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The global trends of automated container terminal: a systematic literature review

W.K. Kon
Department of Maritime Management, Faculty of Maritime Studies, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia

Noorul Shaiful Fitri Abdul Rahman
Department of Logistics Management, International Maritime College Oman, Sohar, Sultanate of Oman, and

Rudiah Md Hanafiah and Saharuddin Abdul Hamid
Department of Maritime Management, Faculty of Maritime Studies, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia

Abstract

Purpose – Since the first automated container terminal (ACT) was introduced at Europe Container Terminals Delta Terminal in Port Rotterdam back in the year 1992, a lot of research had been done to improve the management of ACT. However, up until recently, the number of literature available still appeared scarce. Hence, this paper aims to review the collection of literature about ACT to generate an exhaustive summary to answer the formulated review question in this study.

Design/methodology/approach – Preferred reporting items for systematic reviews and meta-analyses to narrow down the search parameters of literature retrieved so that only relevant articles were only selected. The systematic literature reviews were applied to analyse the content of the articles retrieved to determine its journal ranking, research findings and timeline of publications.

Findings – The adoption of ACT technology by container terminal operators could increase the terminal efficiency in productivity, cost reduction and environmental sustainability. Owing to global environmental awareness, the research trend of container terminal field and container terminal operator in the terminal design is much more environmentally friendly oriented.

Research limitations/implications – The limited numbers of experts in the management of ACT are causing challenges in data collections.

Practical implications – The analysis of the global ACT trend could help academicians and industrial investors to review the revolution timeline of maritime technology in port and shipping that is happening rapidly.

Originality/value – The analysis of timeline and collective literature leads to the propose of the conceptual framework to determine the relationship between increased productivity, cost reduction and environmentally sustainable.

Keywords Technology, Systematic literature review, PRISMA, Container terminal, Automated container terminal

Paper type Research paper

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1. Introduction

The rapid economic growth due to global trade is causing the container terminal operator to increase the handling capacity of the terminal; the importance of automated container terminal (ACT) is becoming increasingly prominent due to the fact (Zhao *et al.*, 2019). The dynamicity of the global trade market required the modern-day container terminal to increase their strength in handling the large volume of containers, currently ACT implementation is in the favourite list of Port and shipping Stakeholders (Wang *et al.*, 2019b). The development of ACT speared the new direction of the port industry in the future, it could be considered as the major revolution in port construction; as the first ACT was built at the Port of Rotterdam in Netherland, other countries such as Singapore, German, UK and Japan had successively emulated the strategy of port automation and the commissioning of ACT (Wang *et al.*, 2019b). Figure 1 shows the numbers of the ACT being built every year. Since the year 2012, the development of ACT had been gaining popularity. Until 2017, 30 ACT was built during the time duration, this number makes up 60% of the ACT available worldwide (PEMA, 2016; UNCTAD, 2018).

The construction of ACT requires large capital investment and it would have generated a lot of impacts on the surrounding area. The container terminal operator would have to take a lot of aspects into consideration before decided to build one. Hence, the question to be answered within this study was formulated as follows:

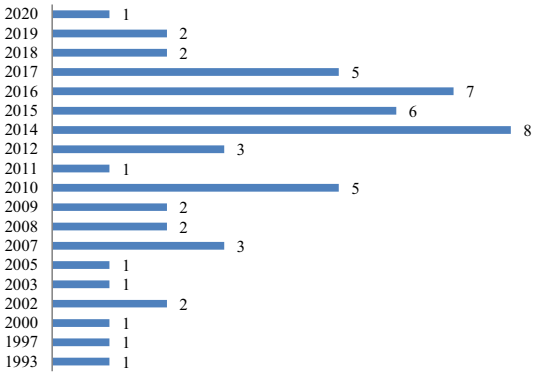
Q1. Why would conventional container terminal adopt the technology of ACT?

In this study, large amounts of literature will be reviewed in an attempt to find the answer to the formulated question. It would enable the understanding of the trending phenomenon that causing the popularity of ACT development. The literature collections will provide the scholar views on the trending phenomenon that will generate the outcome for a contribution towards the future study.

2. Review methodology

2.1 Systematic literature review

Systematic literature review (SLR) was used to review existing literature of scientific topic in a far more objective and organised way; it could be considered as a less biased evidence-



Source: Developed based on data from PEMA (2016), UNCTAD (2018)

Figure 1.
ACT built every year worldwide

based conclusions review methodology that would lead to the gradual adoption and acceptance of theoretical framework (Munn *et al.*, 2018). Conducting SLR is recommended before began research to study the previous research studies and briefly understand the advances made so far in global regarding a particular research topic; SLR could provide answers in more scientific secure conclusions based on large collections of literature (Schünemann *et al.*, 2017). By using SLR, existing literature could have been review more rigorously and transparently through the investigation of studies from various scientific sources; this type of review method is reliable and organised as it could reduce the risk of getting inaccurate conclusions that are too subjective or incomplete (Maynard *et al.*, 2018). One of the notable strength of SLR is that it could provide a summary of massive current literature that noted in detail and ready to be updated and amended based on current research needs; when combined with preferred reporting items for systematic reviews and meta-analyses (PRISMA) proposed by Moher *et al.* (2010), it could assist researchers to report the analyse outcome of reviews systematically through the steps of scoping, planning, identification, screening, eligibility assessment and interpretation of the result. After formulating a review question, SLR is required to seek for the answer through a series of actions such as identification, selections and critical appraisal where it would follow a clearly defined protocol before the review began; the searches of literature would be done comprehensively throughout multiple databases to identify all literature replicated or reproduced to generate a result that could specifically answer the formulated review question (Dewey and Drahota, 2016).

2.2 Setting review criteria

To perform SLR on collected literature, it is necessary to formulate a review question. The formulated question was available in Section 1 based on the problem statement that exists in the current trend of the maritime industry. However, merely the word of mouth and journal articles (UNCTAD, 2018; Wang *et al.*, 2019a; Zhao *et al.*, 2019) were genuinely insufficient to justify the necessity to carry out the study. Hence, it was decided then to identify the criteria that would function as a beacon to perform the review. In this study, the criteria would be originated from a scholar who is well experienced in the research field of maritime studies. After reading a series of literature, it was found that the publication in 2017 titled *The Future of Port Logistics: Meeting the Challenges of Supply Chain Integration* by *Professor Theo Notteboom* and *Kris Neyens* critically mentioned several criteria that would contribute to the answer of formulated review questions. Table 1 below shows the detail of the identified criteria within the publication.

Table 1. Identified criteria to answer the review question

Content identified as criteria	Page
. . . Companies will have no choice but to perform in the most **environmentally sustainable** way possible; one because the political and legislative will is inexorably driven that way; two because the consumers want it and three because reducing waste and fuel **reduces cost** . . .	26
. . . Differentiation and **cost optimisation** can be achieved through improved online customer experience and automation . . .	38
. . . To this extent companies must further invest and focus on **tackling** the most pressing **challenges** of port infrastructure such as spatial constraints and the pressure on **productivity** . . .	78

Source: Notteboom and Neyens (2017)

2.3 Systematic literature review framework design

Figure 2 shows the process steps of SLR with PRISMA integration to review the articles searched in this study. The framework contained the integration of the SLR review process (Dewey and Drahota, 2016; Maynard *et al.*, 2018; Munn *et al.*, 2018; Schünemann *et al.*, 2017) and the PRISMA framework proposed by Moher *et al.* (2010). The designed framework would provide a graphical view of how the review process was carried out towards the findings of results.

Based on Figure 2, the review started with the formulation of the review questions that serve as a primary focus within this study. A formulated question defined protocol or plan where the criteria are clearly stated before the review will be conducted (Dewey and Drahota, 2016). In this study, the question formulated attempts to find out why Conventional Container Terminal would adopt the technology of ACT.

The next process of the review methodology was begun by setting the review criteria for the upcoming articles searching process. The setting of selected search criteria will determine the inclusion and rejection of searched studies in literature searching to answer the formulated review question by minimizing selection bias as minimum as possible (Piper, 2013). In this study, the search criteria were based on the content retrieved from *The Future of Port Logistics: Meeting the Challenges of Supply Chain Integration* by *Theo Notteboom* and *Kris Neyens* that was published in 2017.

Upon the complete set of review criteria, the search of the literature was begun. The upcoming four stages will be regarded as the process of PRISMA that was mentioned in Section 2.1. PRISMA was regarded as an evidence-based minimum set of items to assist the researcher in reporting the systematic review and meta-analyses that had evaluated collected research studies and literature (Moher *et al.*, 2010).

The first stage of PRISMA was the identification of articles journals. At this stage, articles from various journals will be retrieved from the search database such as Science Direct, Springer Link, Taylor and Francis Online, Web of Science, SCOPUS and Emerald Insight. There were 1,819 articles journals in total that were retrieved from the mentioned databases.

The second stage of PRISMA was the screening of articles journals. The articles identified in stage one was examined thoroughly to exclude the duplicated articles of the same titles that were available in multiple search databases. Upon the finish exclusion of duplicate articles, the articles that were unrelated to the ACT research scope were removed as well. At the end of this stage, there were 1,303 articles in total were excluded and 516 articles in total were screened and remain.

The third stage of PRISMA would be the process of articles reviewing. In this stage, the article review would be reviewed in an attempt to retain those articles were eligible for further review later. The articles that were retained at this stage would be those which were discussed about the outcome of ACT technology adoption in container terminal such as productivity, cost and environmental. This stage would use the criteria that were mentioned in Section 2.2. The stage concluded with the exclusion of 293 articles and only 223 articles remained.

The fourth stage of PRISMA would the identification of findings. This stage would identify the articles that mentioned the findings of AC adoption in the container terminal. The articles that achieved the findings associated with the adoption of productivity, cost and environment would be valuable for further review later on. Like the previous, stage criteria of Section 2.2 were also used in this stage to narrow down the review. Towards the end of the PRISMA, there were 46 articles in total were removed and 177 articles in total were retained.

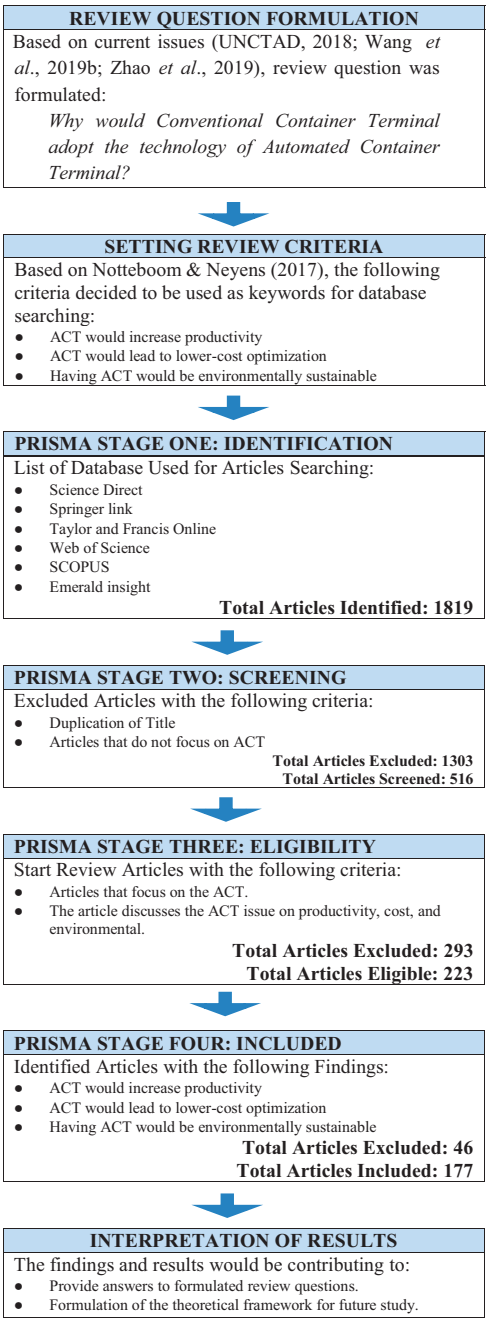


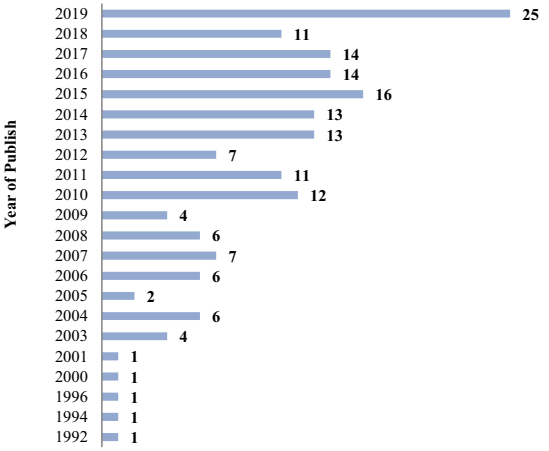
Figure 2.
SLR with PRISMA framework

Finally, the 177 articles that were retained after the stage of PRISMA would be reviewed comprehensively in an attempt to identify the findings within the articles. The accumulated findings in the articles would be recorded in statistical form to find out the trend that would provide answers for formulated review questions in Section 1. Also, the results would contribute to the formulation of the theoretical framework for future study.

3. Systematic literature review descriptive analysis

The first ACT that started the operation was the Europe Container Terminals (ECT) Delta Terminal in Port of Rotterdam in the year 1993 (Evers and Koppers, 1996). Due to this, it was decided that the literature timeline search began from the year 1993 onwards. The search was made through databases such as Science Direct, Springer Link, Taylor and Francis Online, Web of Science, SCOPUS and Emerald insight. The retrieved articles from these databases were 1,819 in total at the beginning during the PRISMA Stage One (Section 2.3). At the end of the process, only 177 articles remained after the extensive review process.

Figure 3 shows the number of articles published from 1992 until 2019 that were reviewed in this study. It appears that the papers that discussed the potential of ACT were quite low in numbers before the year 2010, there only less than 10 articles published globally during the time. Probably the ACT technology at the time was still at the infancy stage, a lot of technical problems persist; stakeholders and investors were still lack of confident to implement in such an advanced technology due to engineers were still experiencing with trial and error design in the technology (Hoshino *et al.*, 2007). However, starting 2010 saw a notable increment in the articles published regarding the ACT; more than 10 articles were published every year until recently, except for 2012 which only 7 articles were published. The trend of increase in publishing could be because of the increase of ACT construction that happened at the same time that accompanies by the increment in research demand to improve the productivity of the container terminal (PEMA, 2016; Sauri Marchán *et al.*, 2014; UNCTAD, 2018). By the year 2019, 177 articles discuss ACT were published in total



Source: Developed Based on Systematic Reviewed Literatures

Figure 3.
Yearly ACT themed article published

It is very essential to identify the source of articles in terms of the journals where it was published; the identification of journal sources would determine the impact factor of the articles where it was published based on their relevant disciplines (Garcia *et al.*, 2011). Furthermore, the reputation of journals would also determine the quality of the research produced to ensure the reliability of the findings discussed (González-Pereira *et al.*, 2010). In Table 2, the journals that published articles regarding ACT were shown to determine the favourable journal towards the title. The journal of *OR Spectrum* had the highest frequency of articles published that discussed ACT; it published 23 articles in total from the year 1992 until 2019. The next journal that favours ACT articles publication is the *European Journal of Operational Research* which published 13 articles in the same period. Also, the journal *of Computers and Operations Research* already published 12 articles that discussed ACT in the findings from the same time frame as well. The rest of the articles were published in small numbers across the various journals in different disciplines. The journals which have a high frequency of publishing the ACT related articles would enable the researcher to consider the subscription for the latest research issues to get the latest update for the contribution in the future research of the same discipline.

4. Findings and discussions

4.1 Automated container terminal improved productivity of the port

The adoption of ACT technology in container terminal would minimise the inefficiency problem that caused the delay in container handling processes by reducing the total travel time of vehicles within the container terminal to increase productivity; ACT could improve the efficiency of the port through the integration of vehicle scheduling and container yard storage plan to minimise the turnover time of vessel that also contributed to the productivity of container terminal (Luo *et al.*, 2016). The adoption of ACT technology in a container terminal is increasing due to the rapid development of global trade that requires the terminal operator to seek technology that could offer higher productivity (Yang *et al.*, 2018). Furthermore, the introduction of automated container operations had proven the solution to be effective and efficient in addressing the problem of space limitation within the container yard (Abdul Rahman *et al.*, 2016).

Figure 4 shows the numbers of articles that supported ACT have higher productivity compare to the conventional container terminal. Before the year 2010, the research about ACT remains very low in numbers; hence, the articles with the related findings that ACT improved productivity of port also very limited. However, there is a significant increase in publishing starting from the year 2010 and beyond. As of 2019, the number of articles with the related findings that ACT improved productivity of port reached 18 articles in the same year. The trend of increase in article publishing was also in line with the trend of increase in ACT construction that happened since 2010 as shown in Figure 1. Hence, it is sufficed to say that the adoption of ACT technology by conventional container terminal is necessary to increase their productivity to remain competitive within the port industry; the container terminal that reluctant to do so would face the grave challenges in competing with other advanced port around the globe to survive.

4.2 Automated container terminal lowered the operation cost

The terminal operators constantly improve the technology to reduce the operating cost that would generate considerable profits; ACT greatly reduces the labour dependency and labour cost that resulted from the epoch effect of automation technology development in container terminal (Li and Lu, 2019). The increasing trend of adoption of ACT technology also resulted from the rapid development of global trade that requires terminal operators to

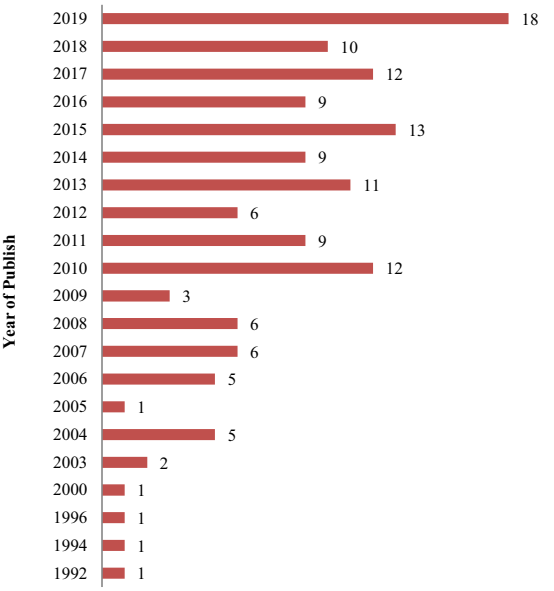
Journal title	Quantity	Quartile ranking
Advanced Engineering Informatics	3	Q1
Advanced Robotics	1	Q1
Annals of Operations Research	1	Q1
Applied Mathematical Modelling	2	Q1
Applied Soft Computing	2	Q1
Automation in Construction	1	Q1
Computational Management Science	1	Q1
Computers and Industrial Engineering	12	Q1
Computers and Operations Research	1	Q1
Control Engineering Practice	1	Q1
Engineering Optimisation	1	Q1
European journal of operational research	13	Q1
Expert Systems with Applications	4	Q1
Flexible Services and Manufacturing Journal	9	Q1
Industrial Management and Data System	1	Q1
International Journal of Control	1	Q1
International Journal of Flexible Manufacturing Systems	1	Q1
International Journal of Physical Distribution and Logistics Management	1	Q1
International Journal of Production Economics	9	Q1
ISA Transactions	1	Q1
Journal of Cleaner Production	2	Q1
Journal of Intelligent and Robotic Systems	1	Q1
Journal of Intelligent Manufacturing	3	Q1
Journal of Optimisation Theory and Applications	1	Q1
Journal of the Operational research Society	3	Q1
Journal of Zhejiang University-Science	2	Q1
Maritime Economics and Logistic	5	Q1
Maritime Policy and Management	2	Q1
Ocean Engineering	1	Q1
OR Spectrum	23	Q1
Research in Engineering Design	1	Q1
Research in Transportation Business and Management	2	Q1
Research in Transportation Economic	2	Q1
Robotics and Autonomous System	2	Q1
Simulation Modelling Practice and Theory	1	Q1
Transport Policy	3	Q1
Transportation Research Part A: Policy and Practice	2	Q1
Transportation Research Part B: Methodological	1	Q1
Transportation Research Part C: Emerging Technologies	7	Q1
Transportation Research Part E: Logistics and Transportation Review	5	Q1
World Development	1	Q1
Information Technology and Management	1	Q2
Journal of mechanical science and technology	1	Q2
Journal of Simulation	1	Q2
Mathematical Problems in Engineering	4	Q2
Periodica Polytechnica Transportation Engineering	1	Q2
Polish Maritime Research	1	Q2
Procedia Manufacturing	1	Q2
Sustainability	1	Q2
WMU Journal of Maritime Affairs	2	Q2
IFAC Proceedings Volumes	8	Q3
IFAC-Papers On-Line	1	Q3

(*continued*)

Table 2.
Quantity of articles included in the review

Journal title	Quantity	Quartile ranking
Natural Computing	1	Q3
NETNOMICS: Economic Research and Electronic Networking	1	Q3
The International Journal of Advanced Manufacturing Technology	1	Q3
Open Automation and Control Systems Journal	1	Q4
Journal of Innovation in Digital Ecosystems	1	Unranked
Procedia CIRP	2	Unranked
Procedia-Social and Behavioural Sciences	1	Unranked
Transportation Research Procedia	4	Unranked
Total Journal reviewed	**177**	

Table 2. **Source**: Developed based on systematically reviewed literature

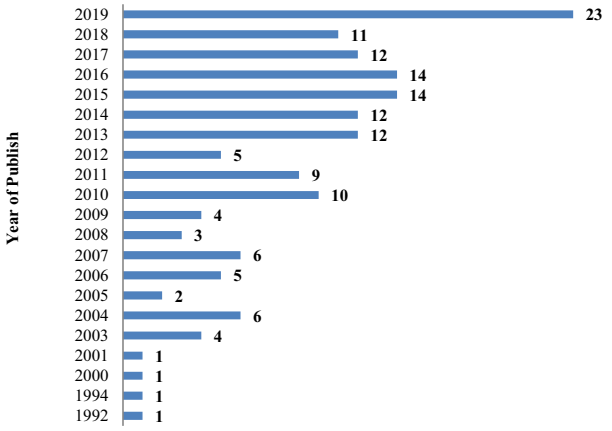


Source: Developed Based on Systematic Reviewed Literatures

Figure 4. Yearly published articles that supported ACT improved productivity

constantly seeking for technology that could generate more profit by reducing cost (Yang *et al.*, 2018). ACT is necessary to provide cost-effective cargo handling services; cargo transporter, terminal operators shipping companies and port authorities are willing to adopt the cutting edge technology to achieve maximum cost savings (Gharehgozli *et al.*, 2019). Furthermore, ACT could reduce the overhead cost for ports and terminals by using the energy at a more efficient level; energy efficiency utilisation in ACT means the same quality of services still can be retained by using less energy at a lower cost (Iris and Lam, 2019).

The articles that supported that ACT lowered the operation cost that was published yearly were presented in Figure 5. The numbers of research regarding ACT remain low



Source: Developed Based on Systematic Reviewed Literatures

Figure 5. Yearly published articles that supported ACT lowered the operation cost

before the year 2010; this is also the reason why the articles with the findings of ACT lowering the operation cost were limited as well. Starting from 2010, the numbers of articles publishing in related topics were increased significantly. By 2019, the number of articles with the findings of ACT lowered the operation cost reached 23 publications in the same year. The increasing trend of publication could be highly associated with the trend of increase in ACT construction that started in 2010 that could be referring to Figure 1. Hence, it was sufficient to claim that the adoption of ACT technology by conventional container terminal is essential to lower the operation cost of the terminal so that the competitiveness can be sustained in the long term.

4.3 Automated container terminal is environmentally sustainable

The rapid development of global trade and continuous construction of the green port is spearheading the direction of existing container terminal towards the adoption ACT technology; considering the high pollution carbon emission from the diesel engine, the replacement of diesel engine vehicles with electric-powered equipment could realise the minimise the effect of climate change and environmental sustainability of green port (Wang *et al.*, 2019a). The adoption of ACT applied the usage of advanced automated and environmentally friendly technologies had demonstrated the effectiveness of ecologically friendly container terminal such as ACT; the success of the first ACT in Port of Rotterdam had proven that ACT is a highly efficient and ecologically friendly container terminal that was recognised and widely accepted in the maritime industry and global port community (Shi *et al.*, 2019).

Figure 6 shows the numbers of research that were done with the findings of ACT are environmentally sustainable. Before the year 2013, the number of articles that were published remains very low with only one publication once in a few years. Beginning from the year 2013, there was a noticeable increase in articles published in relevant subjects but the numbers remained low with less than 10 publications within every year. The year 2019 saw a significant increase in the publication in the discussed matter as much as 14 publications. The trend of publication could be associated with the increasing environmental concerns of global warming due to carbon emission from diesel vehicles that

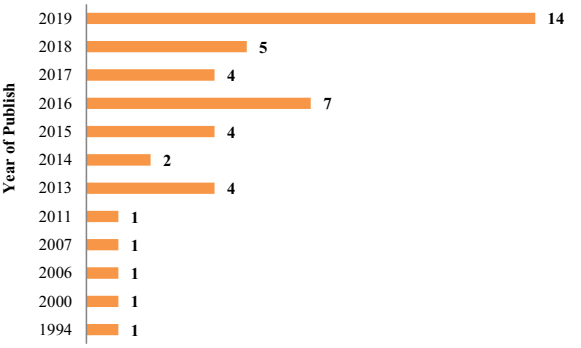


Figure 6.
Yearly published articles that supported ACT is environmentally friendly

Source: Developed Based on Systematic Reviewed Literatures

were mentioned by Wang *et al.* (2019b) that received lots of attention from scholars and industrial players. Thus, the collections of reviewed literature show that the ACT technology application in a container terminal is necessary to sustain environmental and the practice of green port; the sustainable green container terminal is necessary to reduce the negative impact of industrial waste into the natural environment that sustains the living of the human.

4.4 Overall journal articles distributions

Figure 7 shows the distribution of journal articles that were based on different findings that supported the adoption of ACT technology. There were 177 articles retrieved in total. However, each article may contain more than one finding. Hence, the number of articles distribution will base on the findings that were identified in each article.

Amongst the 177 articles reviewed, 141 articles mentioned about ACT technology could increase the productivity of the container terminal as shown in Figure 7. As the container vessel becoming bigger, the handling volume of the container also increased, the containers have to be processed as fast as possible; the demand for such kind of service quality requires the enormous productivity level of container terminals and only ACT could offer services at such velocity (Briskorn *et al.*, 2019). Hence, it is no surprise that the majority of container

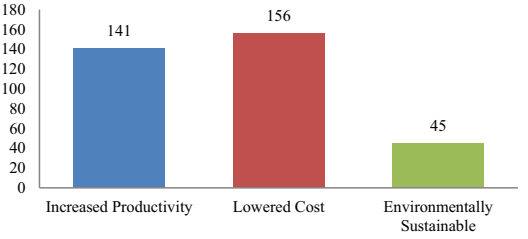


Figure 7.
Distribution of journal articles based on findings

Source: Developed Based on Systematic Reviewed Literatures

terminal stakeholders agreed that ACT could provide higher productivity levels compared to conventional container terminal that was still largely in practice at present.

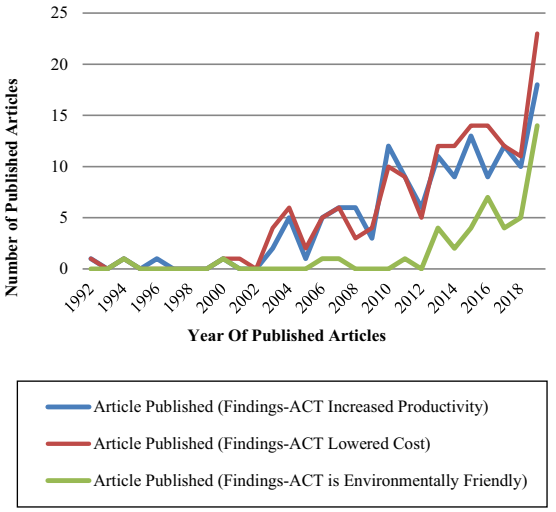
In terms of articles that mentioned the findings that ACT technology lowered the operation cost, there were 156 articles in total were identified during the review as shown in Figure 7. Bjerkan and Seter (2019) found that ACT could reduce the waiting time for the incoming and outgoing ship at Shanghai Port and Port of Gothenburg; by using the simulation model, they also confirmed that the ACT technology indeed improved the operational cost of the port. Hence, it is sufficient to say that the investor of the container terminal will always favour the new technologies that are more cost saving in the exchange for a higher profit margin.

The research of environmental concerns at the port surrounding area also received attention in recent years; this is proven by 45 publications of articles that found ACT is environmentally sustainable as presented in Figure 7. The increasing concern of the environmental impact of port activities and expansion due to climate change and energy conservation is becoming critical in recent year; the adoption of ACT technology based on the concept of Green Port is receiving a lot of acceptance amongst the port industrial players to ensure the environmental sustainability around the container terminal (Lam and Li, 2019).

4.5 The trend of findings in automated container terminal research

The research about the ACT saw its dusk begun in the year of 1992. Some of the noticeable pioneer researchers are Wan *et al.* (1992), Vepsalainen (1994) and Evers and Koppers (1996). These researchers open the path in the field of research about ACT; their research studies are still cited and benefitted the present researchers. The roles of these trailblazers in ACT research marks the beginning era of technology innovation in the port automation; as then, various institutions around the globe started to look deeper into the more specific findings in ACT research.

Figure 8 summarises the trend of ACT research remains low in the early 1990s until the early 2000s. Starting from the year 2003 and beyond, the ACT research started to show



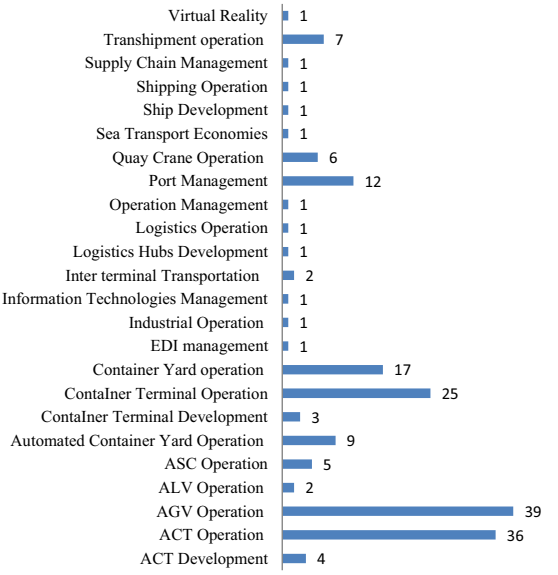
Source: Developed Based on Systematic Reviewed Literatures

Figure 8.
Trend comparison of articles published

some promising trend and reach the highest peak in the year between 2004 until 2006. The noticeable researchers that active in ACT research studies during the year 2000s are IFA Vis, Koo PH, Gunther, Grunow and Lau HY. These researchers focus on different aspects of ACT according to their research area. For example, IFA Vis done the research of ACT that focusses on operational management, Koo PH focusses on AGV fleet sizing, Gunther focusses on container terminal cargo handling, Grunow focusses on AGV despatching and Lau HY focusses on the scheduling of container handling equipment in the ACT. The publication's information on these research studies is available in the Appendix section.

4.6 The trend of focusses on automated container terminal research

The research of ACT reaches another threshold between 2014 and 2017 with more focusses on AGV as shown in Figure 9. The trigger of the research trends could be associated with the constructions of ACT around the globe that were so frequent at during the time, there was more than 20 ACT were built between 2014 and 2017, the numbers make up 30% of available of global ACT in total as of present. Overall the trend of research about ACT is gaining a lot of attention after the year 2017. There was a slight decrease in research studies in the year 2018; the numbers quickly increased in the year 2019 with more than 20 publications. The most obvious increase in the ACT research trend is the environmental sustainable focussed research papers, the possible reasons are that environmental concern and natural resources depletion is becoming a serious issue in recent years (Lam and Li, 2019). This research trend is also in line with the Sustainable Goals Development Policy that was proposed by the United Nations that was signed in 2015; this initiative aims to protect and restores the environment through continuous advancing economic and social development (Alexander and Delabre, 2019).

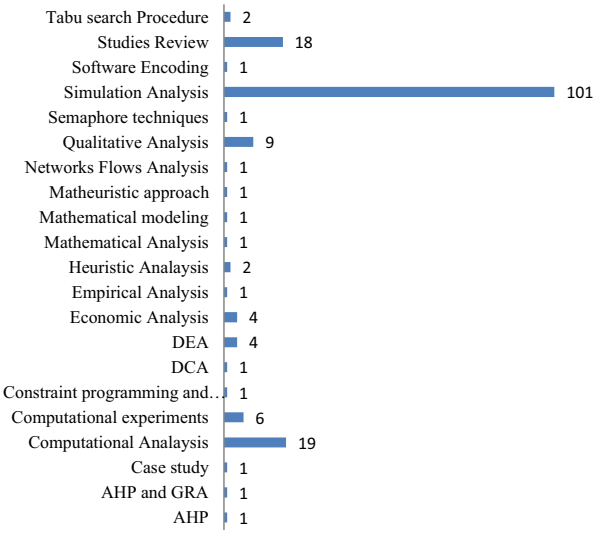


Source: Developed Based on Systematic Reviewed Literatures

Figure 9.
Research focus of articles published

4.7 The trend of innovations breakthrough in automated container terminal research

As the trade volumes expand, the demand for technologies with greater efficiency and productivity would be required. Such a demand spark light the motivation of the researcher to keep on improvises the current technologies with unique innovations every year. Figure 10 shows the innovations that were achieved by some scholars from the year 2016 until the year 2019. The *Intelligent Autonomous Vehicles Cooperative Model* that was developed by Bahnes *et al.* (2016) aimed to enhance the operational efficiency of the container terminal. In the same year, Chandrakumar *et al.* (2016) successfully incorporated *LEAN and Green Concepts* in transshipment terminal operations that ended up with productivity enhancement; a model based on this innovation was also developed. As the container vessels become bigger, the industrial players need to assess the necessity for technological upgrades; hence, Meng *et al.* (2017) developed the *Mega Vessels Impact Analysis Model* that specifically tailored for container terminal operations. Gattuso and Cassone *(*2018) were trying to develop a model that could reduce the operation costs of Automated Guided Wagon in container yard; their research outcome manages to introduce the *AGW Efficient Transport Model* that could level up the efficiency of freight transport in the container yard. As electric-powered vehicles become the norm in the industry, the battery life of the vehicles becomes one of the benchmark performances in the ACT; to improve the battery utilisation of electric-powered vehicles, Zhan *et al.* (2019) developed the model that could improvise the battery charging in the ACT. These mentioned innovations above are just tips of the iceberg that were being developed in recent years, more innovations reviewed results are available in the Appendix section in this article (Table 3).



Notes: DCA = Difference of Convex Algorithm; DEA = Data envelopment analysis; AHP = analytical hierarchy process; ALV = automated lifting vehicle
Source: Developed Based on Systematic Reviewed Literatures

Figure 10. Research methodologies of articles published

Articles published	Innovations
Bahnes, N., Kechar, B., and Haffaf, H. (2016). Cooperation Between Intelligent Autonomous Vehicles To Enhance Container Terminal Operations. Journal Of Innovation In Digital Ecosystems, 3(1), 22–29	Intelligent autonomous vehicles cooperative model
Chandrakumar, C., Gowrynathan, J., Kulatunga, A. K., and Sanjeevan, N. (2016). Incorporate LEAN And Green Concepts To Enhance The Productivity Of Transhipment Terminal Operations. Procedia CIRP, 40, 301–306	Productivity enhancement model through incorporate LEAN and green concepts
Meng, Q., Weng, J., and Suyi, L. (2017). Impact Analysis Of Mega Vessels On Container Terminal Operations. Transportation Research Procedia, 25, 187-204	Mega vessels impact analysis model
Gattuso, D., and Cassone, G. C. (2018). AGW For Efficient Freight Transport In Container Yard: Models And Costs. Transportation Research Procedia, 31, 108–120	AGW efficient transport model
Zhan, X., Xu, L., Zhang, J., and Li, A. (2019). Study On AGV Battery Charging Strategy For Improving Utilisation. Procedia CIRP, 81, 558–563	Battery charging utilisation model

Table 3.
Research innovations of articles published

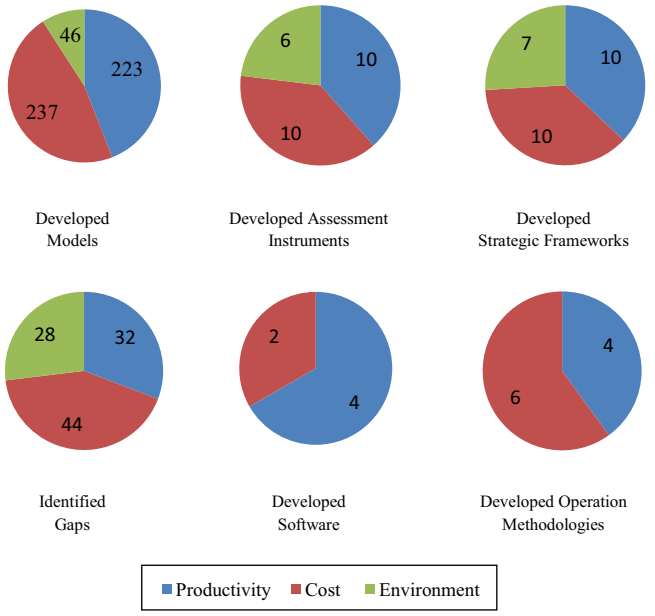
Source: Developed based on systematically reviewed literature

4.8 The trend of methodologies application in automated container terminal research

Various research methodologies were observed in articles published in the period from 1992 to 2019. The popularity of methodologies applied also correlates with the research focus of the researcher. Figure 11 shows the trend of methodologies that were applied in the research in the past until recently. In Figure 9 of Section 4.6, it was shown that the maritime operation remains one of the most popular topics for the research. The nature of the research that focusses on maritime operation requires the researcher to keep on looking for innovation to improve the productivity of the container terminal (Chandrakumar *et al.*, 2016). Using the data that were extracted from the real-world terminal operation, scholars such as Meng *et al.* (2017) would attempt to run the data in the virtual simulation to predict the different scenarios that were developed. This method of simulation analysis remains the popular technique until today due to its infinite possibility and opportunities for technological improvement. The simulation analysis methodology could be applied to the research that focusses on container terminal operations such as AGV Operation (Zhan *et al.*, 2019), Quay crane operation (Zhan *et al.*, 2019) and container yard operation (He *et al.*, 2019). Research method such as studies review that was applied in this paper may not seem popular amongst the researcher in the field of ACT, but it is still outstanding compare to other methods that were applied in the same field, a scholar such as Heilig *et al.* (2019) reviewed the IT application in the terminal management, while Doumbia-Henry (2016) reviewed the sustainability of the port terminal.

4.9 The trend of contributions in automated container terminal research

From 1992 until 2019, a lot of research studies had been completed with successful innovations and their contributions. Throughout the years, various simulation models had been developed to assist the terminal in the productivity improvement such as *Strategic Battery Charging* (Zhan *et al.*, 2019), *AGV Efficient Transportation (*Gattuso and Cassone, 2018) and *Productivity Enhancement Through Incorporate LEAN And Green Concep*ts by Chandrakumar *et al.* (2016). Besides simulation models, many researchers also developed the



Source: Developed Based on Systematic Reviewed Literatures

Figure 11. Research contributions of articles published

assessment instruments for container terminal; scholars such as Meng *et al.* (2017) developed *Impact Analysis For Mega Vessel*, Gil Ropero *et al.* (2019) developed *BootStrap Application for Port Efficiency* and Jun *et al.* (2018) developed *Input-Output Analysis for Smart Port*. Besides innovations, some researchers perform studies reviews such as this article to identify the research gaps amongst the existing studies; scholars such as Heilig *et al.* (2017) identified the gap of IT application in the seaport, Doumbia-Henry (2016) identified the gap of sustainability in port development and Iris and Lam (2019) who identified the gap of operation strategy in the container port. Figure 12 shows the total distributed numbers of innovations and output of the research studies in the ACT field from the year 1992 until 2019. For detail innovations produced by every scholar can refer to the Appendix section within this article.

5. Conceptual framework for future study

There was various research that was done before that attempt to find out the main reasons behind the adoption of automation technology by the maritime industry such as Bjerkan and Seter (2019), Iris and Lam (2019), Li and Fung (2019) and Zhang *et al.* (2019). The current SLR research paper found out that the adoption of ACT technology would increase the productivity of the container terminal, this is supported by the cumulative findings of 141 research articles that were reviewed systematically in this paper. Secondly, the adoption of ACT technology would lower the cost of the container terminal, cumulative findings of 156 systematically reviewed articles supported this. Finally, SLR analysis within this paper shows that the adoption of ACT technology would render the container terminal environmentally sustainable; there were 45 articles in total that supported this idea.

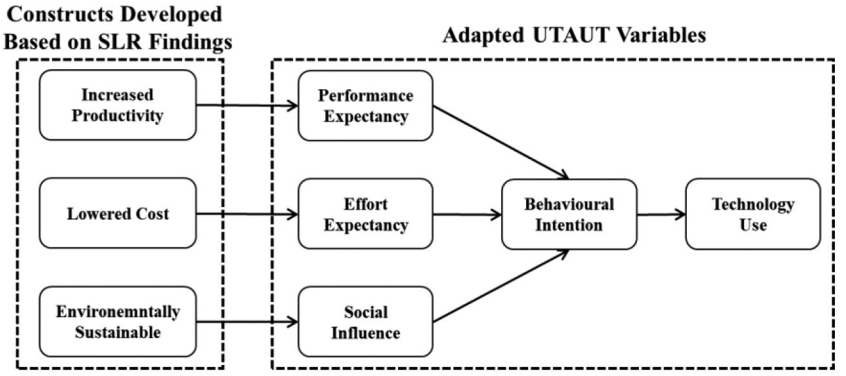


Figure 12.
Conceptual framework for future research

Source: Developed Based on Systematic Reviewed Literature and adaption of the UTAUT model by Venkatesh *et al.* (2016)

Future research will require a framework or model for describing, explaining and predicting the acceptance, adoption and use of ACT technologies in the container terminal industry. The conceptual framework will be based on constructs that were developed using the results that were obtained in this SLR study. As the target of ACT will be technology users, the conceptual framework will adapt UTAUT (Unified theory of acceptance and use of technology) variables from Venkatesh *et al.* (2016). Performance expectancy refers to the degree of using technology to help users in performing chosen activities. Effort expectancy refers to the degree of freedom to use technologies. Social Influence refers to perceptions that support the use of technologies. The conceptual framework will have constructs that suit the context and users of the container terminal industry. Finally, the purpose of identifying the drivers for adoption, adaption and use of ACT technologies will be investigated in detail. Figure 12 shows the developed conceptual framework formulated based on the results of the current SLR study and the adaption of the UTAUT model.

6. Conclusion

The volume of shipments will keep on increasing because of the convenience of global trade in recent years. Hence, the need for ACT in the port sector is inevitable. The ECT Delta Terminal at Rotterdam Port marks the new era of automation in the port industry. As time goes by, the ACT technologies will become more matured and reliable. Hence, the mass ACT technology adoption by the major container terminals around the world is just a matter of time. However, finding out the real factors ACT technology adoption is more relevant at the moment because it could assist the current container terminals that were not automated yet in deciding on the investment in automated technology.

The main purpose of this research is to verify the factors of ACT technology adoption by container terminal operators. The methodology used in this paper was SLR that systematically reviewed the existing literature. The collectively reviewed literature was analysed that generated statistical results after that. These results were significant in developing the conceptual framework that would benefit the future study of ACT research. Given the fact that ACT technology is not widely used around the world yet, this research would serve as a part of the contribution in collective literature for future researchers.

The literature reviewed in this paper mainly focusses on research about ACT and the outcome of its application in the maritime industry. The statistical results show that the research publications were rather slow at the beginning era of ACT introduction in the industry, probably due to limited locations of available ACT during the time. However, as time goes by, ACT numbers were increasing significantly and provide opportunities for scholars to initiate the study more conveniently. Additionally, the findings of the reviewed literature showed that the factors for container terminal operators to invest in the ACT were limited to production increment and cost reduction during the early days; however, the environmental concerns factor were taken into accounts at present.

Many works of the literature suggested that container terminal operators would benefit from the adoption of ACT technology in long term. The analysis results also show that quantitative methods were common in the literature with empirical statistics and only limited research studies that used qualitative methods in their studies previously. The used literature analysis technique in this study allowed the researcher to find out the pattern and trends of research findings that will generate clearer insights for future study. The ACT research topic could be considered a relatively fresh topic in the maritime industry because there are only limited numbers of ACT available around the world.

The research in the ACT could apply various methodologies ranging from operational research, case studies, economics modelling, simulation and software engineering due to the freshness of the topic. However, this literature review only assesses the trends of ACT research outcomes throughout the timeline. A broader review in the future probably could allow the expansion of a more detailed research area under the same topic. The conceptual framework that was generated at the end of the research aims to provide future research opportunities to conduct the study in the way of empirical.

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Corresponding author

Noorul Shaiful Fitri Abdul Rahman can be contacted at: noorul@imco.edu.om