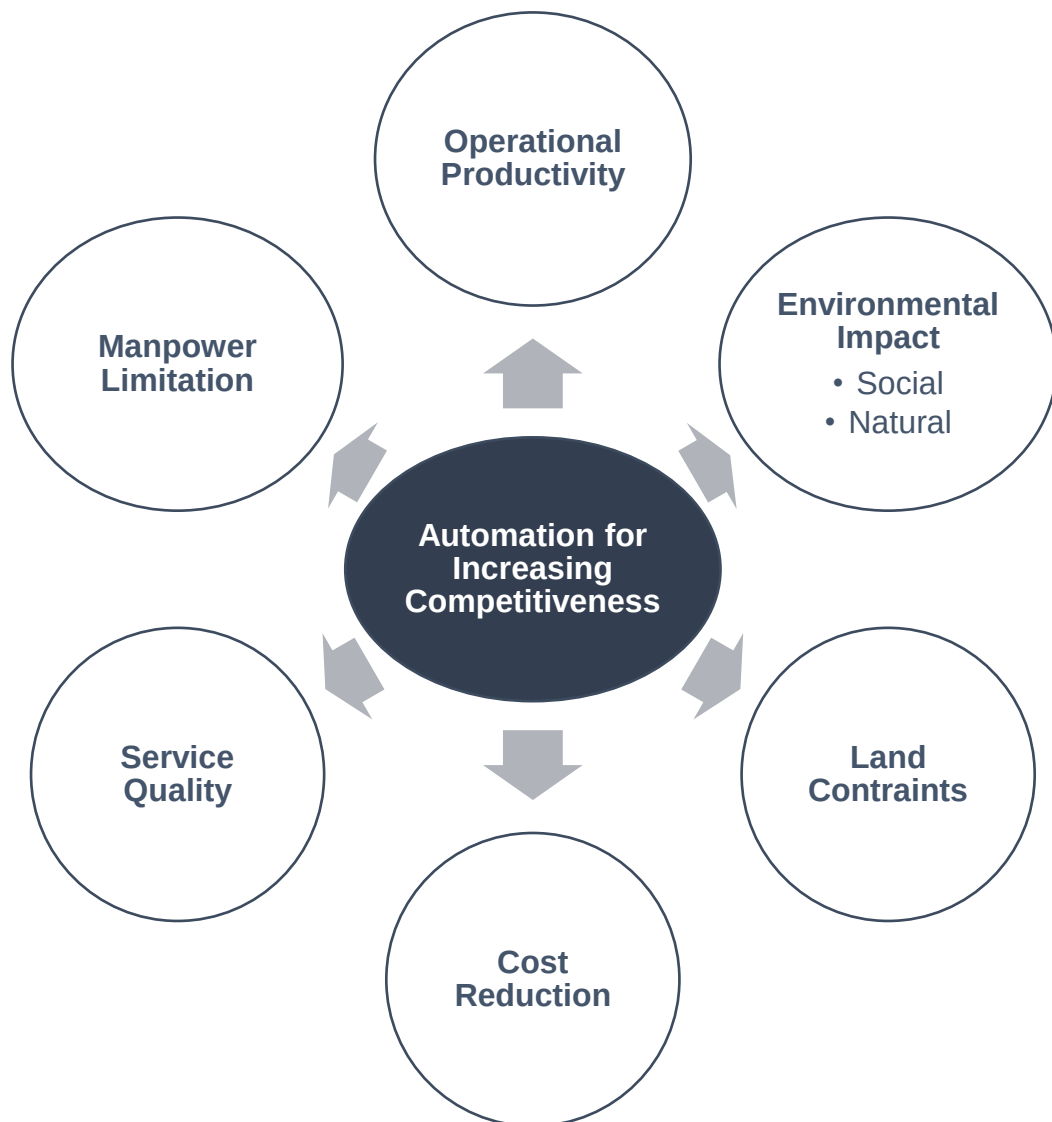


Figure 21: Drivers for automation for increasing competitiveness

(Source: Author's own, 2017)

4.2. Data Analysis

In this segment, the researcher will analyse the impact of automation based on the components of port competitiveness.

4.2.1. Operational implications

4.2.1.1. Increase Port Productivity

In order to increase competitiveness, the turnaround time in port, container handling equipment and berth productivity are the key factors that needs to be improved. Singapore Port was reputed to be highly efficient and having the ability to handle over 2,000 containers per vessel, with a turnaround time of less than 12 hours (MPA, 2017b). In 2014, Singapore's container port moved an average of 66 containers per hour per ship, however, its neighbouring rivals, PTP racked up an average of 81 containers and Port Klang with 69 containers (Tan, 2015).

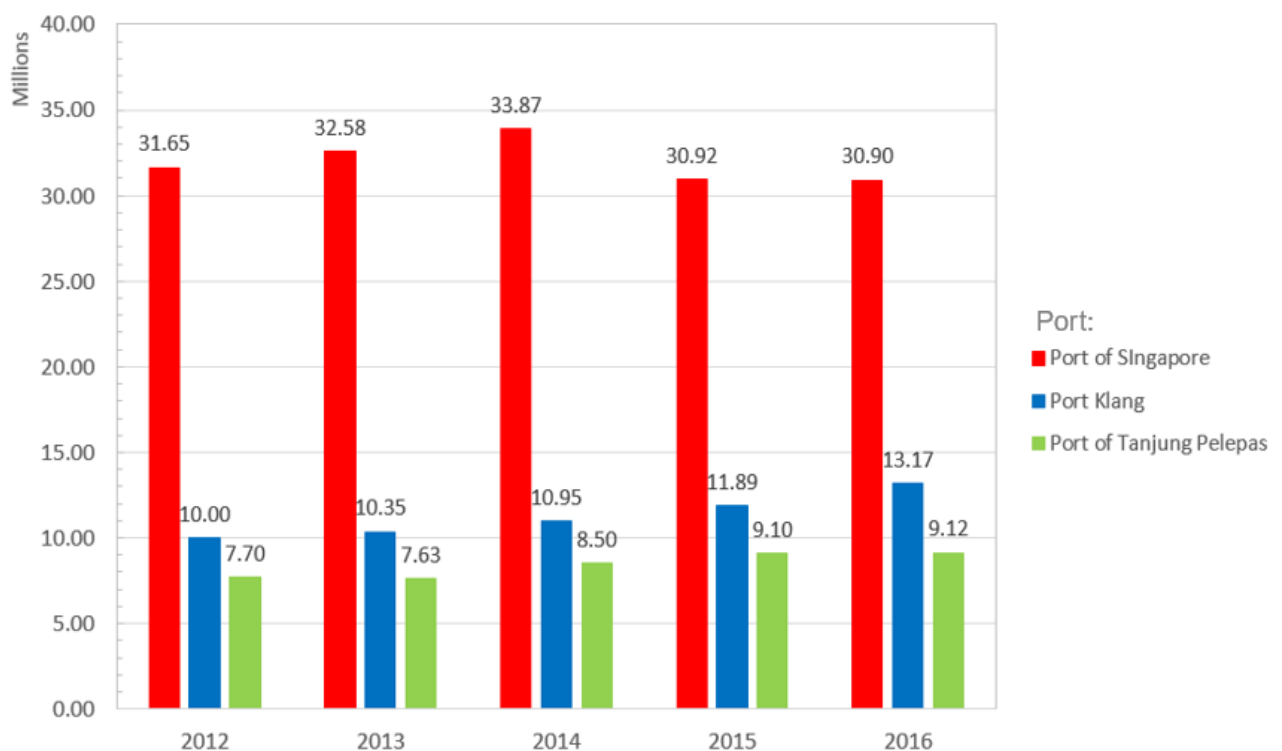


Figure 22: Container throughput from Year 2012 – 2016

(Source: MPA, 2017c; Lloyd's List, 2016; World Shipping Council, 2017; Port Klang Authority, 2017)

As seen from Figure 22, from year 2012 to 2015, there has been a wide gap between Singapore's container throughput and its neighbouring competitors, Port Klang and PTP. Singapore Port has a slight fluctuation of container throughput whereby its

highest was 33.87 million TEUs in 2014 and dropped to 30.90 million TEUS in 2016. However, Port Klang has been steadily increasing its throughput annually, from 10 million TEUs to 13.17 million TEUs. Likewise, PTP is also catching up from 7.70 million TEUs to 9.12 million TEUs.

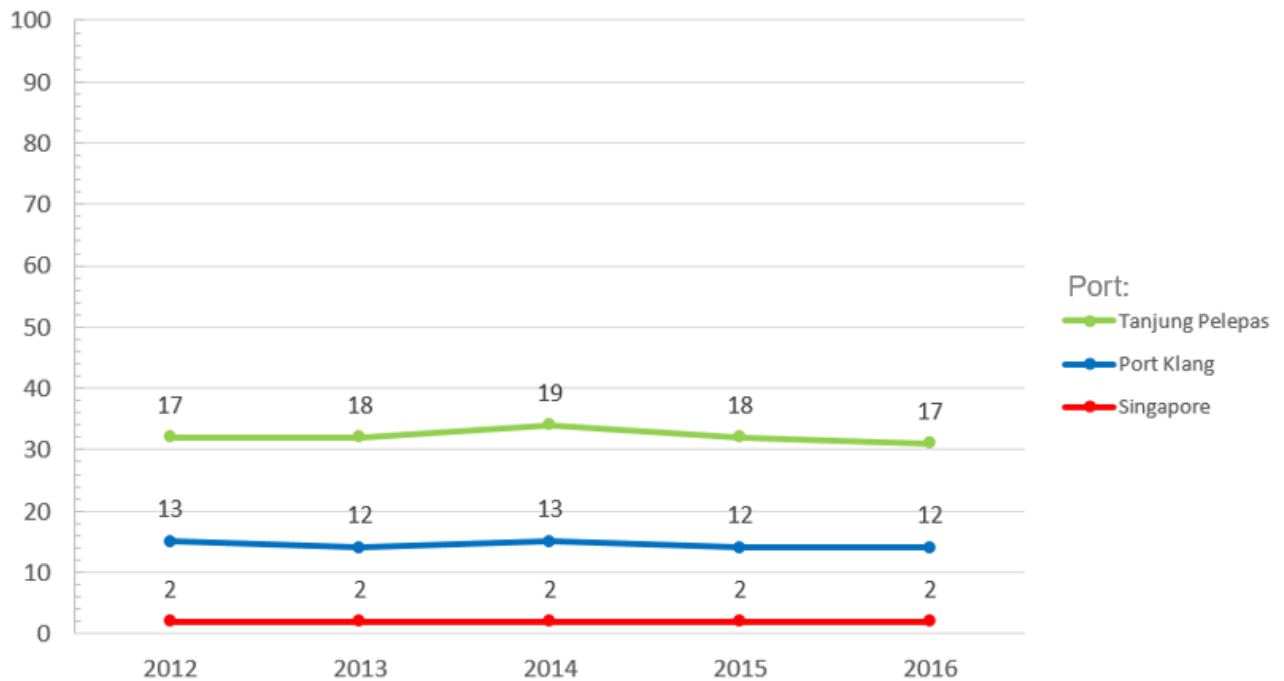


Figure 23: Port ranking from Year 2012 – 2016

(Source: Lloyd's List, 2016)

It is a matter of time for Port Klang and PTP to further increase their container throughput. Seeing their improvement in handling containers, this further explains the climb of their ranking from year 2014 to 2016 in Figure 23, while Singapore is still maintaining its top second position over the years. Competition from neighbouring ports pushes Singapore Port to adopt automation in keeping up with competitiveness.

Automation provides greater predictability and consistency of operations (Davidson, 2016). In an automated terminal, there are longer working hours since machines can operate 24/7 without the need for refreshment and comfort breaks, and have no aversion to unsociable hours (Davidson, 2016). AGVs can enable faster delivery of goods and products in warehouses since it carries out processes consistently whereas comparing to human workers, their capability and speed depends physically and mentally on one's body.

Having greater control in machines, increases the predictability of operations as figures are generated automatically from computing systems based on the consistency of container movement which also makes planning easier. It would be helpful for a ship planning system to have the capability of automatically changing work schedule adaptively (Kim and Lee, 2015), which helps port operators to better predict ships' port turnaround time. As a result, more containers can be handled when the waiting time is shortened and relieved from port congestion. The constancy provided by automated equipment increases productivity. As productivity improves, so does the port's competitiveness (Yeo et al., 2011)

4.2.1.2. Lack of Flexibility

However, automated terminal lacks flexibility for operational planning (Martín-Soberón et al., 2014). Their physical layout is difficult to change once fixed thus decisions have to be made at the design stage which require judging the terminal's needs over decades ahead (Davidson, 2016). Important variables like the activities of the terminal and the needs of its customers may change over time as well as the processes carried out by a terminal are not necessarily stable and homogenous (Davidson, 2016). Since automation prefers a high degree of repetition and predictability, it is more difficult to react to exceptions (Davidson, 2016; Martín-Soberón et al., 2014).

Increasing dependency on systems and automation raises the risk that port workers become mere "button pushers", unable to handle unexpected events and to blame poor performance on perceived system short comings too readily (Martin, 2009). Automated equipment always needs to operate faultlessly to ensure it does not become a constraint on the performance of the terminal whereas manual container handling equipment will work even in imperfect condition, because human operators can work around the deficiencies of equipment or deal with exceptions in operational processes (Keskinen et al., 2017). However, well-trained labours will be free from doing repetitive processes which are replaced with robotization and now armed with higher level skills of understanding on resolving issues and managing exceptions.

4.2.2. Manpower Implications

4.2.2.1. Employment Opportunities

The main drivers for automation are the high labour costs as ports are usually labour intensive. Through automation, the advantage is that there is a reduction of direct human intervention in operations, which creates better job opportunities to handle automations (Martín-Soberón et al., 2014). The common benefit brought by automation was that driverless AGVs will ferry containers around the port at Tuas instead of prime movers driven by humans. This will provide new job opportunities in engineering and software development (Teo, 2016). Technicians in Singapore Port will no longer need to perform routine maintenance work and focus on higher-level and more complex tasks.

With up-skilling over the years, current port operations professionals have the technical expertise to remotely operate multi-million dollar cranes (Subbaraman, 2016). Not only has this helped to attain the high service which Singapore was known for, but also enabled wages to rise as workers acquired new skills and responsibilities (Subbaraman, 2016). Meanwhile, the next-generation Vessel Traffic Management System to be deployed at Tuas will need skilled data analysts and data scientists to predict congestion hotspots and to avoid potential collisions (Teo, 2016). Also, leading to new developments in knowledge and new training and employment opportunities for the younger generation (Aarts et al., 2012). Having highly-skilled workforce sets Singapore apart from its competitors which increases its competitiveness.

4.2.2.2. Loss of Employment

The shift from low to highly skilled labour in ports results in inevitable consequence of automation, which is the loss of employment for low-skilled workers such as prime mover drivers and stevedores (Aarts et al., 2012). However, Singapore do not have the intention of retrenching any workers. In recent months, PSA Singapore has moved some workers to PPT to pick up new skills relating to automated operating equipment (Woo, 2017).

4.2.3. Cost implications

4.2.3.1. Economic and financial profitability

Based on the investment of automated equipment, operational costs and labour costs, these 3 factors will be used to determine whether the aim of automation in reducing overall costs to increase competitiveness.

The initial cost of the investment of equipment is high. Automated machines are expensive thus requires higher capital than in manual terminal (Davidson, 2016). However, good port equipment is necessary for effective port operations. In consideration to the cost of all the equipment, port terminals attempt to optimise the capacity of their equipment in relation to the projected peak cargo flows (OCED, 2014). Automated equipment will eventually benefit Singapore Port in the long term.

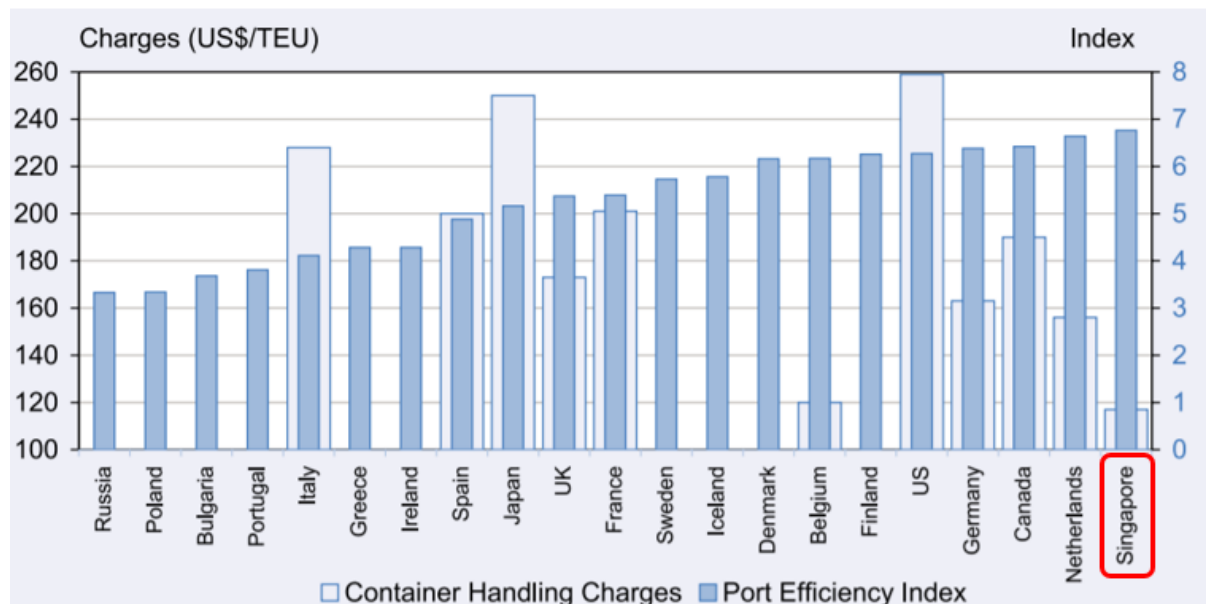


Figure 24: Port efficiency and container handling charges

(Source: Clark et al., 2004)

Every terminal aims to achieve low operating costs and high quality of service to increase competitiveness. In Figure 24, Singapore has the lowest container handling charges and the highest port efficiency index as compared to the other countries. However, when comparing PTP against Singapore Port, PTP has a cost advantage over Singapore and it is estimated that PTP's costs are 30% to 40% lower than those of Singapore (Kleywegt, 2002). Furthermore, Singapore received a huge blow from the shift of Maersk Sealand and Evergreen Marine from PSA Singapore to PTP in year

2002, however, Singapore quickly recovered the loss of around 3 million TEUs from the departure of Maersk and Evergreen (Gordon et al., 2005). The cost advantage of PTP is the drive for automation in Singapore.

Automation could dramatically increase throughput and reduce cost (Liu et al., 2002), also to justify the investment on expensive automated equipment. Furthermore, the future Tuas terminal is able to handle more container capacity of 65 million TEUs which can create economies of scale and reduces operating costs, time taken, business costs and road congestion to trucked between the five container terminals in Singapore (BDP International, 2012).

In terms of labour costs, automation reduces labour costs as manual drivers will be displaced with robotic machines to carry out routine work. Due to Malaysia's lower labour and land costs, Singapore will be losing in cost competitiveness as many view Malaysia's ports as viable, cost-effective alternatives for regional transshipment operations (BMT Asia Pacific, 2014).

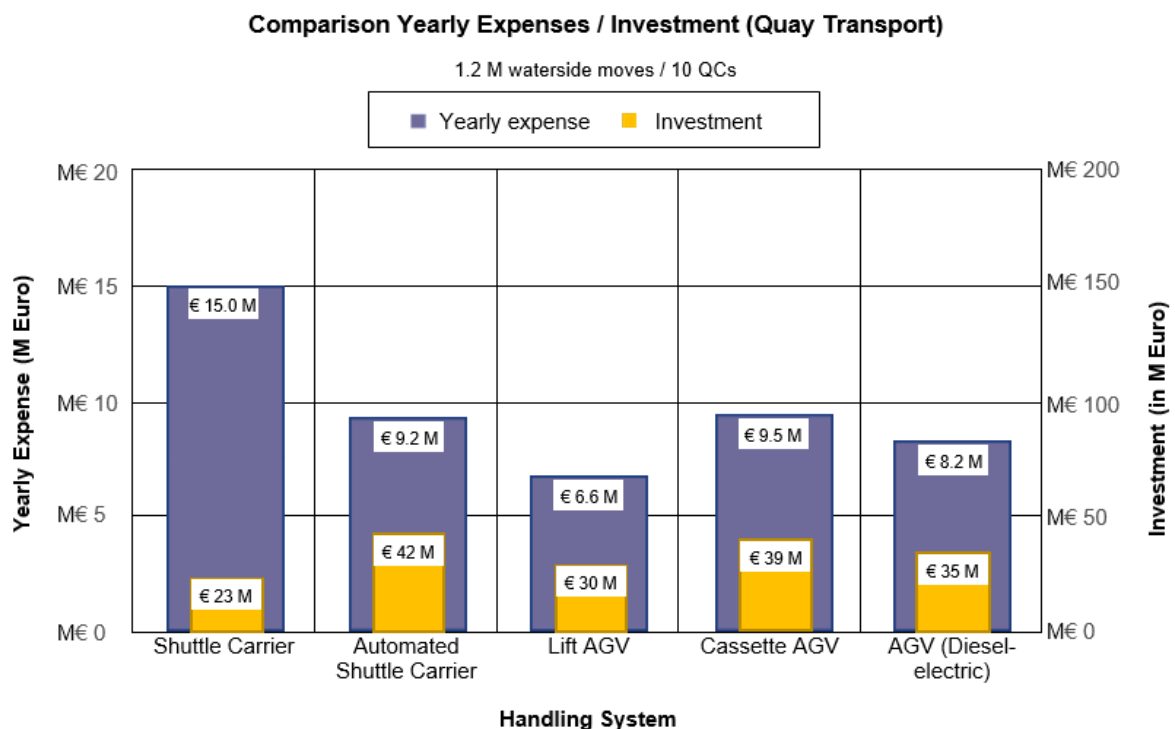


Figure 25: Comparison of manned system and automated system

(Source: TBA BV, 2017)

As seen in Figure 25, shuttle carrier which is the manned system, has a lower investment but a higher yearly expense as compared to the rest of the automated systems.

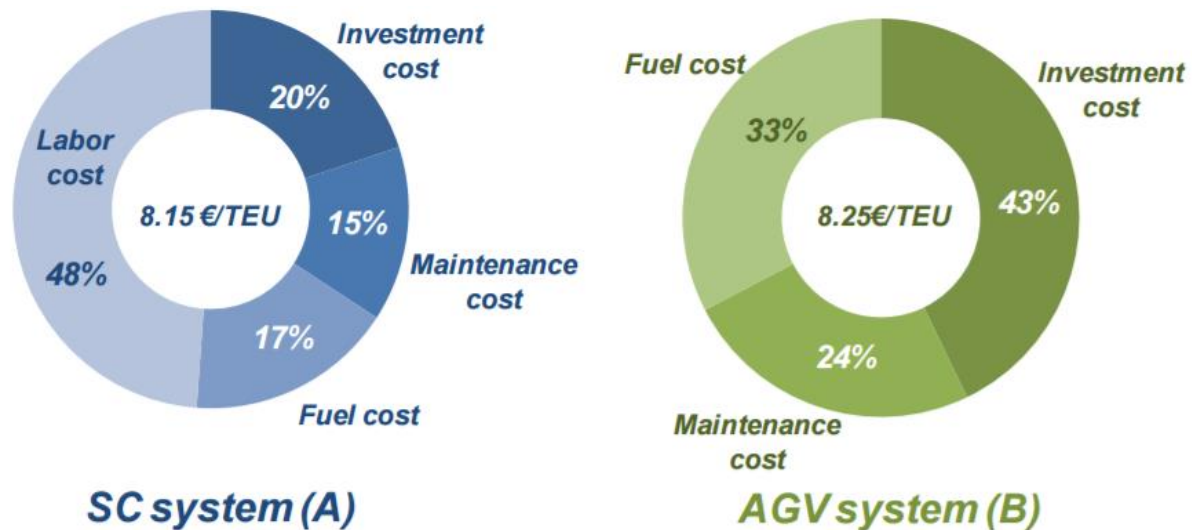


Figure 26: Cost differences between manned system and automated system

(Source: Saurí et al., 2014)

Therefore, saving on labour cost for manned system is crucial as it takes up 48% of the total operating cost whereas for automated system, the investment cost takes up the most percentage as seen in Figure 26. It is certain that implementation of automation reduces low-skilled labour cost, on the other hand, it requires high capital investment but generates lesser expenses annually.

According to Saanen et al. (2003), the overall cost of the automated terminal is significantly lower than of the manned terminal. Thus, reducing costs induced by operations, equipment or employment can increase the competitiveness of Singapore Port.

4.2.4. Environmental implications

4.2.4.1. Port Safety

In a social environment, automation promises all the benefits of safety, reliability, efficiency and reduced human error in port operations (Hepworth, 2016). It also reduces the impact of potential accidents where operations are physically carried out by workers. There is greater safety as fewer or no humans are present in the equipment operating areas (Davidson, 2016). Furthermore, automation also changes the working condition of operating workers by transitioning to indoor desk work. This will reduce workers' exposure to noise and other emissions, bad ergonomics or vibrations.

4.2.4.2. Green Practices

Green practices in the shipping industry such as using clean burning low sulphur fuels, environmental-friendly materials and equipment, and adopting environmental friendly design shipbuilding have positive impact on green performances and firm competitiveness (Yang et al., 2013).

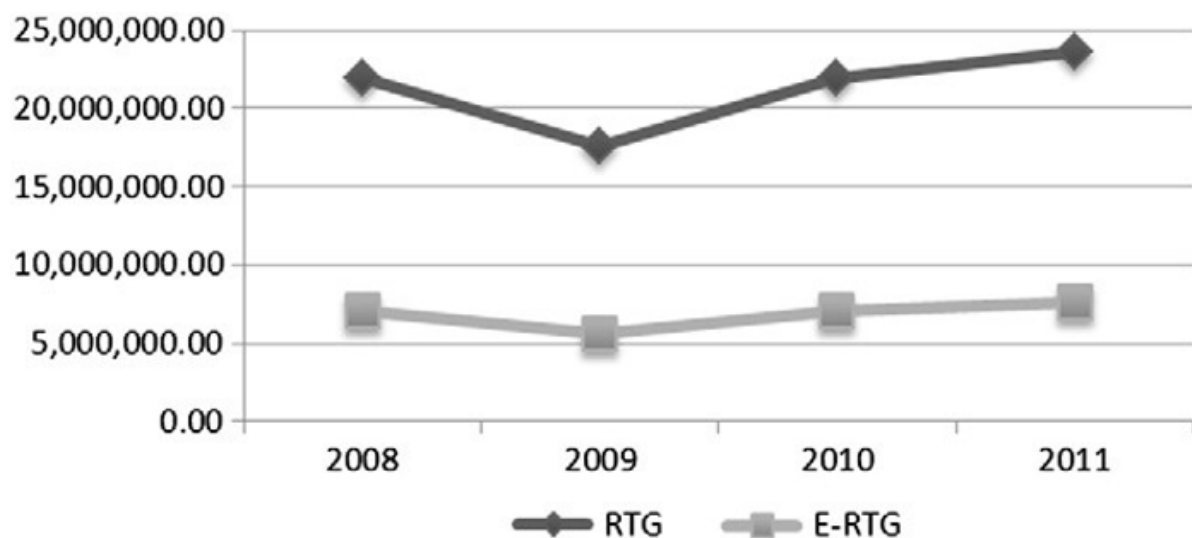


Figure 27: Comparison of total CO₂ emission of RTGs and ETGs (kg)

(Source: Yang and Chang, 2013)

Converting from RTG to Electric Rubber Tyred Gantry (E-RTG) is one way for port operators to reduce fuel consumption and CO₂ emissions. Half of CO₂ emissions generated by terminal operations are often accounted by diesel-powered RTGs, furthermore the economic and environmental effects of conversion are

correspondingly large (Conductix, 2012). The use of E-RTGs can reduce CO₂ emissions by 60% to 80% as compared with conventional diesel-powered RTGs as seen in Figure 27, which can result in decreasing by 20% per TEU handled in the overall terminal CO₂ emissions (Naicker and Allopi, 2011).

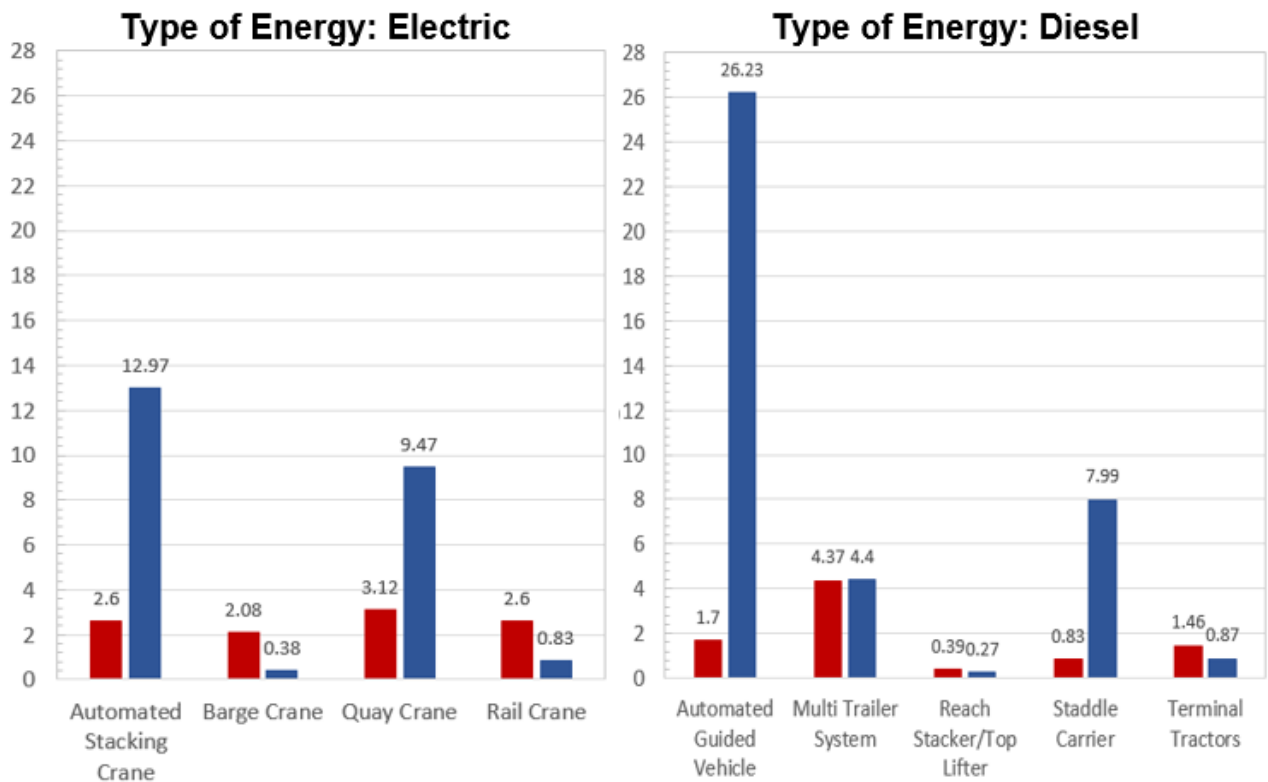


Figure 28: CO₂ emissions per equipment using two different type of energy

(Source: Geerlings and Duin, 2011)

With respect to the mitigation of CO₂ emissions, compared with the electrically powered equipment, the diesel-powered terminal equipment represents a large fraction of the total CO₂ emissions by transshipment processes as seen from Figure 28. Since automated equipment is usually electric rather than diesel powered, they are potentially greener and more environmentally friendly (Davidson, 2016). MPA has been working closely with shipping lines to further reduce carbon dioxide emission through its Green Ship Programme (GSP).

With the increasing traffic in a busy port like Singapore, the reduction of emission may not be significant. However, Singapore is showing their effort by investing initiatives and programmes that incentivise maritime companies to adopt green shipping practices.

4.2.5. Land space implications

Singapore has been reclaiming land using the landfill method to overcome land constraints (LSH, 2011). Thus, to break the current berth capacity ceiling, one potential idea is to use a two-tiered container terminal which will significantly increase the yard storage capacity and quay crane productivity (Tan, 2015). It is often decided on the terminal-design level to improve yard density by increasing the stacking height of yard blocks, due to growing container volumes and scarce land resources (Kempe, 2013)

Based on Figure 29, while comparing the stacking tiers of SCs with RMG and AGV, it is certain that SC only has a medium stacking density. Its strength is more on horizontal transport as it can travel faster without following a pre-set route, however, it could cause congestion within yard area during peak period. RMG cranes are normally dedicated to a specific area and unable to move long distances, AGV play its part by relieving traffic congestion, through following a pre-set route between rail and yard operations. Thus, the combination of RMG and AGV allows stacking to reach 4 to 5 tiers which increases the yard capacity tremendously. With more yard space available, storage-day charges decreases which will increase cost competitiveness.

<i>Operations System</i>	<i>Required equipment per Quay Crane</i>	<i>Stacking Tiers [1-over-<i>n</i>-high]</i>	<i>Yard Capacity [TEU / ha]</i>
<i>Pure SC</i>	4–5	2	500
		3	750
<i>RMG & AGV</i>	5–6	4–5	1,000 (or more)

Figure 29: Comparison of capacity between SC and RMG with AGV

(Source: Brinkmann, 2011)

Singapore is not restricting itself to traditional port layouts and is actively thinking out of the box to intensify land use. There is also the possibility of developing underground storage (Han, 2016). Tuas port as a greenfield site will offer an opportunity to try out new concepts in terms of land use (Seatrade Global, 2015). The space available for development are usually located in adjacent areas fronting the coast and river, container terminal is expanded to capitalise on economies through larger-scale production by generating higher traffic volumes in bigger land (Yap and Lam, 2013). This strategy is utilised by many ports to stay ahead of competition and to construct sustainable land space for long-term port development.

4.2.6. Service Quality implications

Service quality is generally defined by Zeithaml (1988) as the consumer's perception and judgement about a company's service performance. Services provided to port customers must be efficient and reliable to increase competitiveness. As seen in Figure 30, all city terminals including PPT will be gathered at the west side of Singapore. In a transshipment hub, there is often a need to transport containers between terminals by trucks. Thus, centralising all port activities in Tuas will help boost efficiency and economies of scale, these elements are critical to a transshipment port (Kan, 2012). Furthermore, it eliminates the need for inter-terminal haulage which will reduce the time taken and business costs for operation as well as relieve road congestions.



Figure 30: Overview of the Tuas Terminal

(Source: Kaur, 2017)

Singapore has started trials for truck platooning which involves a human-driven lead truck leading a convoy of driverless trucks (Abdullah, 2017). The trial will initially involve transporting containers from Brani Terminal to PPT along a 10km long test route on the West Coast Highway as seen in Figure 31 (Riviera Maritime Media, 2016). Truck platooning will also alleviate shortage of manpower, and allow more freight movement to be conducted at night to ease traffic congestion (MOT-PSA, 2017). The

technology may eventually be scaled up for haulage within the port area instead of between terminals. Autonomous truck platooning enable better service quality and increases port productivity, competitiveness increases.



Figure 31: Designated route for autonomous truck platooning trials

(Source: MOT and PSA, 2017)

4.3. Discussion

In this segment, the research will evaluate whether port automation serves as a solution for increasing competitiveness in Singapore through meeting research's objectives.

The objective (1) and (2) of the research in chapter 1 are achieved through a detailed literature review in chapter 2. It is important to understand the maritime trend of adopting automation and hence the concept of automation was introduced. Various benefits from the application of automation were mentioned, such as improving efficiency with automated equipment and systems. Port efficiency affects competitiveness, thus being one of the crucial factors in analysing the feasibility of automation as a solution for Singapore Port. Current features of Singapore Port such as the transshipment hub and the future Tuas terminal are also elaborated for further understanding of research.

The increasing size in vessels is a common challenge for most ports, land constraints has been a constant troubling issue for Singapore as well as competition from neighbouring ports have been a challenge since they emerged. Hence, the need for automation aims to grow Singapore port and maintain its position as a global port hub as well as an international maritime centre. The current and future level of automation was addressed in this research to give a clearer idea on Singapore Port's growth and efforts in increasing competitiveness. Advantages and disadvantages of automation were identified in the operations, economic, labour force, service quality and environment areas. Factors affecting competitiveness were listed to further examine impact of automation and also to ensure reliable analysis to be performed in the later chapter.

Objective (3) and (4) are achieved through analysing the data collected and discussion based on automation's impact on Singapore Port and whether it serves as a feasible solution for increasing competitiveness in chapter 4. Using a thematic analysis, codes were identified in the earlier literature and then classified into a total of 6 themes. The researcher has summarised the contribution of advantages and disadvantages to increasing port competitiveness in Table 3.

Table 3: Summary of the impact of automation contributing to competitiveness

(Source: Author's Own, 2017)

	Advantages	Disadvantages
Operational Performance	• 24/7 working hours with consistent operations • Increased speed of operation • Increased operational productivity and berth productivity • Better organised planning due to increase predictability of operations • Shorten vessel waiting time • Relieves port congestion With improving port productivity, competitiveness increases.	• Lacks flexibility in operational planning • Possibility of equipment breakdown resulting in operational delays • Time invested to plan, test and develop automation systems
Manpower	• Creates higher-level job opportunities • Up-skilling opportunities for workers • New skills and responsibilities acquires result in pay rise With better skilled workforce, competitiveness increases.	• Possibility of retrenchment for low-skilled workers

Cost	• Reduction in labour costs by reducing manpower • Reduction in operating costs by increasing efficiency • Increased in container throughput by reducing container handling charges • Reduction in maintenance costs in the long run With lower costs, competitiveness increases.	• Requires large initial capital investment • High initial maintenance costs • Investment in high-skilled workers
Environmental Impact	• Increased safety and reduced potential accidents in port operations • Increased use of low sulphur fuels and environmental-friendly equipment • Reduction in CO₂ emissions • Actively participating in Green initiative programmes Positive green port performances, competitiveness increases.	
Land Space	• Increased land space for development • Increased yard storage capacity • Improved yard density More yard space, storage charges decreases, competitiveness increases.	• High landfill cost

Service Quality	• Increased efficiency and reliability in services • Increased accessibility within port With better service quality, competitiveness increases.	
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As seen in Table 3, it is certain that the implementation of automation has much more potential benefits than negative impacts as well as its contribution to increasing port competitiveness. From the analysed data, Tuas port being a greenfield site and also located at the far western part of Singapore away from the city, that part of land is of lesser commercial value and closer to the industries it supports in longer term (Lui and Tan, 2001). Many new technologies or concepts can be tested, such as AGV, Autonomous Truck Platooning and also Automatic Yard System, in this greenfield to enhance Singapore's competitive advantage as a global hub port. With reclaimed land, Singapore enjoys its large container capacity resulting in improving economies of scale and efficiently handle upcoming mega ships which would justify the operating, labour and equipment costs by generating higher traffic volumes. With new high-technology introduced, skilfully trained labour to expertise in that particular field is needed. Thus, to meet the sector's long-term demand for talent, the Singapore Maritime Foundation is working with government agencies and private companies to offer incentives such as scholarships (Kuar, 2017). Furthermore, port operators working on low-skilled job with be offered to take up trainings to work with high-skilled jobs in the future.

Keeping up with positive impact of a green port, Singapore will be developing a vibrant International Maritime Centre (IMC) eco-system to raise its competitiveness as a destination for business, and strengthen the suite of maritime services (MPA, 2015). Therefore, automation can be seen as a long-term project as beneficial results need a period of time to show, such as the improvement in port productivity and connectivity as well as the increase in port capacity to accommodate the growing transshipment industry.

5. Conclusion

Looking ahead in the future, port operators will face a different set of challenges. The usual challenges such as the increasing in size of container ships, growing numbers of feeder vessels and ship connections put pressure on many transshipment port in the world. With the recent trend of port expansion and automation as well as the time that needs to be taken into account for developments and establishments, new innovations has to be explored and port layouts has to be forward planned and designed based on predictions of maritime future. Being part of an industry which is highly influenced by the dynamic economy and the competitiveness of the market, technology becomes a key role in enhancing the business efficiency and productivity.

The future Tuas mega port which is scheduled to open in phases from 2020, becoming one of the world's largest port when finalized. It will be incorporated with smart and green technologies in its operations, which further boost the port with high standard of service quality, handling efficiency and knowledgeable employees, on top of that, a positive influence on image with green practices. With the increase in competitiveness, port automation for Singapore is certainly feasible, furthermore it will be greatly anticipated to witness more of its contributions in the future. The aim of the research is achieved as it is definite that automation is essential for the growth of Singapore port and increasing its competitiveness. Thus, Singapore's continuous investment in automation will be justified with higher efficiency once Tuas mega port is fully completed.

The limitations of this study include having limited data provided from official port authorities' websites. Due to time constraint, primary data cannot be collected thus the research focused more on collecting secondary data through archival research and analysed using data collected and factors to substantiate the study. Due to the limitations of the study, the research focused mainly on automated handling processes. Therefore, the research has identified some future research work.

Singapore has to keep a wary eye on its neighbouring competitors consistently to keep up with the competition. Being so geographically close to each other, there is always a tight competition in transshipment cargoes. It will take time to see the growth of container throughput upon implementing automation, however, competition from neighbouring ports are inevitable a constant challenge for Singapore. Thus, it can be

further research into analysing Singapore's Tuas port against other regional competitors like Hong Kong and Shanghai to remain competitive. Next, automated ships, self-directing terminal equipment, and truck and inland barge platooning can lead to radically different needs that ports require to meet (Meersman et al., 2016). Thus, further research into which of these technologies would emerge to be successful, and the impacts they would generate on different types of players can be explored.

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Appendix 1 - Ethics Form

UNIVERSITY OF PLYMOUTH FACULTY OF BUSINESS

ETHICAL APPROVAL OF ALL BUSINESS PLACEMENT REPORTS
AND RESEARCH-BASED DISSERTATIONS INVOLVING HUMAN SUBJECTS AND
MATERIAL COVERED BY CONFIDENTIALITY AT TAUGHT MASTERS LEVEL AND
BELOW

Please read the attached extract from the University of Plymouth's Research Policies and Procedures relating to Ethical Principles for Research involving human participants before completing and signing below.

Ethical Protection & Declaration

To the best of my knowledge and belief, the proposed research conforms to the ethical principles for research involving human participants contained in the University of Plymouth's Research Policies and Procedures with regard to the following (please tick appropriate box).

- | | | | |
|-----|----------------------|---|-----------------------------|
| (a) | Openness and honesty | Yes ☒ | No ☐ |
| (b) | Protection from harm | Yes ☒ | No ☐ |
| (c) | Right to withdraw | Yes ☒ | No ☐ |
| (d) | Debriefing | Yes ☒ | No ☐ |
| (e) | Confidentiality | Yes ☒ | No ☐ |
| (f) | Informed consent | Yes ☒ | No ☐ |

Note: I agree to abide by the ethical protocol. The Supervisor signs to state that he/she has read and is satisfied with the content of this application.

Sign below where appropriate:

Principal

Investigator: Name Tan Jia Qi

Signature



Date 6 May 2017