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Simulation modelling in ports and container terminals: literature overview and analysis by research field, application area and tool

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Abstract The simulation modelling of shore- and sea-side port operations constitutes a fundamental prerequisite for effective project planning in port development, as the influence of numerous often interactive parameters has to be addressed at an early stage to account for the optimum supply of port facilities and services to current and future demand. This paper presents a detailed review of the available research literature on the application of simulation models in port development, through extensive reference to published journal papers from the onset of the relevant simulation modelling and through the course of the past 54 years (1961–2015). With focus on container terminals, this review aims at analysing the use of port related simulation models and ultimately at assessing their contribution into building the research knowledge necessary to promote sustainable ship-port interfaces and freight transport chains. It was found that over the past 50 years the use of simulation models has been increasingly favoured and instrumental in the development of ports and more specifically of container terminals. Most of the research literature addresses operational issues, accounting for its highest concentration and coherence in the research field of operations research, although the need to utilise the wide-ranging capabilities of simulation modelling in order to offer integrated solutions is recently promoting the dissemination of the relevant literature through sector-specific (i.e. transport and maritime) research fields. Finally, the observed tendency to employ simulation tools which offer the most realistic results reflects the research effort to ensure that simulation modelling offers tangible solutions to the maritime and transport industry.

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1 Introduction

The progress in simulation modelling has been consistent with the growth of information technology and the increasing demand for quick and reliable solutions to complex problems. This progress was also harnessed by the port industry in response to the mounting pressure for improved shipping operations in general and effective integration of shipping into the logistics of freight in particular. It is interesting to note that Steer and Page (1961) and Beattie et al. (1971) were two pioneering studies based on the Montecode package specifically for Monte Carlo statistics (produced by the British Iron and Steel Research Association). Subsequently, Lawrence (1973) and Borovits and Ein-Dor (1975) developed port simulations in FORTRAN addressing the emerging challenges of containerisation. By the end of the 1970s, David and Collier (1979) simulated the operation of container handling equipment (fork-lifts and cranes) in conjunction with a ship's turnaround time in order to study the optimisation of cargo handling rates. Therefore, through the advances in computing including the first introduction of microcomputers during the 1970s, port simulation models experienced a step improvement and by the end of the 1980s they became sector and operation specific which inevitably facilitated the rapid expansion of simulation modelling in port development. During the last decade, the accelerated use of simulation models (SM) in port development and particularly in container terminals (CT) presents a clear demonstration of its appeal towards optimised port development, whether this involves the establishment of new or the expansion of existing facilities and services. This impetus not only justifies the treatment of port SM as a distinct research area, but also dictates the need to produce a clearer picture of the relevant knowledge base in order to promote its effective utilisation by all stakeholders and especially amongst researchers.

A total of 226 papers are analyzed here. Among these, 209 papers present a simulation model of a port or container terminal operation; seven papers are literature reviews that are not included in Table 1 in Appendix; and 10 papers are literature reviews that are included in Appendix Table 1. Thus, a total of 219 papers are listed in Table 1 indicating the number of journal papers in our database.

The bottom of Table 1 in Appendix shows a list of ten literature review papers (Vis and de Koster 2003; Steenken et al. 2004; Günther and Kim 2006; Stahlbock and Voss 2008; Angeloudis and Bell 2011; Luo et al. 2011; Rashidi and Tsang 2013; Carlo et al. 2014a, b; Carlo et al. 2015) published between 2003 and 2015 which cover a wide range of operations research (OR) techniques applied to CTs. They generally offer a concise description for each of the reviewed items, whilst the work by Angeloudis and Bell (2011) extends into the presentation of the empirical aspect of 30 individual SM applications. In addition to these, there are seven other literature reviews that are not listed in Table 1 since they consider related topics. Bierwirth and Meisel (2010) presented a first survey of berth allocation and quay crane scheduling problems in CTs up to 2009 and in that sense they provided an update of their paper in Bierwirth and Meisel (2015). The problem of loading and unloading container stacks as is faced in yard operations and stowage planning was investigated in Lehnfeld and Knust (2014). In building the multidisciplinary picture of port research, the literature reviews by Pallis et al. (2010, 2011) on port economics, policy and management over 12 years (1997–2008) are most informative, whilst those by Woo et al. (2011, 2012) present a decadal analysis of trends and themes since the 1980s.

Amongst the previous review papers, the most extensive was the work conducted by Angeloudis and Bell (2011) which included 30 journal papers and that by Rashidi and Tsang (2013) with an even shorter reference of papers. Both papers considered limited number of simulation studies that investigate the impact of management decisions on the performance of CTs.

Besides the use of the extensive database of 219 papers, the major contribution of the current review stems from the development and presentation of several tables and figures which enable the reader to obtain a concise and thorough knowledge of this research. This entails: (1) the journals in which these papers have been published; (2) the type of software that was used to develop the SMs; (3) the main features of the SMs; (4) the specific port (if any) that inspired the development of the SMs, and (5) the general topic (application area) investigated.

The current paper is the first comprehensive review article in this area, since the classification of published SM research according to areas of application and tools employed provides a comprehensive presentation of the structure of the attained knowledge base, so far. In this manner, the evaluation of the current research literature ultimately facilitates the identification of gaps in the simulation modelling of ports amidst the trend of port operations with increasing complexity, range and interdependence.

With regard to the structure of the paper, the next section delivers a concise presentation of port operations. The third section presents the selection and classification of the reviewed literature, followed by a detailed analysis and discussion on the review results, whilst the final section presents the conclusions. With regard to the terminology, the terms are used in full on their first reference in the text followed by their acronym or abbreviation in brackets, whilst their explanation for the remainder of the text may also be obtained through the list of terms shown in Appendix Table 2.

2 Background of port operations

The significance of the application of SM in ports is relevant to their pivotal role in supporting international seaborne trade. With particular reference to the fastest growing shipping sector of containerised freight, the main function of a port system is to improve intermodality through securing the seamless transfer of containers within the port, as well as between the sea and land modes of transport. A port represents a complex system consisting of different types of terminals with highly dynamic interactions between the various handling, transportation, and storage units. The port process can be divided into the following principal links with the specification of port operations, summarized in Fig. 1: anchorage-ship-berth link with the loading/unloading stage of ships, an internal transport link for moving cargo from apron area to storage area and vice versa, cargo storage and receiving/ delivery operations from/to external vehicles (EVs) (shore-side link). SM is applied to these links either separately or complementary to each other. The most explored area of simulated port operations refers to the anchorage-ship-berth link. The handling processes at a CT includes: ship operations, receiving/delivery operations from/to EVs and container handling and storage operations on the container yard (CY). Loaded and unloaded containers are temporarily stored awaiting a new journey. Inbound containers arrive by ship and quay cranes (QC) transfer containers to a yard truck or automated guided vehicle (AGV) [or buffer space for straddle carriers (SC), shuttle carriers and automated lifting vehicles (ALV)]. The transfer equipment then delivers the inbound container to a yard crane (YC) which picks it off the yard truck or AGV (or from CY buffer space) and stacks it into the respective storage location, which moves back to the quay crane to receive the next unloaded container. The storage location is given by row, bay and tier within the block and is assigned in real time upon arrival of the container in the terminal. Inbound as well as outbound containers are stocked in a CY which is divided into a number of blocks. Each block consists of the container stacks which are reserved for reefer containers or to store hazardous goods among others. For the loading operation, the process is reversed. This is an indirect transfer system (ITS) in which container handling equipment delivers a container between the apron area and the CY. Rubber-tired or rail-mounted gantry cranes store the containers at yard stacks in CY. In direct transfer system (DTS), no YCs are needed because SC is used to pick up (put down) containers from (into) the CY, deliver it to (from) the apron, and transfer it to (from) a quay crane. European CTs are based upon the DTS in which transport of containers from ship to stack and vice versa and stacking (retrieval) of containers into (from) the slots assigned in the CY are performed by SCs. It is pure SC systems or SC terminals. DTS requires the larger area due to dedicated lanes required for SCs to access slot position, while the ITS minimizes yard area requirements (Stahlbock and Voss 2008).

According to the different types of handling equipment two main categories with containers being stacked on top of each other by either SCs or YCs are common in Europe and Asia. A third type which is used quite often in North America, is an on-chassis system where every containers are stacked on a chassis and a tractor pulls the chassis between the apron and the CY.

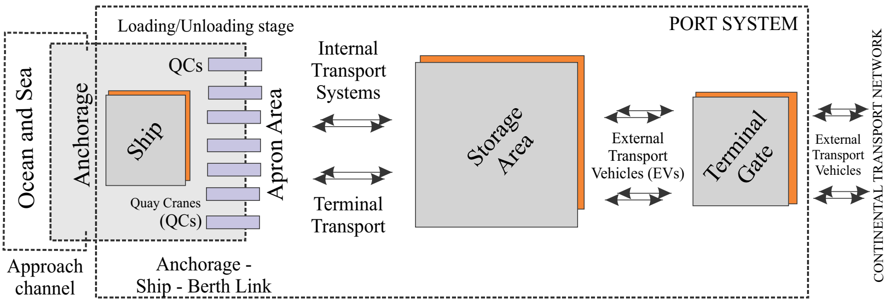

Fig. 1 Port system with main subsystems

CTs are greatly differing by the type of transfer and handling equipment used. Improving CTs operations and attaining handling processes excellence to gain competitive advantage has attracted a lot of attention in the last few years. Many CT operations and many of the technological advances in port like Decision Support Systems, AGVs, ALVs, Automated Stacking Cranes, Global Positioning Systems (GPS), differential GPS, Radio Frequency Identification, Real-time Location System, Information Technologies, QC double cycling, indented container berth, dual-hoist tandem QC, dual-hoist triple tandem QC and automated CT admit modelling via SMs. In this paper, the literature available on the application of SMs in port is reviewed.

3 Review methodology

The literature database is shown in Table 1 of the Appendix and contains 219 journal papers. Among these, 209 papers present a SM of a port or CT operation and 10 are review papers. Their temporal distribution covers 32 papers from 1961 to 1999, which are substantially lower than the 187 published papers in the period of 2000–2015. Enriching and extending the work of the ten previous reviews (of Table 1), the current paper also constitutes a follow-up review of individual SM applications in ports and CTs from 1961 to 2015. The total number of papers in the previous ten reviews that contain the application SM in ports was equal to 65 and all of them were also included in the current review.

In order to collect all relevant publications of port or container terminal SMs, an extensive literature search was conducted in the online-resources of the publishers Inderscience, Springer, Elsevier, ASCE, SAGE, Hindawi, Taylor & Francis, Palgrave and scientific database Google Scholar. The keywords used for our search were port, port operation and container terminal from which we only selected the ones addressing the following items: simulation, simulation model, simulation–optimisation, simulation-based optimisation, simulation-based heuristic method and agent-based system or model. Altogether, this search produced the database of 219 papers which have been published in 71 international scientific journals, i.e. on average 3.08 papers in each journal. In total, the authorship of these papers was shared by 614 researchers. The average number of authors per paper was 2.8, whilst 32 (14.6 %) of the papers were written by a single author, whilst the maximum number of authors in a single paper was six. For each paper, the affiliation of the first author was located as follows: Europe 115 papers, Asia 49 papers, North America 42 papers, Australia seven papers, Africa three papers and South America three papers. In total, the first authorship of the papers under the current review was distributed in 37 different countries, namely 35 papers from the United States of America, 22 from Netherlands, 20 from Italy, 18 from China, 12 from South Korea, 10 from Germany, 10 from Turkey, 7 from Australia, 6 from Greece, 6 from Singapore, 5 from Spain, whilst the first author of the 68 remaining papers was located in 26 other countries.

In order to improve the reliability of the literature review process towards fulfilling its objectives, the full text of each paper was screened and included in this review after meeting the following criteria: (1) exclusive coverage of SM applications in ports; (2) does not contain SM with reference to navigation, maritime environment and conditions, geographical space considerations and port uses other than shipping e.g. fishing and (3) is not a “grey” literature item (i.e. textbook, conference paper, monograph, doctoral dissertation and book chapter). Furthermore, it should be noted that although the papers of the WinterSim Proceedings constitute an important outlet of simulation papers which covers applications in various ports (http://informs-sim.org/), the current review was focused on papers mainly (by almost 90 %) published in SCI or SSCI Journals. The aforementioned criteria are considered appropriate as they offer the ability to surpass the exemplary approach in reliably reviewing the evolution of major advances, significant gaps, current debates and emerging challenges on this topic.

Port SM literature has been published in journals covering various research fields ranging from generic informatics (e.g. computer science) to transportation and sector specific (i.e. maritime or shipping) and port SM literature finds application in various areas ranging from port project planning to management (incl. performance evaluation of terminal services and operations). Therefore, with regard to the SM application area, each paper was classified according to its general description (conveyed through the title of paper, abstract, keywords), its detailed content (based on its literature review, methodology and results) and its research contribution (outlined in conclusions). Furthermore, taking into account that SM involves computer programming written in a general purpose language or in a special simulation-oriented language, the reviewed literature was analysed on the basis of the tools employed.

By adopting a review approach which focuses on the identification of research fields, application areas, simulation tools and other critical features, a systematic assessment of the research literature on port SM was ensured, whilst its citation analysis captured the impact of the various tools in pushing the research agenda forward and the level of coherence achieved amongst the various application areas. Finally, the review results were summarised according to:

- the journals in which these papers have been published,
- the area of application to port operations,
- the port simulation model statements by application area in respect to importance, contribution, benefits and output results of SMs,
- the specific port (if any) that inspired the development of the SMs,
- the most widely used simulation tools and SM features, and
- the main features of the SMs.

4 Review results and discussion

4.1 Analysis by research field

The distribution of the reviewed literature according to the journals in which it was published is presented in Fig. 2. Furthermore, a research field classification was produced through grouping journals on the basis of their theme (i.e. computer Science, OR, maritime transport, transportation and other research fields).

As shown, all collected port SM papers appeared in journals of different research fields; 31 journals included 179 papers, each containing two papers at least, whilst the remaining 40 papers were published in one journal. According to further analysis, it was found that 18.7 % of port SM papers were associated with the computer science journals, 20.1 % were published in OR journals, 16.0 % of the papers in maritime journals and 12.3 % of the papers were included in journals specialising in the field of transportation research. The remaining 32.9 % of port SM papers were attached to other research field journals.

4.2 Analysis by application area

The application of SM in ports was found to be very concentrated in the CT sector represented by the highest number of papers (166 papers), followed by applications to ports in general (24 papers), port traffic (15 papers) and bulk cargo terminals (14 papers).

As shown in Fig. 3, all papers were classified into four port SM application areas: bulk terminal operations (6.4 %), ports in general (11 %), port traffic (6.8 %) and CT operations (75.8 %). It can be seen that SM has been used to solve a problem (whether real-life or hypothetical) in over 72.2 % of the papers, whereas the remaining 27.8 % have explored methodological issues. Further analysis of the papers reviewed per port application area is presented in Table 1 of the Appendix.

The predominance of SM applications in the CT sector has been manifested during the last decade through its rapid expansion in specific CT operations. In this context, through the current review it was possible to identify 11 subareas of SM

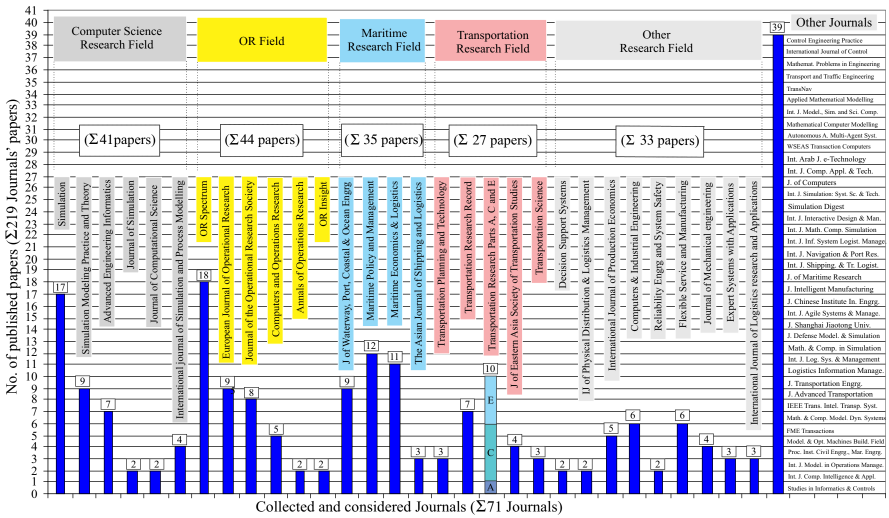

Fig. 2 Distribution of port SM research literature according to journal field

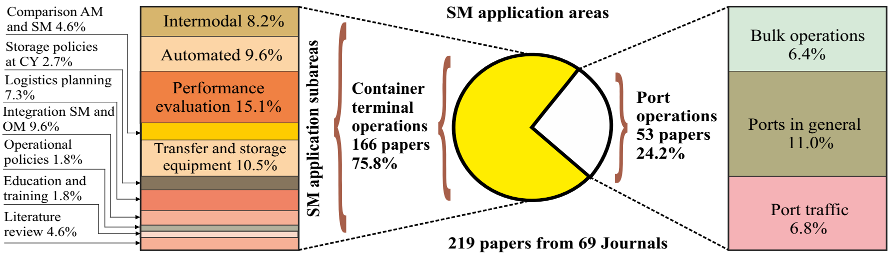

Fig. 3 Distribution of port SM research literature according to application area

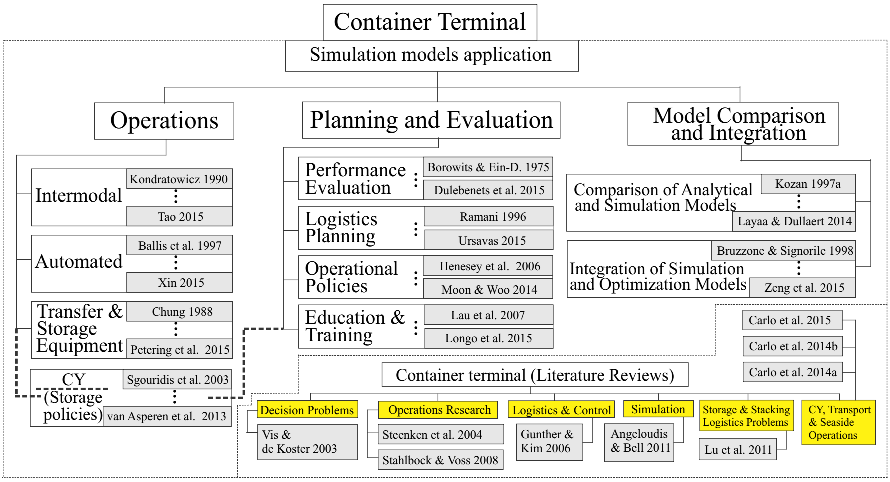

Fig. 4 Classification of literature on SM at CT

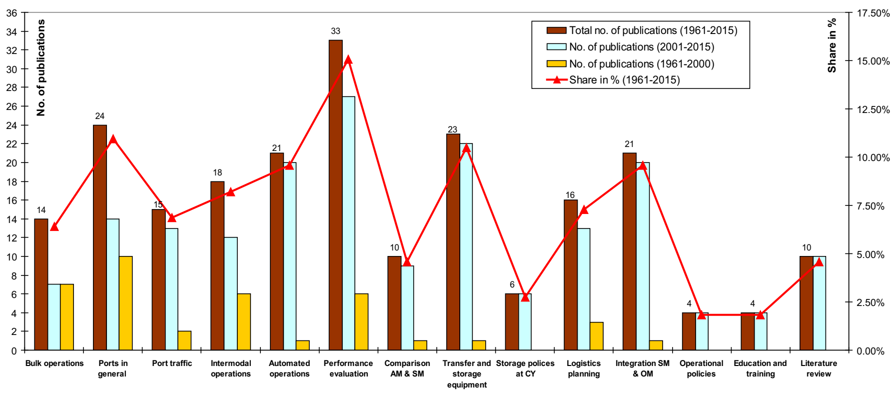

Fig. 5 Distribution of publications according to their application

application, i.e. intermodal operations (18 papers), automated operations (21 papers), performance evaluation (33 papers), comparison of analytical models (AM) and SM (10 papers), transfer and storage equipment (23 papers), storage policies at CY (6 papers), logistics planning (16 papers), integration of simulation and optimisation models (OM) (21 papers), operational policies (OP) (4 papers), education and training (E&T) (4 papers), and literature review (10 papers).

Figure 4 presents a schematic classification of the application of SM within the CT sector and provides an indication of the duration of research engagement in each area through reference to the first and last relevant paper.

Table 1 of the Appendix presents the main results of the research literature review, showing the application area, the specific focus (port system) and the employed tools of the SMs, as well as other basic features. These are highly consistent with the results of previous review papers, indicating that many SMs are increasingly incorporating knowledge of port operations, modelling and analysis into port system to provide users the capability of intelligent assistance. Very often, computations are performed using various types of AM to generate solution while SM components into port systems provide necessary data, monitoring the calculation process, and evaluating AM results to assist users on a real time basis.

The distribution of the reviewed literature produced during the pre- and post-2000 period according to SM application areas and subareas is shown in Fig. 5. The majority of papers published between 1961 and 2000 addressed bulk operations and ports in general by 50 and 41.6 %, respectively. In contrast, this earlier period was poor with regard to the consideration of stacking and operational policies, education and training, whilst no literature review was delivered. During 2001–2015, most papers were related to performance evaluation (84.8 % per subarea), automated operations (95.2 % per subarea) and transfer and storage equipment (95.6 % per subarea) while the minimum number of published papers were in relation to operational policies, as well as education and training (four papers per subarea).

Figure 5 reveals an increase in SM application with regard to real-life port issues, compared to the findings reported in the previous reviews. This is attributed to the improved dissemination of the accumulated knowledge and experience gained in port SM, whilst the demand for prompt and reliable solutions to several port problems is increasing rapidly driven by the stronger competition within the sector. Unlike the past, most ports recently build databases through recording and analysing massive data, from transaction processing systems to support port resource assignment and planning, which provide essential support to SM utilisation.

Furthermore, Fig. 6 shows the annual distribution of papers by SM application area and subarea, according to which with an average of seven applications per year a total of 201 port SMs were published during the period from 1995 to 2015. This is a remarkable increase compared to the preceding period of 1961–1994 which was associated with less than one application per year. During 2011–2015, 17.2 publications were recorded annually in comparison to 11.4, 7.6 and 3.8 for 2006–2010, 2001–2005 and 1996–2000, respectively. Therefore, it is evident that with the passage of time the application areas of port SM have diversified mostly into CT subareas (23 papers in 2015) with the predominant subareas being integration of SM and OM, transfer and storage equipment and performance

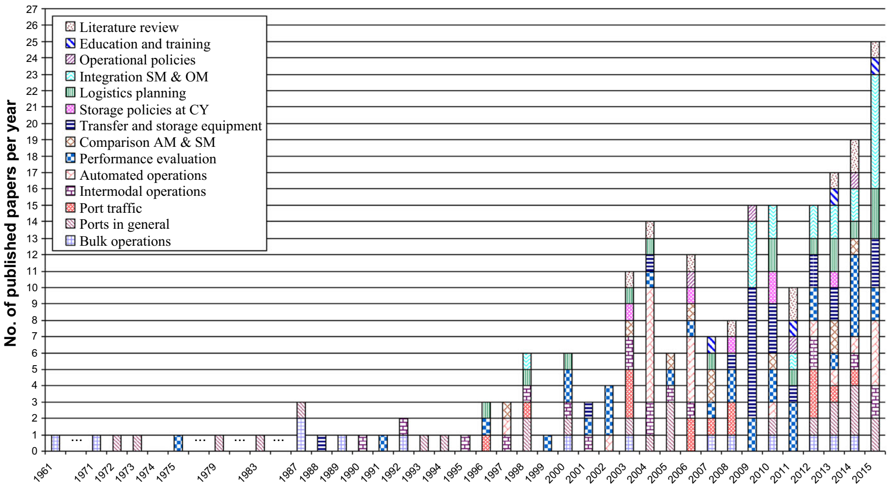

Fig. 6 Distribution of SM papers by year of publication

evaluation. Analyses show that the number of journal papers published per year on simulation modeling in seaports and seaport container terminals continues to increase on an annual basis with a peak of 25 papers in 2015.

4.3 Analysis by simulation tool

The list of simulation languages and tools that have been used for modelling port processes and operations are presented in Table 1 of the Appendix. In a synoptic form, Fig. 7 shows a plethora of employed simulation tools per port application area.

There are 26 simulation tools used at least twice whilst other 29 are used only once. Approximately 21.4 % of port SMs are developed in ARENA, which reveals the user's animation attempts to realistically represent object movement in terms of speed, direction, orientation and interaction with other objects. About 9.6 % of port SMs are built in C and C++, 5.9 % in FORTRAN, 6.4 % in Java, 5.9 % in MATLAB, 3.75 % in AweSim, 3.2 % in (Flexsim, Witness) separately, 2.1 % (PORTSIM, Agent Based) for each of them, 1.6 % in (MODSIM, SLAM, GPSS/H, VISCOT, Monte Carlo, Visual Basic, eM-Plant) for each of them and 1.1 % (Pascal, Taylor II, Siman, PortModel, iThink & Micro World (MW), MUST, SimPort, AnyLogic and NetLogo), respectively. The remaining 15.5 % of SMs are developed in other simulation languages as already shown in Fig. 7.

To distinguish the presence of simulation tools in all application areas, a classification of main elements of SMs was developed which is defined by six binary variables A, B, C, D, E and F (see Appendix Table 1—Column *Main features of SMs*). Each binary variable served as an indicator of whether an SM possesses a particular feature. For example, A = 1 indicates that the SM has a flow

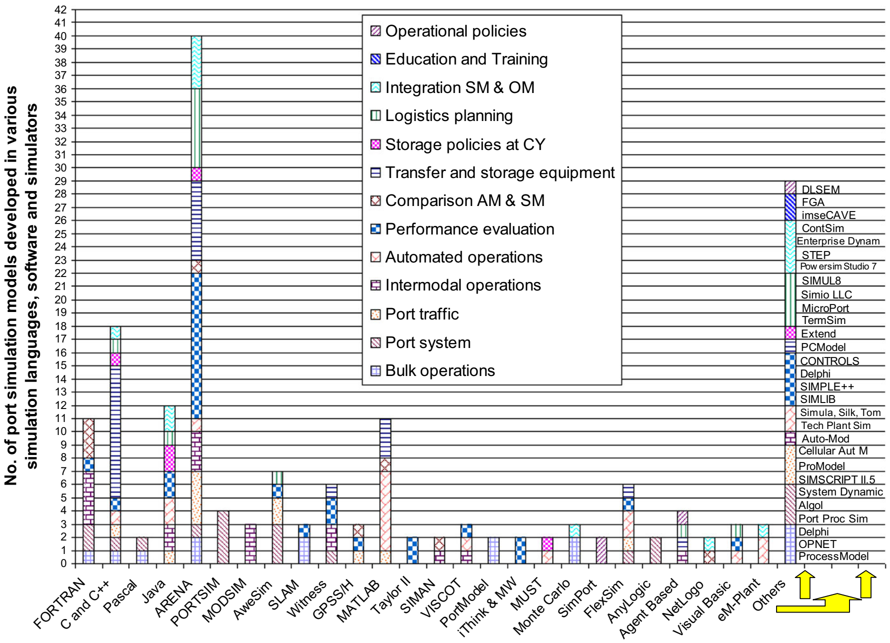

Fig. 7 Distribution of employed simulation tools per port application area

diagram. Otherwise, the SM does not possess a flow diagram. These binary variables are explained below:

Variable	Value	Interpretation
A	0	There is no flow diagram of the SM
	1	There is flow diagram of the SM
B	0	There is no screen or code of the models and submodels
	1	There is screen or code of the models and submodels
C	0	There is no port and terminal layout
	1	There is port and terminal layout
D	0	There is no simulation graphics and animations
	1	There is simulation graphics and animations
E	0	There is no integration among terminal subsystems
	1	There is integration among terminal subsystems
F	0	There is no experimental strategy and sensitivity analysis
	1	There is experimental strategy and sensitivity analysis

The tuple (A, B, C, D, E and F) was used to describe features of simulations processes for each paper and complete the application of SMs. Moreover, defined binary variables were sufficient to describe a physical layout of ports and their operational features.

5 Conclusions

Port SM has made meaningful progress over the past five decades and has strengthened its impetus in port and terminal research, despite the increasing prominence of other modelling techniques based on mixed integer programming, various heuristics and so on. Based upon the statistics of the 219 reviewed items, it was found that during 2000–2015 the number of papers on port SM literature is almost sixfold in comparison to the pre-2000 period, showing an 85.4 and 14.6 % distribution, respectively. By virtue of its ability to produce prompt and reliable solutions to a multitude of port related problems, SM has been a very important and popular decision support tool for port developers, whilst its effectiveness has been mostly demonstrated in the area of port operations.

The results of this port SM literature review are summarised as follows:

- Five research fields have been identified, with the predominance of OR with 44 papers published in six journals.
- Four areas and 11 subareas of application have been identified, with the predominance of port performance evaluation and container terminals, respectively.
- The observed application diversification of port SM demonstrates its wide-ranging capabilities.

Discrete-event simulation remains one of the most popular techniques in port operations modelling (more than 20 % SMs were built in ARENA), despite the introduction of new techniques such as agent based modelling, network based modelling, simulation-based education, web-based simulation and so on.

The current literature review provides evidence that future port SM will continue to follow the trend of developing a general simulation platform, broadening simulation into new domains of applications and integrating with other simulation approaches. This trend would undoubtedly fulfil the need for future port SM to be concentrated in developing tools and techniques which would be able to meet the emerging challenges in the management of port development and operation. Amongst these challenges the most important is that of improving the influence of ports and particularly of container terminals in the optimisation of the freight transport chain.

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Appendix

See Tables 1 and 2.

Table 1 Publications reviewed—structured by application areas and subareas with main features

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
Port simulation modelling				
Bulk operations	1. Steer and Page (1961)	Monte Carlo	An Bulk Terminal	(1, 0, 1, 0, 0, 1)
	2. Beattie et al. (1971)	Monte Carlo	UK ports	(0, 0, 1, 0, 0, 0)
	3. Park and Noh (1987a)	SLAM	Port of Mobile, Alabama, USA	(1, 0, 1, 0, 0, 1)
	4. Park and Noh (1987b)	SLAM	Port of Mobile, Alabama, USA	(1, 1, 1, 0, 0, 1)
	5. Guimaraes and Kingsman (1989)	FORTRAN	Portugals' grain terminals (Leixoes)	(0, 1, 1, 0, 0, 1)
	6. Wadhwa (1992)	Pascal	Australian ports	(1, 0, 0, 0, 0, 1)
	7. Wadhwa (2000)	ARENA	Australian ports	(0, 0, 1, 0, 0, 1)
	8. Dahal et al. (2003)	PortModel		(1, 1, 1, 0, 1, 1)
	9. Dahal et al. (2007)	PortModel		(1, 1, 1, 0, 1, 1)
	10. Harris et al. (2008)	ProcessModel	Mc Duffie Coal Term, Alabama	(1, 0, 0, 0, 0, 1)
	11. Alvarez et al. (2010)	C++		(1, 0, 1, 0, 1, 1)
	12. Mondragon et al. (2012)	OPNET		(1, 1, 0, 1, 1, 1)
	13. Cigolini et al. (2013)	ARENA	Floating barges terminal	(1, 1, 0, 0, 1, 1)
	14. van Vianen et al. (2014)	Delphi (TOMAS)		(1, 1, 0, 0, 1, 1)
Ports in general	1. Hansen (1972)	FORTRAN	An Bulk Terminal	(1, 0, 0, 0, 0, 1)
	2. Lawrence (1973)	FORTRAN	Vancouver	(1, 0, 0, 0, 0, 1)
	3. David and Collier (1979)	Algol	Newport, UK	(1, 0, 1, 0, 1, 1)
	4. Tugcu (1983)		Istanbul port	(1, 0, 0, 0, 0, 1)
	5. El Sheikh et al. (1987)	Pascal		(1, 0, 0, 0, 0, 1)
	6. Hassan (1993)			(1, 0, 0, 0, 0, 1)
	7. Hayuth et al. (1994)	C	Israel ports (Port of Ashdod, Haifa and Eilat)	(0, 0, 1, 0, 1, 1)
	8. Nevins et al. (1998a)	PORTSIM	Port of Savannah	(1, 0, 1, 1, 0, 1)
	9. Nevins et al. (1998b)	PORTSIM	Port of Savannah	(1, 1, 1, 0, 1, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	10. Turner (2000)		Port of Seattle	(0, 0, 0, 0, 0, 1)
	11. Demirci (2003)	AweSim	Port of Trabzon	(1, 0, 1, 0, 0, 1)
	12. Howard et al. (2004)	PORTSIM		(1, 1, 0, 1, 1, 1)
	13. Casaca (2005)			(0, 0, 0, 0, 0, 1)
	14. Mathew et al. (2005)	PORTSIM		(1, 0, 0, 0, 0, 1)
	15. Yazdani et al. (2005)	Port Process Sim	Baltic Ports	(1, 1, 1, 1, 0, 1)
	16. Ragheb et al. (2010)	AweSim	Alexandria	(1, 0, 0, 0, 0, 1)
	17. Hernandez et al. (2012)	Witness	S Ports Company in the UK	(0, 0, 1, 1, 1, 1)
	18. Longo et al. (2013)	AnyLogic	The port of Salerno	(1, 1, 1, 1, 1, 1)
	19. Yeo et al. (2013)	System dinamic	Korean ports	(1, 1, 0, 0, 1, 1)
	20. Lagoudis et al. (2014)	Excel spreadsheet model based on Monte Carlo	Southeast Asian multipurpose port	(0, 0, 0, 0, 0, 1)
	21. Ugurlu et al. (2014)	AweSim	Botas Ceyhan Marine terminal	(1, 1, 1, 0, 1, 1)
	22. Dragović et al. (2014)	Flexsim	Port of Kotor	(1, 0, 1, 1, 0, 1)
	23. Kondratyev (2015)	AnyLogic		(1, 1, 0, 0, 1, 1)
	24. Fanti et al. (2015)	ARENA	Trieste	(1, 1, 0, 1, 1, 1)
Port traffic	1. Darzentas and Spyrou (1996)	SIMSCRIPT II.5	Aegean Ports	(1, 0, 1, 1, 0, 1)
	2. Thiers and Janssens (1998)	ARENA	Port of Antwerp	(1, 0, 1, 0, 0, 1)
	3. Pachakis and Kiremidjian (2003)	GPSS/H	USA ports	(1, 0, 0, 0, 0, 1)
	4. Merrick et al. (2003)		San Francisco Bay	(0, 0, 1, 1, 0, 1)
	5 Kose et al. (2003)	AweSim	Istanbul (Bosporus) Strait	(0, 1, 1, 0, 0, 1)
	6. Ng and Wong (2006)	ProModel	Port of Hong Kong	(1, 0, 1, 0, 0, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	7. Khatiashvili et al. (2006)	ARENA	Port of Dover	(1, 0, 1, 0, 0, 1)
	8. Yeo et al. (2007)	AweSim	Port of Busan	(1, 1, 1, 0, 0, 1)
	9. Mavrakis and Kontinakis (2008)	ANSI C	Istanbul (Bosporus) Strait	(0, 0, 1, 0, 0, 1)
	10. Quy et al. (2008)	MATLAB	Port of CamPha, Vietnam	(1, 0, 0, 0, 0, 1)
	11. Almaz and Altiok (2012)	ARENA	Delaware river and Bay, USA	(1, 0, 1, 0, 1, 1)
	12. Qu and Meng (2012)	Cellular Automata model	Singapore Strait	(1, 1, 0, 1, 0, 1)
	13. Perković et al. (2012)		Ports of Trieste and Koper	(1, 0, 1, 1, 0, 1)
	14. Kofjač et al. (2013)	Flexsim	Port of Kotor	(1, 0, 1, 1, 0, 1)
	15. Guolei et al. (2014)	Java	Qinhuangdao Port	(1, 1, 1, 1, 0, 1)
Port simulation modelling				
Container terminal operations				
Intermodal	1. Kondratowicz (1990)	TRANSNODE (FORTRAN code)		(1, 1, 0, 0, 1, 1)
	2. Kondratowicz (1992)	TRANSNODE (FORTRAN code)		(1, 0, 0, 0, 1, 0)
	3. Pope et al. (1995)	Q-GERT (FORTRAN code)	Virginia Int. Terminal	(0, 1, 1, 0, 0, 1)
	4. Kozan (1997b)	SIMAN	Accacia Ridge, Brisbane	(0, 0, 1, 0, 0, 1)
	5. Gambardella et al. (1998)	Modsim III	La Spezia CT	(1, 0, 1, 1, 1, 1)
	6. Holguín-Veras and Walton (1997)	FORTRAN	Port of Houston	(0, 0, 1, 0, 0, 1)
	7. Gambardella et al. (2001)	Modsim III	La Spezia CT	(1, 1, 1, 0, 1, 1)
	8. Rizzoli et al. (2002)	Modsim III	Intermodal Terminal Verona	(0, 0, 0, 0, 0, 1)
	9. Luo and Grigalunas (2003)	Java	USA ports	(1, 0, 1, 0, 0, 1)
	10. Ballis (2004)	VISCOT		(0, 0, 1, 0, 0, 1)
	11. Martinez et al. (2004)	Witness	Port-Bou, Spain	(0, 1, 1, 0, 0, 1)
	12. Parola and Sciomachen (2005)	Witness	Genoa and La Spezia	(1, 1, 0, 0, 1, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	13. Kozan (2006)	ARENA	Accacia Ridge, Brisbane	(0, 0, 1, 0, 0, 1)
	14. Douma et al. (2012)	Multi-agent system	Port of Rotterdam	(0, 0, 1, 0, 1, 1)
	15. Veenstra et al. (2012)	Java	Port of Rotterdam	(0, 0, 0, 0, 0, 1)
	16. Zehendner and Feillet (2014)	ARENA	Grand Port Maritime de Marseille	(0, 0, 1, 0, 0, 1)
	17. Wall et al. (2015)	ARENA	Port of Savannah	(1, 1, 1, 0, 0, 1)
	18. Tao and Qiu (2015)	Auto-Mod	Shekou CT, Shenzhen	(0, 0, 1, 0, 0, 1)
Automated	1. Ballis et al. (1997)	VISCOT	Port of Piraeus	(1, 0, 1, 0, 1, 1)
	2. Liu et al. (2002)	MATLAB (S and S)		(0, 1, 1, 0, 0, 1)
	3. Liu et al. (2004)	MATLAB (S and S)	Norfolk, USA	(0, 0, 1, 0, 1, 1)
	4. Vis and Harika (2004)	ARENA		(1, 1, 1, 0, 1, 1)
	5. Yang et al. (2004)	Visual BASIC	Kwangyang ACT	(1, 0, 1, 1, 1, 1)
	6. Hartmann (2004)	C	HHLA CT, Altenwerder, Hamburg	(1, 0, 0, 0, 1, 1)
	7. Kim and Bae (2004)			(0, 0, 1, 0, 1, 1)
	8. Kim et al. (2004)	Java		(1, 1, 1, 0, 1, 1)
	9. Grunow et al. (2004)	eM-Plant 6.0		(0, 1, 1, 0, 1, 1)
	10. Ottjes et al. (2006)	Simula, Silk, Tomas	Maasvlakte CTs	(1, 1, 1, 0, 1, 1)
	11. Duinkerken et al. (2006)	MUST	Maasvlakte CTs	(1, 0, 1, 0, 1, 1)
	12. Grunow et al. (2006)	eM-Plant 6.0		(0, 1, 1, 0, 1, 1)
	13. Briskorn et al. (2006)	Desmo-J, based in Java	HHLA CT, Altenwerder, Hamburg	(0, 0, 1, 0, 1, 1)
	14. Zhu et al. (2010)		Shanghai	(1, 0, 1, 1, 0, 1)
	15. Kemme (2012)	Tecnomatix Plant Sim.		(1, 0, 1, 0, 0, 1)
	16. Gelereh et al. (2013)	Flexsim	Dublin Ferryport Terminal	(0, 0, 1, 1, 1, 1)
	17. Xin et al. (2014)	MATLAB	Automated CTs	(0, 0, 1, 0, 1, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	18. Kavakeb et al. (2015)	Flexsim	A small size CT in Europe	(0, 1, 1, 1, 1, 1)
	19. Xin et al. (2015a)	MATLAB	Automated CTs	(0, 0, 1, 0, 1, 1)
	20. Xin et al. (2015b)			
	21. Xin et al. (2015c)			
Port simulation modelling				
Container terminal operations				
Performance evaluation	1. Borovits and Ein-Dor (1975)	FORTRAN	Port of Ashdod	(1, 0, 1, 0, 0, 1)
	2. Silberholz et al. (1991)	SIMLIB	Port of Miami	(1, 1, 1, 0, 0, 1)
	3. Ballis and Abacoumkin (1996)	VISCOT	Port of Piraeus	(1, 0, 1, 1, 1, 1)
	4. Yun and Choi (1999)	SIMPLE++	PECT (Port of Busan)	(1, 1, 1, 1, 1, 1)
	5. Tahar and Hussain (2000)	ARENA	Kelang	(0, 0, 1, 0, 1, 1)
	6. Kia et al. (2000)	Taylor II	Melbourne	(1, 0, 1, 0, 0, 1)
	7. Legato and Mazza (2001)	SLAM	Gioia Tauro CT	(1, 1, 1, 0, 0, 1)
	8. Shabayek and Yeung (2002)	Witness	Hong Kong	(1, 1, 1, 0, 0, 1)
	9. Kia et al. (2002)	Taylor II	Melbourne	(0, 0, 1, 0, 0, 1)
	10. Nam et al. (2002)	AweSim	Gamman CT (Port of Busan)	(1, 0, 1, 0, 0, 1)
	11. Choi (2004)	C++	UAM CT (Port of Busan)	(1, 0, 0, 0, 1, 1)
	12. Dragović et al. (2005)	GPSS/H	PECT	(1, 0, 1, 0, 0, 1)
	13. Bielli et al. (2006)	Java	Casablanca CT	(1, 1, 1, 1, 1, 1)
	14. Park et al. (2007)	ARENA	Korean CTs	(0, 0, 0, 0, 1, 1)
	15. Canonaco et al. (2008)	Delphi	Gioia Tauro	(1, 1, 1, 0, 0, 1)
	16. Huang et al. (2008)			(1, 0, 0, 0, 0, 1)
	17. Park and Dragović (2009)	ARENA	Korean CTs	(1, 0, 0, 0, 0, 1)
	18. Na and Shinozuka (2009)	ARENA		(1, 0, 1, 0, 0, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	19. Vis and van Anholt (2010)	ARENA	Amsterdam CT	(1, 0, 1, 0, 1, 1)
	20. Ding (2010)		Zheijang Province Port	(1, 0, 0, 0, 0, 1)
	21. Wanke (2011)	ARENA	Rio de Janeiro (multi Rio CT)	(1, 1, 1, 0, 0, 1)
	22. Cheng et al. (2011a)	iThink & Microworlds		(0, 1, 0, 1, 0, 1)
	23. Cheng et al. (2011b)	iThink & Microworlds		(0, 1, 0, 1, 0, 1)
	24. Carteni and de Luca (2012)	Witness	Salerno CT	(1, 1, 1, 0, 0, 1)
	25. Boer and Saanen (2012)	CONTROLS		(1, 1, 1, 1, 1, 1)
	26. Esmer et al. (2013)	ARENA	Alsancak CT, Izmir	(0, 1, 0, 1, 0, 1)
	27. Taner et al. (2014)	ARENA	Various layout of artificial CTs	(1, 1, 1, 0, 1, 1)
	28. Zhang et al. (2014)	Java		(1, 0, 0, 0, 0, 1)
	29. Lin et al. (2014)	ARENA	Humen Port	(1, 1, 1, 0, 1, 1)
	30. Nicoletti et al. (2014)	ARENA	A medium size CT of the Mediterranean area	(1, 1, 0, 1, 0, 1)
	32. Ursavas (2014)		Izmir	(1, 0, 0, 1, 1, 1)
	31. Aydogdu and Aksoy (2015)	ARENA	Turkish port	(1, 0, 0, 1, 0, 1)
	33. Dulebenets et al. (2015)	Flexsim		(1, 0, 1, 0, 1, 1)
Comparison of AM and SM	1. Kozan (1997a)	SIMAN	Fisherman Island CT, Australia	(0, 0, 0, 0, 0, 1)
	2. Yamada et al. (2003)		Osaka port	(0, 0, 0, 0, 0, 1)
	3. Vis et al. (2005)	ARENA		(0, 0, 1, 0, 0, 1)
	4. Dragović et al. (2006)	GPSS/H	PECT	(1, 0, 1, 0, 0, 1)
	5. Huang et al. (2007b)	FORTRAN	Kaohsiung port CT	(1, 0, 0, 0, 0, 1)
	6. Huang et al. (2007a)	FORTRAN	Kaohsiung port CT	(1, 0, 1, 0, 0, 1)
	7. Huang et al. (2010)	FORTRAN	Kaohsiung port CT	(1, 0, 1, 0, 0, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	8. Zhao and Goodchild (2013)	MATLAB		(1, 1, 0, 0, 1, 1)
	9. Fleming et al. (2013)	NetLogo	Bayport terminal	(0, 0, 1, 1, 0, 1)
	10. Layaa and Dullaert (2014)		Dar es Salaam	(0, 0, 0, 0, 1, 1)
Port simulation modelling				
Container terminal operations				
Transfer and storage equipment	1. Chung et al. (1988)	PCModel	Port of Portland	(1, 0, 1, 0, 0, 1)
	2. Nam and Ha (2001)		Busan New Port	(0, 0, 0, 0, 0, 1)
	3. Huynh et al. (2004)	ARENA	Port of Houston	(1, 0, 1, 1, 1, 1)
	4. Huynh and Walton (2008)	ARENA	Port of Houston Barbours cut CT	(1, 0, 1, 0, 0, 1)
	5. Huynh (2009)	Flexsim	Port of Houston	(1, 1, 1, 1, 0, 1)
	6. Hadjiconstantinou and Ma (2009)	C++	Piraeus	(1, 0, 0, 0, 1, 1)
	7. Park et al. (2009)	ARENA	Korean CT	(0, 1, 1, 1, 1, 1)
	8. Soriguera et al. (2006)		Barcelona CT	(0, 0, 1, 1, 0, 1)
	9. Petering et al. (2009)	C++		(0, 0, 1, 0, 1, 1)
	10. Petering (2009)	C++		(0, 0, 1, 0, 1, 1)
	11. Petering and Murty (2009)	C++		(0, 0, 1, 0, 1, 1)
	12. Legato et al. (2009)	ARENA	Gioia Tauro	(1, 1, 1, 0, 1, 1)
	13. Petering (2010)	C++		(0, 0, 1, 0, 1, 1)
	14. Zhao and Goodchild (2010)	MATLAB		(1, 0, 1, 0, 1, 1)
	15. Esmer et al. (2010)	ARENA	Turkish ports	(1, 1, 0, 0, 0, 1)
	16. Petering (2011)	C++		(0, 0, 1, 0, 1, 1)
	17. Jaoua et al. (2012)	ARENA		(1, 1, 0, 0, 1, 1)
	18. Guo and Huang (2012)	C++		(1, 1, 1, 0, 1, 1)
	19. Dekker et al. (2013)	MATLAB	Port of Rotterdam	(0, 0, 0, 0, 1, 1)
	20. Sauri et al. (2014)	Witness	Port of Barcelona	(0, 0, 1, 0, 1, 1)
	21. Garro et al. (2015)	Agent-based		(1, 1, 1, 0, 1, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	22. Carlo and Martinez-Acevedo (2015)	C++		(0, 0, 0, 0, 1, 1)
	23. Petering (2015)	C++		(0, 0, 1, 0, 1, 1)
Storage policies	1. Sgouridis et al. (2003)	Extend		(1, 1, 1, 1, 0, 1)
	2. Dekker et al. (2006)	MUST	Port of Rotterdam	(0, 0, 1, 0, 1, 1)
	3. Laik and Hadjiconstantinou (2008)	C	Port of Felixstowe	(1, 0, 1, 0, 1, 1)
	4. Borgman et al. (2010)	Java	ECT Delta, Port of Rotterdam	(0, 0, 1, 0, 1, 1)
	5. Guldogan (2010)	ARENA	Port of Izmir	(0, 1, 1, 0, 1, 1)
	6. van Asperen et al. (2013)	Java	ECT Delta, Port of Rotterdam	(0, 0, 1, 0, 1, 1)
Logistics planning	1. Ramani (1996)	C	Indian ports	(1, 0, 0, 0, 0, 1)
	2. Merkuryev et al. (1998)	ARENA	Riga Harbour CT	(1, 0, 0, 0, 0, 1)
	3. Merkuryeva et al. (2000)	ARENA	Baltic CT	(1, 1, 1, 1, 1, 1)
	4. Lee et al. (2003)	ARENA	PECT	(1, 0, 1, 0, 1, 1)
	5. Veenstra and Lang (2004)	D-SOL, Java	Delta Sea Land CT	(1, 0, 1, 1, 1, 1)
	6. Cortes et al. (2007)	ARENA	Port of Seville	(0, 1, 1, 1, 1, 1)
	7. Longo (2010)	Java		(1, 1, 1, 1, 1, 1)
	8. Guan and Yang (2010)	AweSim	Port of Keelung	(1, 0, 1, 0, 1, 1)
	9. Chang et al. (2011)			(1, 0, 1, 0, 1, 1)
	10. Sun et al. (2012)	MicroPort	Singapore	(1, 1, 1, 1, 1, 1)
	11. Kulak et al. (2013)	ARENA	Istanbul	(1, 0, 1, 0, 1, 1)
	12. Sun et al. (2013)	Multi-agent system (Dynamic programming language Lua)	Kwai Chung CTs	(1, 1, 1, 1, 1, 1)
	13. Do et al. (2014)		A seaport in the US	(1, 0, 0, 0, 1, 1)
	14. Lima et al. (2015)	Simio LLC		(1, 1, 1, 1, 1, 1)
	15. ElMesmary et al. (2015)	SIMUL8	Alexandria	(1, 1, 0, 0, 1, 1)
	16. Ursavas (2015)	ARENA	Izmir	(1, 1, 1, 0, 0, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
Port simulation modelling				
Container terminal operations				
Integration of SM and OM	1. Bruzzone and Signorile (1998)	ARENA	Port in Liguria	(1, 0, 1, 1, 1, 1)
	2. Sacone and Siri (2009)	ARENA		(1, 1, 1, 0, 1, 1)
	3. Zeng and Yang (2009)	ARENA	Port of Dalian	(1, 0, 0, 0, 0, 1)
	4. Li and Wang (2009)	C++		(1, 0, 1, 0, 1, 1)
	5. Briano et al. (2009)	Powersim Studio 7	Voltri terminal	(1, 1, 1, 1, 0, 1)
	6. Zeng and Yang (2010)			(1, 0, 0, 0, 0, 1)
	7. Legato et al. (2010)	Java	Gioia Tauro Medcenter CT	(1, 1, 1, 0, 0, 1)
	8. Arango et al. (2011)	ARENA	Port of Seville	(0, 1, 1, 1, 1, 1)
	9. Bruzzone et al. (2012)	STEP—simulation and analysis of container terminal processes	CT, located in the upper Tyrrhenian Sea	(0, 1, 1, 1, 1, 1)
	10. Sharif and Huynh (2012)	(Agent-based model) Netlogo		(1, 1, 1, 1, 1, 1)
	11. Hartmann (2013)	emPlant/Plant Simulation (SimTalk)	HHLA CT, Altenwerder, Hamburg	(1, 0,1, 0, 1, 1)
	12. He et al. (2013)		Tianjin	(1, 1, 1, 0, 1, 1)
	13. Legato et al. (2014)	Monte Carlo	Gioia Tauro	(1, 1, 0, 0, 1, 1)
	14. Ilati et al. (2014)	Enterprise Dynamics	Rajaee Port	(1, 0, 0, 0, 1, 1)
	15. He et al. (2015a)			(1, 1, 1, 0, 1, 1)
	16. He et al. (2015b)			(1, 1, 1, 0, 1, 1)
	17. He et al. (2015c)			(0, 1, 1, 0, 1, 1)
	18. Clausen and Kaffka (2015)	ContSim	Hamburg	(1, 1, 1, 1, 1, 1)
	19. Cordeau et al. (2015)	Process interaction worldview; Java	Gioia Tauro	(1, 1, 1, 0, 1, 1)
	20. Zehendner et al. (2015)	ARENA	Grand Port Maritime de Marseille	(0, 0, 1, 0, 0, 1)
	21. Zeng et al. (2015)	ARENA	Yantian International CT (Shenzhen Port)	(1, 1, 1, 0, 0, 1)

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
Operational policies papers (OP)				
OP	1. Henesey et al. (2006)	SimPort	CT in North Europe	(1, 0, 1, 1, 1, 1)
	2. Henesey et al. (2009)	SimPort	CT in India	(1, 0, 1, 1, 1, 1)
	3. Yin et al. (2011)	Distributed agent system		(1, 1, 1, 1, 1, 1)
	4. Moon and Woo (2014)	Dynamic liner service evaluation model		(1, 1, 0, 0, 1, 1)
Education and Training papers (E&T)				
E&T	1. Lau et al. (2007)	imseCAVE system Cave Automatic Virtual Environment		(0, 0, 1, 1, 1, 0)
	2. Elazony et al. (2011)	Formal Graphical Approach (FGA) and e-learning system (Training Simulator)	Damietta port	(0, 0, 1, 1, 1, 1)
	3. Massei et al. (2013)	Distributed simulation (HLA—high level arhitecture)		(1, 0, 1, 1, 1, 1)
	4. Longo et al. (2015)		Salerno port	(0, 0, 1, 1, 0, 0)
Literature reviews papers (LRPs)				
LRPs	1. Vis and de Koster (2003)	Summarized 8 above mentioned papers	*Remark* In total 65 various above mentioned papers were cited at least once.	
	2. Steenken et al. (2004)	Reviewed 21 above mentioned papers		
	3. Günther and Kim (2006)	Analysed 4 above mentioned papers		
	4. Stahlbock and Voss (2008)	Described 21 above mentioned papers		
	5. Angeloudis and Bell (2011)	Considered 30 above mentioned papers		
	6. Luo et al. (2011)	Collected 7 above mentioned papers		
	7. Rashidi and Tsang (2013)	Surveyed 6 above mentioned papers		
	8. Carlo et al. (2014a)	Summarized 22 above mentioned papers		

Table 1 continued

Application areas and subareas	References	Simulation tools	Application of SMs in port system	Main features of SMs (A, B, C, D, E, F)
	9. Carlo et al. (2014b)	Reviewed 23 above mentioned papers		
	10. Carlo et al. (2015)	Analysed 6 above mentioned papers		

Table 2 List of acronyms and abbreviations

AGV	Automated guided vehicle	ITS	Indirect transfer system
ALV	Automated lifting vehicle	LEPs	Literature reviews papers
AM	Analytical model	OM	Optimization models
CT	Container terminal	OP	Operational policies
CY	Container yard	QC	Quay cranes
DTS	Direct transfer system	OR	Operations research
E&T	Education and training	SC	Straddle carriers
EVs	External vehicles	SM	Simulation model
GPS	Global Positioning Systems	YC	Yard cranes

References

Almaz AO, Altiok T (2012) Simulation modelling of the vessel traffic in Delaware river: impact of deepening on port performance. Simul Model Pract Theory 22(3):146–165

Alvarez JF, Longva T, Engebrethsen ES (2010) A methodology to assess vessel berthing and speed optimization policies. Marit Econ Logist 12(4):327–346

Angeloudis P, Bell MGH (2011) A review of container terminal simulation models. Marit Policy Manag 38(5):523–540

Arango C, Cortes P, Munuzuri J, Onieva L (2011) Berth allocation planning in Seville Inland Port by simulation and optimisation. Adv Eng Inform 25(3):452–461

Aydogdu YV, Aksoy S (2015) A study on quantitative benefits of port community systems. Marit Policy Manag 42(1):1–10

Ballis A (2004) Introducing level-of-service standards for intermodal freight terminals. Transp Res Rec 1873:79–88

Ballis A, Abacoumkin C (1996) A container terminal simulation model with animation capabilities. J Adv Transp 30(1):37–57

Ballis A, Golias J, Abacoumkin C (1997) A comparison between conventional and advanced handling systems for low volume container maritime terminals. Marit Policy Manag 24(1):73–92

Beattie CJ, Brown AP, Norris ME (1971) Planning deep-water ports. J Oper Res Soc 22(1s):63–75

Bielli M, Boulmakoul A, Rida M (2006) Object oriented model for container terminal distributed simulation. Eur J Oper Res 175(3):1731–1751

Bierwirth C, Meisel F (2010) A survey of berth allocation and quay crane scheduling problems in container terminals. Eur J Oper Res 202(3):615–627

Bierwirth C, Meisel F (2015) A follow-up survey of berth allocation and quay crane scheduling problems in container terminals. Eur J Oper Res 244:675–689

Boer CA, Saanen YA (2012) Improving container terminal efficiency through emulation. J Simul 6:267–278

Borgman B, van Asperen E, Dekker R (2010) Online rules for container stacking. OR Spectrum 32(3):687–716
Borovits I, Ein-Dor P (1975) Computer simulation of a seaport container terminal. Simulation 25(2):141–144
Briano E, Caballini C, Mosca M, Revetria R (2009) A system dynamics decision cockpit for a container terminal: the case of Voltri terminal Europe. Int J Math Comput Simul 2(3):55–64
Briskorn D, Drexl A, Hartmann S (2006) Inventory-based dispatching of automated guided vehicles on container terminals. OR Spectrum 28(4):611–630
Bruzzone A, Signorile R (1998) Simulation and genetic algorithms for ship planning and shipyard layout. Simulation 71(2):74–83
Bruzzone A, Longo F, Nicoletti L, Bottani E, Montanari R (2012) Simulation, analysis and optimization of container terminals processes. Int J Model Simul Sci Comput. doi:10.1142/S1793962312400065
Canonaco P, Legato P, Mazza RM, Musmanno R (2008) A queuing network model for the management of berth crane operations. Comput Oper Res 35(8):2432–2446
Carlo HJ, Martinez-Acevedo FL (2015) Priority rules for twin automated stacking cranes that collaborate. Comput Ind Eng 89:23–33
Carlo HJ, Vis IFA, Roodbergen KJ (2014a) Storage yard operations in container terminals: literature overview, trends, and research directions. Eur J Oper Res 235(2):412–430
Carlo HJ, Vis IFA, Roodbergen KJ (2014b) Transport operations in container terminals: literature overview, trends, research directions and classification scheme. Eur J Oper Res 236:1–13
Carlo HJ, Vis IFA, Roodbergen KJ (2015) Seaside operations in container terminals: literature overview, trends, and research directions. Flex Serv Manuf 27(2):224–262
Carteni A, de Luca S (2012) Tactical and strategic planning for a container terminal: modelling issues within a discrete event simulation approach. Simul Model Pract Theory 21(1):123–145
Casaca ACP (2005) Simulation and the lean port environment. Marit Econ Logist 7(3):262–280
Chang D, Jiang Z, Yan W, He J (2011) Developing a dynamic rolling-horizon decision strategy for yard crane scheduling. Adv Eng Inform 25(11):485–494
Cheng JK, Ang CL, Tahar RM (2011a) Interactive microworlds for container terminal. Int J Model Oper Manage 1(3):289–309
Cheng JK, Tahar RM, Ang CL (2011b) A system dynamics approach to operational and strategic planning of a container terminal. Int J Logist Syst Manag 10(4):420–436
Choi YS (2004) Simulation study of performance measures of resources in a port container terminal. Int J Navig Port Res 28(7):587–591
Chung YG, Randhawa SU, McDowell ED (1988) A simulation analysis for a transtainer-based container handling facility. Comput Ind Eng 14(2):113–125
Cigolini R, Pero M, Rossi T, Sianes A (2013) Using simulation to optimize transhipment systems: applications in field. Marit Econ Logist 15(3):332–348
Clausen U, Kaffka J (2015) Development of priority rules for handlings in inland port container terminals with simulation. J Simul. doi:10.1057/jos.2015.11
Cordeau JF, Legato P, Mazza RM, Trunfio R (2015) Simulation-based optimization for housekeeping in a container transshipment terminal. Comput Oper Res 53:81–95
Cortes P, Munuzuri J, Ibanez JN, Guadix J (2007) Simulation of freight traffic in the Seville Inland Port. Simul Model Pract Theory 15(3):256–271
Dahal KP, Galloway SJ, Burt GM, McDonald JR, Hopkins I (2003) A port system simulation facility with an optimisation capability. Int J Comput Intell Appl 3(4):395–410
Dahal KP, Galloway SJ, Burt GM, McDonald JR, Hopkins I (2007) Modelling, simulation and optimisation of port system management. Int J Agile Syst Manag 2(1):92–108
Darzentas J, Spyrou T (1996) Ferry traffic in the Aegean islands: a simulation study. J Oper Res Soc 47(2):203–216
David RJ, Collier PI (1979) The simulation of a fork-lift truck and crane transfer operation. Marit Policy Manag 6(2):157–166
Dekker R, Voogd P, van Asperen E (2006) Advanced methods for container stacking. OR Spectrum 28(4):563–586
Dekker R, Heide S, van Asperen E, Ypsilantis P (2013) A chassis exchange terminal to reduce truck congestion at container terminals. Flex Serv Manuf J 25(4):528–542
Demirci E (2003) Simulation modelling and analysis of a port investment. Simulation 79(2):94–105
Ding YZ (2010) Throughput capacity of a container terminal considering the combination patterns of the types of arriving vessels. J Shanghai Jiaotong Univ (Sci) 15(1):124–128

Do NAD, Nielsen IE, Chen G, Nielsen P (2014) A simulation-based genetic algorithm approach for reducing emissions from import container pick-up operation at container terminal. Ann Oper Res. doi:10.1007/s10479-014-1636-0

Douma AM, van Hillegersberg J, Schuur PC (2012) Design and evaluation of a simulation game to introduce a multi-agent system for barge handling in a seaport. Decis Support Syst 53(3):465–472

Dragović B, Park NK, Radmilović Z, Maraš V (2005) Simulation modelling of ship-berth link with priority service. Marit Econ Logist 7(4):316–335

Dragović B, Park NK, Radmilović Z (2006) Ship-berth link performance evaluation—simulation and analytical approaches. Marit Policy Manag 33(3):281–299

Dragović B, Škurić M, Kofjač D (2014) A proposed simulation based operational policy for cruise ships in the Port of Kotor. Marit Policy Manag 41(6):560–588

Duinkerken MB, Dekker R, Kurstjens STGL, Ottjes JA, Dellaert NP (2006) Comparing transportation systems for inter-terminal transport at the Maasvlakte container terminals. OR Spectrum 28(4):469–493

Dulebenets MA, Golias MM, Mishra S, Heasle WC (2015) Evaluation of the floaterm concept at marine container terminal via simulation. Simul Model Pract Theory 54:19–35

El Sheikh AAR, Paul RJ, Harding AS, Balmer DW (1987) A microcomputer-based simulation study of a port. J Oper Res Soc 38(8):673–681

Elazony M, Khalifa A, Alsaied M (2011) Design and implementation of a port simulator using formal graphical approach (FGA). Int Arab J e-Technol 2(1):36–43

ElMesmary HT, Song DP, Dinwoodie J (2015) Pipe flow modelling of container terminal logistics processes: a case study in Alexandria. Int J Logist Res Appl 18(2):168–187

Esmer S, Cetin IB, Tuna O (2010) A simulation for optimum terminal truck number in a Turkish port based on lean and green concept. Asian J Shipp Logist 26(2):277–296

Esmer S, Yildiz G, Tuna O (2013) A new simulation modelling approach to continuous berth allocation. Int J Logist Res Appl 16(5):398–409

Fanti MP, Iacobellis G, Ukovich W, Boschian V, Georgoulas G, Stylios C (2015) A simulation based decision support system for logistics management. J Comput Sci 10:86–96

Fleming M, Huynh N, Xie Y (2013) Agent-based simulation tool for evaluating pooled queue performance at marine container terminals. Transp Res Rec 2330:103–112

Gambardella LM, Rizzoli AE, Zaffalon M (1998) Simulation and planning of intermodal container terminal. Simulation 71(2):107–116

Gambardella LM, Mastrolilli M, Rizzoli AE, Zaffalon M (2001) An optimisation methodology for intermodal terminal management. J Intell Manuf 12(5–6):521–534

Garro A, Monaco MF, Russo W, Sammarra M, Sorrentino G (2015) Agent-based simulation for the evaluation of a new dispatching model for the straddle carrier pooling problem. Simulation 91(2):181–202

Gelereh S, Merzouki R, McGinley K, Murray R (2013) Scheduling of intelligent and autonomous vehicles under pairing/unpairing collaboration strategy in container terminals. Transp Res Part C 33:1–21

Grunow M, Günther HO, Lehmann M (2004) Dispatching multi-load AGVs in highly automated seaport container terminals. OR Spectrum 26(2):211–235

Grunow M, Günther HO, Lehmann M (2006) Strategies for dispatching AGVs at automated seaport container terminals. OR Spectrum 28(4):587–610

Guan Y, Yang KH (2010) Analysis of berth allocation and inspection operations in a container terminal. Marit Econ Logist 12(4):347–369

Guimaraes RC, Kingsman BG (1989) Simulation-optimisation: the method and its application in the analysis of grain terminal operations. Eur J Oper Res 41(1):44–53

Guldogan EU (2010) Simulation-based analysis for hierarchical storage assignment policies in a container terminal. Simulation 87(6):523–537

Günther HO, Kim KH (2006) Container terminals and terminal operations. OR Spectrum 28(4):437–445

Guo X, Huang SY (2012) Dynamic space and time partitioning for yard crane workload management in container terminals. Transp Sci 46(1):134–148

Guolei T, Zijian G, Xuhui Y, Xiangqun Pengcheng (2014) SPAC to improve port performance for seaports with very long one-way entrance channels. J Waterw Port Coast Ocean Eng 140(40):04014011–04014013

Hadjiconstantinou E, Ma NL (2009) Evaluating straddle carrier deployment policies: a simulation study for the Piraeus container terminal. Marit Policy Manag 36(4):353–366

Hansen JB (1972) Optimising ports through computer simulation sensitivity analysis of pertinent parameters. J Oper Res Soc 23(4):519–530
Harris AG, Holden AR, Schroer BJ, Möeller DPF (2008) A simulation approach to evaluating productivity improvement at a seaport coal terminal. Transp Res Rec 2062:19–24
Hartmann S (2013) Scheduling reefer mechanics at container terminals. Transp Res Part E 51:17–27
Hartmann S (2004) Generating scenarios for simulation and optimisation of container terminal logistics. OR Spectrum 26(2):171–192
Hassan SA (1993) Port activity simulation: an overview. Simul Dig 23(2):17–36
Hayuth Y, Pollatschek MA, Roll Y (1994) Building a port simulator. Simulation 63(3):179–189
He J, Zhang W, Huang Y, Yan W (2013) A simulation optimization method for internal trucks sharing assignment among multiple container terminals. Adv Eng Inform 27(4):598–614
He J, Huang Y, Yan W (2015a) Yard crane scheduling in a container terminal for the trade-off between efficiency and energy consumption. Adv Eng Inform 29(1):59–75
He J, Huang Y, Chang D (2015b) Simulation-based heuristic method for container supply chain network optimization. Adv Eng Inform 29(13):339–354
He J, Huang Y, Yan W, Wang S (2015c) Integrated internal truck, yard crane and quay crane scheduling in a container terminal considering energy consumption. Expert Syst Appl 42(5):2464–2487
Henesey L, Davidsson P, Persson JA (2006) Evaluating container terminal transshipment operational policies: an agent based simulation approach. WSEAS Trans Comput 5(9):2090–2098
Henesey L, Davidsson P, Persson JA (2009) Agent based simulation architecture for evaluating operational policies in transshipping containers. Auton Agent Multi-Agent Syst 18(2):220–238
Hernandez AJA, Cho SW, Pak MS (2012) Fuel consumption within cargo operations at the port industry—a simulation analysis on the case of S Port Company in the UK. Asian J Shipp Logist 28(2):227–254
Holguín-Veras J, Walton CM (1997) Implementation of priority systems for containers at marine intermodal terminals. Transp Res Rec 1602:57–64
Howard DL, Bragen MJ, Burke JF, Love RJ (2004) PORTSIM 5: modelling from a seaport level. Math Comput Model 39(6–8):715–731
Huang WC, Kuo TC, Wu CT, Li G (2007a) Evaluation of operation performance for container terminal from micro point view. J East Asia Soc Transp Stud 7(1):3103–3118
Huang WC, Kuo TC, Wu CT (2007b) A comparison of analytical methods and simulation for container terminal planning. J Chin Inst Ind Eng 24(3):200–209
Huang SY, Hsu WJ, Chen C, Ye R, Nautiyal S (2008) Capacity analysis of container terminals using simulation techniques. Int J Comput Appl Technol 32(4):246–253
Huang WC, Kuo TC, Wang J, Wu CT (2010) A research of improvement strategy of the operation performance of container terminal. J East Asia Soc Transp Stud 8(1):2256–2271
Huynh N (2009) Reducing truck turn times at marine terminals with appointment scheduling. Transp Res Rec 2100:47–57
Huynh N, Walton CM (2008) Robust scheduling of truck arrivals at marine container terminals. J Transp Eng 134(8):347–353
Huynh N, Walton CM, Davis J (2004) Finding the number of yard cranes needed to achieve desired truck turn time at marine container terminals. Transp Res Rec 1873:99–108
Ilati G, Sheikholeslami A, Hassannayebi E (2014) A simulation-based optimization approach for integrated port resource allocation problem. Transp Traffic Eng 26(3):243–255
Jaoua A, Riopel D, Gamache M (2012) A simulation framework for real-time fleet management in internal transport systems. Simul Model Pract Theory 21(1):78–90
Kavakeb S, Nguyen TT, McGinley K, Yang Z, Jenkinson I, Murray R (2015) Green vehicle technology to enhance the performance of a European port: a simulation model with a cost-benefit approach. Transp Res Part C 60:169–188
Kemme N (2012) Effects of storage block layout and automated yard crane systems on the performance of seaport container terminals. OR Spectrum 34(3):563–591
Khatiashvili S, Bakeev C, Fidler M (2006) Application of simulation modelling to harbour operations. Proc Inst Civil Eng Marit Eng 159(MA3):121–128
Kia M, Shayan E, Ghotb F (2000) The importance of information technology in port terminal operations. Int J Phys Distrib Logist Manag 30(3/4):331–344
Kia M, Shayan E, Ghotb F (2002) Investigation of port capacity under a new approach by computer simulation. Comput Ind Eng 42(2–4):533–540

Kim KH, Bae JW (2004) A look-ahead dispatching method for automated guided vehicles in automated port container terminals. Transp Sci 38(2):224–234
Kim KH, Won SH, Lim JK, Takahashi T (2004) An architectural design of control software for automated container terminals. Comput Ind Eng 46(4):741–754
Kofjač D, Škurić M, Dragović B, Škraba A (2013) Traffic modeling and performance evaluation in the Kotor Cruise Port. J Mech Eng 59(9):526–535
Kondratowicz LJ (1990) Simulation methodology for intermodal freight transportation terminals. Simulation 55(1):49–59
Kondratowicz LJ (1992) Methodological solutions for increased efficiency of modelling and simulation of seaports and inland freight terminals. Marit Policy Manag 19(2):157–164
Kondratyev M (2015) An object-oriented approach to port activity simulation. Int J Simul Process Model 10(1):1–9
Kose E, Basar E, Demirci E, Guneroglu A, Erkebay S (2003) A simulation of marine traffic in Istanbul strait. Simul Model Pract Theory 11(5):579–608
Kozan E (1997a) Comparison of analytical and simulation planning models of seaport container terminals. Transp Plan Technol 20(3):235–248
Kozan E (1997b) Increasing the operational efficiency of container terminals in Australia. J Oper Res Soc 48(9):151–161
Kozan E (2006) Optimum capacity for intermodal container terminals. Transp Plan Technol 29(6):471–482
Kulak O, Polat O, Gujjula R, Günther HO (2013) Strategies for improving a long-established terminal's performance: a simulation study of a Turkish container terminal. Flex Serv Manuf J 25(4):503–527
Lagoudis IN, Rice JB, Salminen JB (2014) Port investment strategies under uncertainty: the case of a Southeast Asian multipurpose port. Asian J Shipp Logist 30(3):299–319
Laik N, Hadjiconstantinou E (2008) Evaluation of operational plans in container terminal yards using discrete-event simulation. OR Insight 21(4):10–18
Lau H, Chan L, Wong R (2007) A virtual container terminal simulator for the design of terminal operation. Int J Interact Design Manuf 1(2):107–113
Lawrence P (1973) A computer simulation model for port planning. Int J Phys Distrib 4(1):26–39
Layaa J, Dullaert W (2014) Measuring and analysing terminal capacity in East Africa: the case of the seaport of Dar es Salaam. Marit Econ Logist 16(2):141–164
Lee TW, Park NK, Lee DW (2003) A simulation study for the logistics planning of a container terminal in view of SCM. Marit Policy Manag 30(3):243–254
Legato P, Mazza RM (2001) Berth planning and resources optimisation at a container terminal via discrete event simulation. Eur J Oper Res 133(3):537–547
Legato P, Canonaco P, Mazza RM (2009) Yard crane management by simulation and optimisation. Marit Econ Logist 11(1):36–57
Legato P, Mazza RM, Trunfio R (2010) Simulation-based optimisation for discharge/loading operations at a maritime container terminal. OR Spectrum 32(3):543–567
Legato P, Mazza RM, Gulli D (2014) Integrating tactical and operational berth allocation decisions via simulation–optimization. Comput Ind Eng 78:84–94
Lehnfeld J, Knust S (2014) Loading, unloading and premarshalling of stacks in storage areas: survey and classification. Eur J Oper Res 239(2):297–312
Li H, Wang D (2009) Parallel simulation-based optimisation on block planning and dynamic truck configuration of container terminals. Int J Inf Syst Logist Manag 4(2):1–8
Lima ADP, de Mascarenhas FW, Frazzon EM (2015) Simulation-based planning and control of transport flows in port logistic systems. Math Probl Eng. doi:10.1155/2015/862635 **(Article ID 862635)**
Lin J, Gao B, Zhang C (2014) Simulation-based investment planning for Humen Port. Simul Model Pract Theory 40:161–175
Liu CI, Jula H, Ioannou PA (2002) Design, simulation, and evaluation of automated container terminals. IEEE Trans Intell Transp Syst 3(1):12–26
Liu CI, Jula H, Vukadinovic K, Ioannou P (2004) Automated guided vehicle system for two container yard layouts. Transp Res Part C 12(4):349–368
Longo F (2010) Design and integration of the containers inspection activities in the container terminal operations. Int J Prod Econ 125(2):272–283
Longo F, Huerta A, Nicoletti L (2013) Performance analysis of a Southern Mediterranean Seaport via discrete-event simulation. J Mech Eng 59(9):517–525

Longo F, Chiurco A, Musmanno R, Nicoletti L (2015) Operative and procedural cooperative training in marine ports. J Comput Sci 10:97–107
Luo M, Grigalunas TA (2003) A spatial-economic multimodal transportation simulation model for US coastal container ports. Marit Econ Logist 5(2):158–178
Luo J, Wu Y, Halldorsson A, Song X (2011) Storage and stacking logistics problems in container terminals. OR Insight 24:256–275
Martinez FM, Gutierrez IG, Oliveira AO, Arreche Bedia LMA (2004) Gantry crane operations to transfer containers between trains: a simulation study of a Spanish terminal. Transp Plan Technol 27(4):261–284
Massei M, Tremori A, Poggi S, Nicoletti L (2013) HLA-based real time distributed simulation of a marine port for training purposes. Int J Simul Process Model 8(1):42–51
Mathew R Jr, Leathrum JF, Mazumdar S, FrithT Joines J (2005) An object-oriented architecture for the simulation of networks of cargo terminal operations. J Def Model Simul Appl Methodol Technol 2(2):101–116
Mavrakis D, Kontinakis N (2008) A queueing model of maritime traffic in Bosporus straits. Simul Model Pract Theory 16(3):315–328
Merkuryev Y, Tolujew J, Blumel E, Novitsky L, Ginters E, Viktorova E, Merkuryeva G, Pronins J (1998) A modelling and simulation methodology for managing the Riga harbour container terminal. Simulation 71(2):84–95
Merkuryeva G, Merkuryev Y, Tolujev J (2000) Computer simulation and metamodelling of logistics processes at a container terminal. Stud Inform Control 9(1):53–59
Merrick JRW, van Dorp JR, Blackford JP, Shaw GL, Harrald J, Mazzuchi TA (2003) A traffic density analysis of proposed ferry service expansion in San Francisco bay using a maritime simulation model. Reliab Eng Syst Saf 81(2):119–132
Mondragon AEC, Lalwani SC, Mondragon ESC, Mondragon CEC, Pawar KS (2012) Intelligent transport systems in multimodal logistics: a case of role and contribution through wireless vehicular networks in a sea port location. Int J Prod Econ 137(1):165–175
Moon DSH, Woo JK (2014) The impact of port operations on efficient ship operation from both economic and environmental perspectives. Marit Policy Manag 41(5):444–461
Na UJ, Shinozuka M (2009) Simulation-based seismic loss estimation of seaport transportation system. Reliab Eng Syst Saf 94(3):722–731
Nam KC, Ha WI (2001) Evaluation of handling systems for container terminals. J Waterw Port Coast Ocean Eng 127(3):171–175
Nam KC, Kwak KS, Yu MS (2002) Simulation study of container terminal performance. J Waterw Port Coast Ocean Eng 128(3):126–132
Nevins MR, Macal CM, Joines J (1998a) A discrete-event simulation model for seaport operations. Simulation 70(4):213–223
Nevins MR, Macal CM, Love RJ, Bragen MJ (1998b) Simulation, animation, and visualization of seaport operations. Simulation 71(2):96–106
Ng WC, Wong CS (2006) Evaluating the impact of vessel-traffic interference on container terminal capacity. J Waterw Port Coast Ocean Eng 132(2):76–82
Nicoletti L, Chiurco A, Arango C, Diaz R (2014) Hybrid approach for container terminals performances evaluation and analysis. Int J Simul Process Model 9(1–2):104–112
Ottjes JA, Veeke HPM, Duinkerken MB, Rijsenbrij JC, Lodewijks G (2006) Simulation of a multiterminal system for container handling. OR Spectrum 28(4):447–468
Pachakis D, Kiremidjian AS (2003) Ship traffic modelling methodology for ports. J Waterw Port Coast Ocean Eng 129(5):193–202
Pallis AA, Vitsounis TK, de Langen PW (2010) Port economics, policy and management: review of an emerging research field. Transp Rev 30(1):115–161
Pallis AA, Vitsounis TK, de Langen PW, Notteboom T (2011) Port economics, policy and management: content classification and survey. Transp Rev 31(4):445–471
Park NK, Dragović B (2009) A study of container terminal planning. FME Trans 37(4):203–209
Park CS, Noh YD (1987a) A port simulation model for bulk cargo operations. Simulation 4(6):236–246
Park CS, Noh YD (1987b) An interactive port capacity expansion simulation model. Eng Costs Prod Econ 11(2):109–124
Park NK, Dragović B, Meštrović R, Kim JY (2007) Simulation and analysis of container terminals operations—case study: Korean Ports. Model Optim Mach Buil Field 13(3):171–180
Park NK, Dragović B, Kim JY (2009) Dynamic equipment deployment at a container terminal: transfer system based on real-time positioning. J Mech Eng 55(2):83–94

Parola F, Sciomachen A (2005) Intermodal container flows in a port system network: analysis of possible growths via simulation models. Int J Prod Econ 97(1):75–88
Perković M, Gucma L, Przywarty M, Gucma M, Petelin S, Vidmar P (2012) Nautical risk assessment for LNG operations at the Port of Koper. J Mech Eng 58(10):607–613
Petering MEH (2009) Effect of block width and storage yard layout on marine container terminal performance. Transp Res Part E 45(4):591–610
Petering MEH (2010) Development and simulation analysis of real-time, dual-load yard truck control systems for seaport container transshipment terminals. OR Spectrum 32(3):633–661
Petering MEH (2011) Decision support for yard capacity, fleet composition, truck substitutability, and scalability issues at seaport container terminals. Transp Res Part E 47(1):85–103
Petering MEH (2015) Real-time container storage location assignment at an RTG-based seaport container transshipment terminal: problem description, control system, simulation model, and penalty scheme experimentation. Flex Serv Manuf 27(2):351–381
Petering MEH, Murty KG (2009) Effect of block length and yard crane deployment systems on overall performance at a seaport container transshipment terminal. Comput Oper Res 36(5):1711–1725
Petering MEH, Wu Y, Li W, Goh M, de Souza R (2009) Development and simulation analysis of real-time yard crane control systems for seaport container transshipment terminals. OR Spectrum 31(4):801–835
Pope JA, Rakes TR, Rees LP, Crouch IWM (1995) A Network simulation of high-congestion road traffic flows in cities with marine container terminals. J Oper Res Soc 46(9):1090–1101
Qu X, Meng Q (2012) Development and applications of a simulation model for vessels in the Singapore Straits. Expert Syst Appl 39:8430–8438
Quy NM, Vrijling JK, van Gelder PHAJM (2008) Risk and simulation-based optimisation of channel depths: entrance channel of Cam Pha Coal Port. Simulation 84(1):41–56
Ragheb M, Rekab K, Tadj L (2010) Validating a port simulation model with application to the port of Alexandria, Egypt. Int J Simul Process Model 6(2):115–125
Ramani KV (1996) An interactive simulation model for the logistics planning of container operations in seaports. Simulation 66(5):291–300
Rashidi H, Tsang EPK (2013) Novel constraints satisfaction models for optimization problems in container terminals. Appl Math Model 37(6):3601–3634
Rizzoli AE, Fornara N, Gambardella LM (2002) A simulation tool for combined rail/road transport in intermodal terminals. Math Comput Simul 59(1–3):57–71
Sacone S, Siri S (2009) An integrated simulation-optimisation framework for the operational planning of seaport container terminals. Math Comput Model Dyn Syst 15(3):275–293
Sauri S, Morales-Fusco P, Martin E, Benitez P (2014) Comparing manned and automated horizontal handling equipment at container terminals: productivity and economic analysis. Transp Res Rec 2409:40–48
Sgouridis SP, Makris D, Angelides DC (2003) Simulation analysis for midterm yard planning in Container terminal. J Waterw Port Coast Ocean Eng 129(4):178–187
Shabayek AA, Yeung WW (2002) A simulation model for the Kwai Chung container terminal in Hong Kong. Eur J Oper Res 140(1):1–11
Sharif O, Huynh N (2012) Yard crane scheduling at container terminals: a comparative study of centralized and decentralized approaches. Marit Econ Logist 14(2):139–161
Silberholz MB, Golden BL, Baker EK (1991) Using simulation to study the impact of work rules on productivity at marine container terminals. Comput Oper Res 18(5):433–452
Soriguera F, Espinet D, Robuste R (2006) A simulation model for straddle carrier operational assessment in a marine container terminal. J Marit Res 3(2):19–34
Stahlbock R, Voss S (2008) Operations research at container terminals: a literature update. OR Spectrum 30(1):1–52
Steenken D, Voss S, Stahlbock R (2004) Container terminal operation and operations research—a classification and literature review. OR Spectrum 26(1):3–49
Steer DT, Page ACC (1961) Feasibility and financial studies of a port installation. J Oper Res Soc 12(3):145–160
Sun Z, Lee LH, Chew EP, Tan KC (2012) MicroPort: a general simulation platform for seaport container terminals. Adv Eng Inform 26(1):80–89
Sun Z, Tan KC, Lee LH, Chew EP (2013) Design and evaluation of mega container terminal configurations: an integrated simulation framework. Simulation 89(6):684–692

Tahar MR, Hussain K (2000) Simulation and analysis for the Kelang container terminal operations. Logist Inf Manag 13(1):14–20
Taner ME, Kulak O, Koyuncuoglu MU (2014) Layout analysis affecting strategic decisions in artificial container terminals. Comput Ind Eng 75:1–12
Tao J, Qiu Y (2015) A simulation optimization method for vehicles dispatching among multiple container terminals. Expert Syst Appl 42(7):3742–3750
Thiers GF, Janssens GK (1998) A port simulation model as a permanent decision instrument. Simulation 71(2):117–125
Tugcu S (1983) A simulation study on the determination of the best investment plan for Istanbul seaport. J Oper Res Soc 34(6):479–487
Turner HS (2000) Evaluating seaport policy alternatives: a simulation study of terminal leasing policy and system performance. Marit Policy Manag 27(3):283–301
Ugurlu O, Yuksekyıldız E, Kose E (2014) Simulation model on determining of port capacity and queue size: a case study for BOTAS Ceyhan Marine Terminal. TransNav Int J Mar Navig Saf Sea Transp 8(1):143–150
Ursavas E (2014) A decision support system for quayside operations in a container terminal. Decis Support Syst 59:312–324
Ursavas E (2015) Priority control of berth allocation problem in container terminals. Ann Oper Res. doi:10.1007/s10479-015-1912-7
van Asperen E, Borgman B, Dekker R (2013) Evaluating impact of truck announcements on container stacking efficiency. Flex Serv Manuf J 25(4):543–556
van Vianen T, Ottjes J, Lodewijks G (2014) Simulation-based determination of the required stockyard size for dry bulk terminals. Simul Model Pract Theory 42:119–128
Veenstra A, Lang N (2004) Economic analysis of a container terminal simulation. Int J Logist Res Appl 7(3):263–279
Veenstra A, Zuidwijk R, van Asperen E (2012) The extended gate concept for container terminals: expanding the notion of dry ports. Marit Econ Logist 14(1):14–32
Vis IFA, de Koster RBM (2003) Transshipment of containers at a container terminal: an overview. Eur J Oper Res 147(1):1–16
Vis IFA, Harika I (2004) Comparison of vehicle types at an automated container terminal. OR Spectrum 26(1):117–143
Vis IFA, van Anholt G (2010) Performance analysis of berth configurations at container terminals. OR Spectrum 32(3):453–476
Vis IFA, de Koster RBM, Savelsbergh MWP (2005) Minimum vehicle fleet size under time-window constraints at a container terminal. Transp Sci 39(2):249–260
Wadhwa L (1992) Planning operations of bulk loading terminals by simulation. J Waterw Port Coast Ocean Eng 118(3):300–315
Wadhwa L (2000) Optimising deployment of shiploaders at bulk export terminal. J Waterw Port Coast Ocean Eng 126(6):297–304
Wall TA, Rodgers MO, Fujimoto R, Hunter MP (2015) A federated simulation method for multi-modal transportation systems: combining a discrete event-based logistics simulator and a discrete time-step-based traffic microsimulator. Simulation 91(2):148–163
Wanke FP (2011) Ship-berth link simulation: impact on total demurrage costs. Int J Shipp Transp Logist 3(3):261–294
Woo SH, Pettit SJ, Kwak DW, Beresford AKC (2011) Seaport research: a structured literature review on methodological issues since the 1980s. Transp Res Part A 45(7):667–685
Woo SH, Pettit SJ, Beresford AKC, Kwak DW (2012) Seaport research: a decadal analysis of trends and themes since the 1980s. Transp Rev 32(3):351–377
Xin J, Negenborn RR, Corman F, Lodewijks G (2014) Energy-aware control for automated container terminals using integrated flow shop scheduling and optimal control. Transp Res Part C 44:214–230
Xin J, Negenborn RR, Corman F, Lodewijks G (2015a) Control of interacting machines in automated container terminals using a sequential planning approach for collision avoidance. Transp Res Part C 60:377–396
Xin J, Negenborn RR, Lodewijks G (2015b) Event-driven receding horizon control for energy-efficient container handling. Control Eng Pract 39:45–55
Xin J, Negenborn RR, Lodewijks G (2015c) Energy-efficient container handling using hybrid model predictive control. Int J Control 88(11):2327–2346

Yamada T, Frazila RB, Yoshizawa G, Mori K (2003) Optimising the handling capacity in a container terminal for investigating efficient handling systems. J East Asia Soc Transp Stud 5(1):597–608
Yang C, Choi Y, Ha T (2004) Simulation-based performance evaluation of transport vehicles at automated container terminals. OR Spectrum 26(2):149–170
Yazdani R, Schmidt FA, Merkuryev Y, Kamperman F (2005) The generic animation and simulation tool for ports and terminals. Int J Simul Syst Sci Technol 6(7–8):61–69
Yeo GT, Michael R, Soak SM (2007) Evaluation of the marine traffic congestion of north harbor in Busan port. J Waterw Port Coast Ocean Eng 133(2):87–93
Yeo GT, Pak J-Y, Yang Z (2013) Analysis of dynamic effects on seaports adopting port security policy. Transp Res Part A 49:285–301
Yin XF, Khoo LP, Chen CH (2011) A distributed agent system for port planning and scheduling. Adv Eng Inform 25(3):403–412
Yun WY, Choi YS (1999) A simulation model for container-terminal operation analysis using an object-oriented approach. Int J Prod Econ 59(1–3):221–230
Zehendner E, Feillet D (2014) Benefits of a truck appointment system on the service quality of inland transport modes at a multimodal container terminal. Eur J Oper Res 235(2):461–469
Zehendner E, Rodriguez-Verjan G, Absi N, Dauzere-Peres S, Feillet D (2015) Optimized allocation of straddle carriers to reduce overall delays at multimodal container terminals. Flex Serv Manuf 27(2):300–330
Zeng Q, Yang Z (2009) Integrating simulation and optimisation to schedule loading operations in container terminals. Comput Oper Res 36(6):1935–1944
Zeng Q, Yang Z (2010) An approach integration simulation and Q-learning algorithm for operation scheduling in container terminals. J East Asia Soc Transp Stud 8:2225–2239
Zeng Q, Diabat A, Zhang Q (2015) A simulation optimization approach for solving the dual-cycling problem in container terminals. Marit Policy Manag 42(8):806–826
Zhang C, Wu T, Kim KH, Mia L (2014) Conservative allocation models for outbound containers in container terminals. Eur J Oper Res 238(1):155–165
Zhao WJ, Goodchild AV (2010) The impact of truck arrival information on container terminal rehandling. Transp Res Part E 46(3):327–343
Zhao WJ, Goodchild AV (2013) Using the truck appointment system to improve yard efficiency in container terminals. Marit Econ Logist 15(1):101–119
Zhu M, Fan X, Cheng H, He Q (2010) Modelling and simulation of automated container terminal operation. J Comput 5(6):951–957

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