CHALLENGES AND OPPORTUNITIES IN IMPLEMENTING GREEN INITIATIVES FOR PORT TERMINALS

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ABSTRACT
The new Green Management Practices (GMP) paradigm has emerged as an effective management tool for firms to achieve superior performance and to deal with both economic and environmental aspects by applying ecological criteria. This is particularly true for port terminals where environmental issues are becoming critical due to the increase in freight volumes. Accordingly, this article proposes a flexible solution capable of recreating (after preliminary customization) a port terminal and while taking into consideration the main factors affecting sustainability of port operations. This approach provides the user with an advanced decision support system (DSS) for investigating managerial and policy implications in an eco-friendly framework. This work is positioned to culminate in the development of a software DSS whose aim is to support business decisions based on the environmental impact analysis of processes and activities performed in the course of the life-cycle of the port terminal, and to simulate and compare design alternatives in terms of both environmental impact and economic sustainability.

Keywords: Green Port, Sustainability, Modeling, Analysis and Simulation, Business Decision

1. INTRODUCTION

There is an increasing pressure in the transportation industry to devise and implement environmentally friendly strategies for global freight movement. Numerous approaches have been developed utilizing technological advances and innovative activities to reduce energy consumption and carbon emission in freight transportation. On one hand it has been argued that a firm can gain differentiation advantage not only by cooperating with supply chain partners, but also by implementing internal environmental operations and adopting environmental strategies throughout the supply chain (Longo 2012). This approach is known as *environmental product differentiation* and asserts that it is possible for firms to enhance their performance and simultaneously reduce the negative effects of their activities on the environment by implementing GMPs (Shrivastava, 1995). On the other hand, it has also been argued that firms perceive a paucity of evidence that the benefits derived from the implementation of Green Management Practices (GMPs) exceed the costs of pursuing these initiatives (Montabon et al. 2007).

Taking into account such conflicting considerations and given the importance of developing GMPs, the main goal of this paper is the definition and development of a framework capable of examining the linkage between the adoption of GMPs and the port's performance metrics - the application area of the framework proposed in this paper - which play the role of transportation intermediaries that facilitate trade flows across the global supply chain (Wong et al., 2009; Yang et al., 2009). Indeed, as far as sustainability in marine ports is concerned, several studies on a variety of ports worldwide have been carried out, e.g., Gupta et al. (2002), Saxe and Larsen (2004), Lucialli et al. (2007), Joseph et al. (2009), Mittal and Baveja (in press). Marine vessels, trucks, cranes, locomotives, and off-road equipment used for moving cargo were identified as the main sources of pollution (Bailey and Solomon, 2004).

Investigating this connection is a strategic issue for many companies (including those operating port terminals) due primarily to market pressures exerted by customers' and suppliers' increasing demand to minimize the negative environmental impact of operations (Karakosta et al., 2009, Golusin et al., 2011). Indeed, the concept of green port has been known since 1992 (Agenda 21), and subsequently, the quest for environmentally friendly measures has been on the rise.

As far as port terminals are concerned, the study of GMPs consists of identifying best practices that simultaneously reduce the negative impacts of port operations on the environment and improve terminal performance metrics. Unlike regulatory requirements, which originate externally, GMPs consist of operational processes that arise from within a firm. At the business planning level, GMPs are collections of internal efforts aiming to define business policies and processes that require the port terminal to assess its environmental impacts, determine environmental goals, and implement operations that establish environmental stewardship, monitor goal attainment, and undergo management review.

This paper reports the preliminary results of an ongoing research project, dubbed T-ESEDRAS (***T****erminals* ***E****nvironmental* ***S****ustainability* ***E****nhancement* *based On **D**ata **R**e-organization **A**nalysis and **S**imulation*). This project is a joint collaborative effort of the MSC-LES lab (University of Calabria), and Italian stakeholders operating in the Gioia Tauro Harbor area (e.g. ICO BLG Automobile Logistics Italia). The main goal is the development of DSS software that supports business decisions based on environmental impact analysis of processes and activities performed in the course of the life cycle of a port terminal. Using a simulation model, this work facilitates comparing alternatives in terms of both environmental impacts and technical and economic sustainability. By modeling sustainability and monitoring environmental impact (Bruzzone 2014), port terminal operations will be able to effect continuous improvement of their performance metrics. By using methodologies such as Life Cycle Assessment (LCA), the T-ESEDRAS simulation model aims to:

- Improve the economic efficiency and rationalize the use of resources in the early stages of the life cycle (often characterized by significant environmental impact);
- Improve and strengthen the firm's market position through the promotion of services designed to be eco-friendly;
- Improve risk management processes by strengthening and promoting collaboration among companies, suppliers, customers, local authorities, research universities and environmental groups.

To summarize, the T-ESEDRAS simulation model aims to test various configurations of green practices, and for each scenario, the model is designed to measure the performance of the tested solution.

The rest of this paper is organized as follows: Section 2 presents an overview of green initiatives in port terminals; Section 3 describes the simulation model architecture and conceptual models. Section 4 presents the T-ESEDRAS simulation model, its main features and functionality. Finally Section 5 summarizes the main findings and conclusions.

2. GREEN INITIATIVES IN PORT TERMINALS

In recent years, ports all around the world have been demonstrating an increasing commitment to environmental protection and sustainable operations through a variety of actions, mandates and initiatives. In order to maximize the benefits of sustainability-related operations, the concept of "*green port*" has been introduced. The idea underlying this concept is to render traffic and port operations eco-friendly. The attainment of "green port" status is one of the most important objectives of many marine ports worldwide; such a status can be reached through the pursuit of various approaches, such as energy efficiency, collecting and recycling rainwater and wastes on board, and "zero emissions" policies. Those marine ports that are located close to major cities must become integrated into their surroundings to ensure that a sustainable development takes place in harmony with the economy and social development of the port itself and of the host city.

In this study, a large number of major ports were considered in order to identify the interventions (GMPs) needed to move towards the green port status. Four different but interrelated aspects are considered:

- *Environmental impact assessment*, by monitoring air and water quality, optimizing the flow of standard and toxic wastes, reducing the noise pollution, etc.;
- *Energy and resource consumption*, in order to save energy and maximize energy efficiency. International seaport authorities are committed to support a more efficient and effective energy management in various ways, such as using renewable energy sources (e.g. sun, wind), installing biodiesel or biofuel systems and assessing available technologies. Such reduction in energy consumption is not necessarily associated with technical changes alone, since it can also result from a better organization and management or improved economic efficiency in the port area;
- *Infrastructures and services* provided by port handling facilities. Ways to maximize the impact of green initiatives in the port include planning and managing port terminals in a sustainable way, improving operations and rationalizing access to the port as well as creating and expanding telematic services based on new technology solutions ;
- *Costs and financial management* (such as "make or buy" analysis or new pricing policies) have to be considered in order to encourage sustainable and environmentally friendly practices.

An exhaustive list of "green initiatives" undertaken globally by top terminal operators has been prepared by using the extant literature, trade reports, news articles and terminal operator's websites; this list is presented in Table 1. Global initiatives can provide a useful benchmark and encourage the adoption/testing of these initiatives in other locations where they are not currently deployed. In order to have a clearer view of worldwide initiatives, these practices have been organized in terms of:

- *Action area*, which constitutes a broader category that includes a single green initiative;
- *Best practice,* intended as a single green management practice;
- *Expected impact*, which includes both direct and indirect consequences of adopting a specific initiative within the port area. In fact, by adopting a green management practice, a direct consequence could be the reduction of pollutant emissions within the port area, though it could entail an indirect power consumption that results in increased pollutant emission where power is generated.

Table 1: Green Practices in Port Terminals

Action Area	Best Practice	Impact
Reduction of energy consumption in exterior lighting of roads, yards and docks	Flow Reductions at nighttime at points of low traffic	Indirect emissions Electrical consumption
	Promoting the incorporation or replacement of high-efficiency equipment (LED lighting)	
	Replacement of existing bulbs with lamps using motion sensors in specific areas of the port with low traffic	
	Optimization of indoor lighting systems in buildings	
Reduction of fuel consumption by machinery	Automatic shutdown in case of stand-by (start & stop systems)	Direct emissions Fuel consumption
	Software for optimizing fuel consumption of port mobile cranes	
	Active Front End technology (AFE) for port cranes	
	RIS.GA system with electrical generators to reduce emissions in stand-by mode	
	Regenerative power	
Reduction of fuel consumption by vessels	Vessel speed reduction while entering the port area	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Onshore Power Supply (Cold Ironing)	
Replacement of equipment	Replacement of Rubber Tired Gantry (RTG) and Terminal Tractor (TT) by Automated Rail Mounted Gantry (ARMG) and Automated Guided Vehicles (AGV)	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Replacement of RTG/RMG by E-RTG or installation of eco-friendly systems	
Power management	Analysis of quarter hours, alarms overruns, load test	Indirect emissions Electrical consumption
	Establishment of consumption patterns	
	Verification of losses in electrical wiring for overloaded lines (reactive compensation)	
	Installation of voltage optimization units to control the equipment's voltage input	
Throughput Enhancing Methods	Traffic reduction and optimization	Direct emissions Fuel consumption
	Minimizing equipment idle time reallocating cranes	
Reduction of emissions by parked vehicles	Industrial hybrid vehicles	Direct emissions Indirect emissions Fuel consumption Electrical consumption
	Movement of employees on bikes and via an organized port e-bus network	
	Electric vehicles for movement of operators	
	Gate policies for incoming trucks	
Improvement in energy efficiency of buildings	Implementation of green roof projects	Direct emissions Fuel consumption Electrical consumption
	Usage of thermal inertia in industrial cooling facilities	
	Landscaping around buildings to reduce urban heat effects and provide cooling	
	Improvements in the consumption of air conditioners by energy classification change	
	Rainwater harvesting and sewage disposal	
Clean fuels usage	Recycling the hydrocarbon fraction of water in oil dumping of tankers to recover its fuel	Direct emissions Fuel consumption
	Using NH3 for cooling systems instead of CFCs	
	Liquefied Natural Gas (LNG)	
	Ultra Low Sulfur Diesel (ULSD)	
	Biodiesel from algae	
	Green-diesel	
	Residual marine oil	
	Marine distillate oil	
	Blending biofuels	

Usage of renewable energies	Installation of wind energy in port facilities	Direct emissions Fuel consumption Electrical consumption
	Installation of photovoltaic energy for buildings	
	Installation of photovoltaic energy for equipment	
	Installation of solar thermal energy	
	Low-enthalpy geothermal energy (sea water heat pump)	
Port waste management	Conversion of waste into syngas or biogas	Direct emissions Fuel consumption Electrical consumption
Relationship-centric policies	Employee training	Direct emissions Fuel Consumption
	Relationships with stakeholders	
Electronic communication	Use of Integrated Information Systems	Direct emissions Fuel consumption Electrical consumption

Concerning the environmental impact of port operations, there is need not only to evaluate the environmental impact in terms of CO_2-equivalent emissions of all the equipment used in the port terminal (e.g. straddle carriers, trucks, tugboats, rail transtainers, ship arrivals and departures, etc.), but it is also required to investigate the environmental and economic consequences of a single or multiple green management practices over the terminal life cycle. Finally, according to Mittal et al. (in press), GMPs can be classified as follows:

- Technology-centric practices, such as cold ironing, replacement of traditional RTG, RMG or straddle carriers by container handling equipment powered by hybrid or fully electrical engines, and replacement of existing bulbs with high-efficiency equipment (LED lighting);
- Process-centric practices, such as gate policies in order to specify a time slot during which trucks are allowed to enter the port area;
- Relationship-centric practices, such as training operators with the goal of minimizing bad practices that can have a negative environmental impact.

3. SIMULATION MODEL ARCHITECTURE AND CONCEPTUAL PROCESS MODELS

Before conceptualizing container terminal operations, special attention should be paid to the general architecture of the simulation model being developed. Three activities need to be carried out in order to offer a rich experimental framework that enables the user to efficiently manage simulation runs, collect, and display and compare output results, and calibrate and optimize the model:

- A simple but sophisticated user-friendly animation view allows the user to observe system evolution in an interactive simulation environment. During model execution, the user can observe any object in action (e.g., a moving straddle carrier), so as to assure the correctness of proper operations flows;
- The model itself is run multiple times at various parameter settings. The user should be able to specify the range and step for parameter settings and let the simulation model runs all combinations. Alternatively, the user can programmatically control how parameter values affect a specific performance metric;
- After inputting model parameters and running the simulation, performance metrics need to be collected so as to compare simulation run outputs, the sensitivity of simulation results to changes in model parameters, and to tune parameters to improve performance metrics.

Conceptual models are used to understand the structure and dynamics of real-world complex systems like port terminals, (note that the T-ESEDRAS simulation model represents a container terminal model). The attendant diagrammatic representations, expressed in terms of mathematical and logical relationships, capture system structure and key aspects of the interaction among its components, thereby promoting deeper understanding of the system under study.

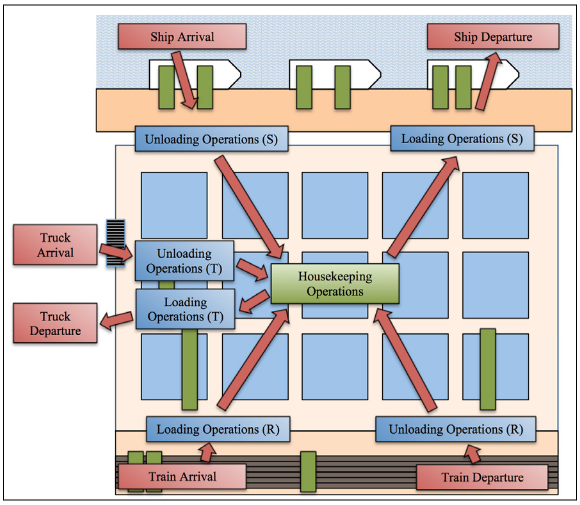

Figure 1: Schematic representation of a container terminal layout

To this end, flowcharts, being abstraction of model processes, are used as guidelines for simulation model development, in our case container terminal processes and activities (Banks, 1998). Figure 1 depicts a schematic representation of a container terminal lay-out. The layout is expressly designed to be as general as possible so as to encompass all key features of a container terminal, while being sufficiently flexible to allow the simulation model to capture multiple port terminal configurations. To this end, it has the following components:

- an approach/departure channel;
- a turning basin;
- a dock with three main berthing points;
- a yard where containers are stored;
- an entrance area connecting the port area with a highway, which is made up of 30 gates for incoming and outgoing trucks to be loaded and unloaded in the yard;
- a railway service with ten tracks.

Figure 2 depicts the flow chart used to abstract ship arrival and departure operations. Before entering the port area and approaching the assigned berth position, the ship is required to contact the port authority to check for berth availability and to require a maritime pilot to direct it to the port area. The ship may also require the assistance of a tugboat for performing maneuvers in the port area and completing entrance and mooring operations. Similar operations are then carried out when the ship leaves the port area. In a similar vein, Figure 3 depicts the flowchart conceptualizing container handling operations (container movements from berth to yard and vice versa) that are mainly performed by using Straddle Carriers (SC). More specifically, consider a container movement from quay to yard; after checking SC availability, if the container is already in the unloading zone (UZ) under the quay crane, the SC moves the container to the assigned slot in the yard area and performs housekeeping operations (if needed) and storage. Similar operations are carried out to move the container from its slot in the yard area to the loading zone (LZ, the buffer under the quay crane).

4. THE T-ESEDRAS SIMULATION MODEL

As mentioned in the Introduction section, this paper reports the preliminary results of an ongoing project named T-ESEDRAS (***T****erminals* ***E****nvironmental* ***S****ustainability* ***E****nhancement based* ***O****n* ***D****ata* ***R****e-organization* ***A****nalysis and* ***S****imulation*). The simulation model, presented in this section, takes the same name as the project.

In order to conform to the concept of Simulation as a Service (SaaS) the execution of a T-ESEDRAS simulation model can be invoked by a standard web browser.

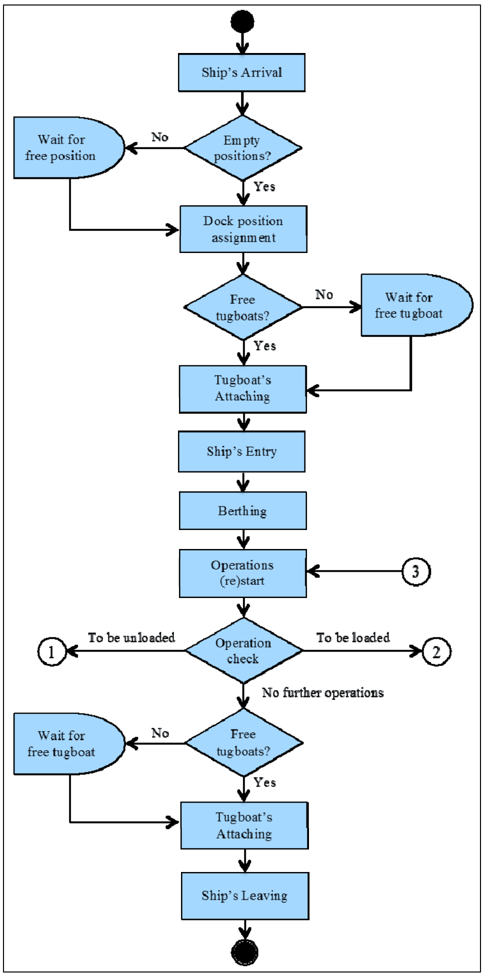

Figure 2: Flowchart for ship arrival and departure operations

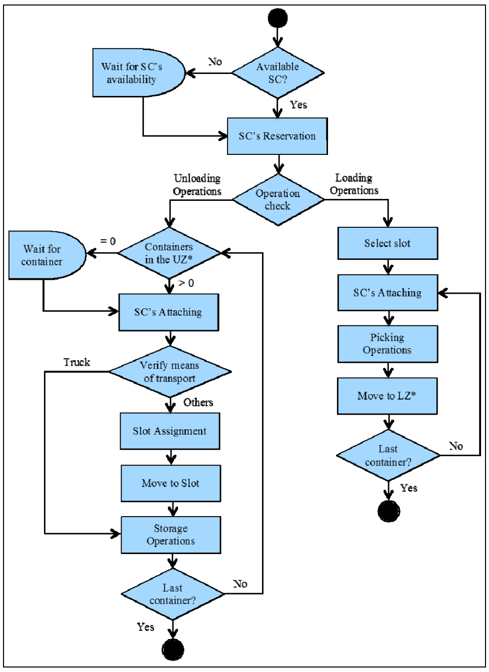

Figure 3: Flowchart conceptualizing container handling operations (container movements from berth to yard and vice versa)

This modeling and coding effort aims to allow users to overcome obstacles that are typical of non-service-oriented software, such as simulation models. Figure 4 displays the simulation model homepage, which allows the user to choose between two options:

- Immediately launch a simulation run with the system's default settings and no model customization;
- Modify the system's default settings and customize the model input parameters to fit the desired real-world system as close as possible by clicking on the *Simulation components* and/or the *Environmental parameters* links.

By clicking on the first customization option, *Simulation components*, a new view materializes where the user can set model parameters that control the behavior of agents in the simulated environment.

Figure 4: T-ESEDRAS simulation model homepage

In this section the user can modify a variety of model parameters, such as:

- The number of containers already stored in the yard. Port operations and activities (primarily unloading and loading operations) don't start as soon as the port is built because the yard is empty. A warm-up period is needed in order to initialize the simulation model with containers;
- The speed (in km/h) within the port area and the capacity (in TEUs) for each container ship, feeder ship, truck or train;
- Parameters related to the behavior of container handling systems (quay cranes, rail-mounted transtainers, straddle carriers, tugboats used to push or tow the vessels, etc.). These include speed, productivity, mean time to failure, etc.;
- The number of straddle carriers assigned to each berthing point, to a single transtainer and to straddle carriers dedicated to unloading and loading trucks in the yard.

By switching from the *Simulation components* view to the second customization option (or clicking on it directly in the homepage), the *Environmental parameters* view materializes. The goal of this view is twofold. Firstly, it gives the user the opportunity to select, through a checkbox, the green management initiatives to be assessed (in terms of environmental and financial impact) and the start-year for the practice. Secondly, it allows customizing all parameters related to the green management practices, including evaluation methodology, fuel and energy prices, emission conversion factors expressed both in terms of CDE and NO_x (to mention just two of the most dangerous pollutants), the type of fuel used by ships, trucks, trains, tugboats and container handling equipment as well as their fuel consumption rate.

Concerning the simulation model animation, a scaled representation of the container terminal and associated entities helps the user to visualize unfolding scenarios in the container terminal in terms of container flows (e.g., loading and unloading operations) and workflow (e.g., truck and train arrivals and departures).

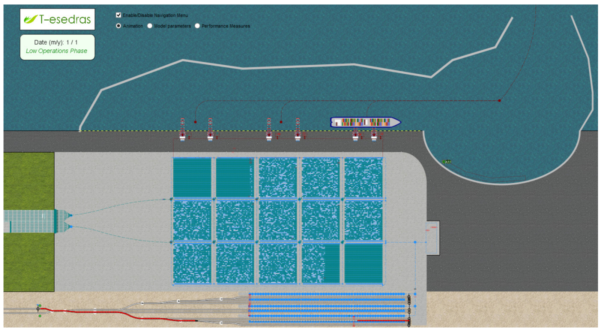

Figure 5: Animation view of a simulation model

The developed simulation model provides a set of performance metrics that measure both operational and financial aspects. All metrics have been selected with a view to assist port management in medium-term planning and control. Such metrics include performance measures related to container terminal operations, which are easy to calculate and simple to understand. While the operational performance of a container terminal is generally measured in terms of the time spent in it by containerships, a port manager would also be interested in the port's asset utilization and financial performance. To this end, Figure 6 shows a view of the operational metrics related to container terminal traffic. Metrics include yearly and monthly throughput in terms of TEUs, monthly totals of containership arrivals, monthly totals of feeder-ship arrivals, average waiting times for ships and trains, turn-around times, total TEUs handled, etc. The user may also change the view to observe container handling equipment utilization levels including those of straddle carriers, quay cranes, rail tracks, berth position, etc.

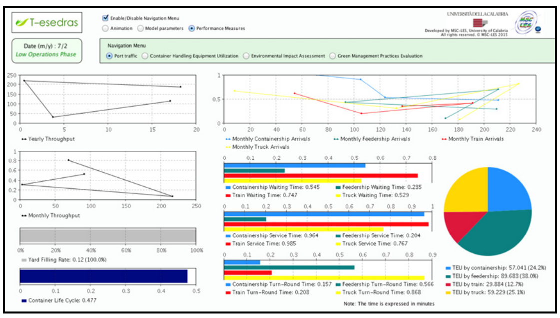

Figure 6: A view of operational metrics of a container terminal

However, the main objective of this study is to propose a set of sustainable environmental management metrics to be used by port authorities. All main activities performed within a container terminal are analyzed for potential environmental impacts and risks. Computed metrics should serve as "signals which allow data to become available for decision-making".

The simulation model provides information about the environmental footprint of the container terminal activities, since studies show that carriers as well as container handling equipment have a major negative environmental impact both on the port area and its surrounding environment. To this end the T-ESEDRAS simulation model has two additional output sections that support the user in carrying out Environmental Impact Assessment and Green Management Practices Evaluation. Figure 7 displays a view of the metrics that support Environmental Impact Assessment. These include monthly fuel CO_2 and NO_x emissions for each container handling equipment.

Finally the T-ESEDRAS simulation model includes financial performance metrics including annual cash inflow/outflow, payback period, payback period diagram, net present value and net present value evolution diagram.

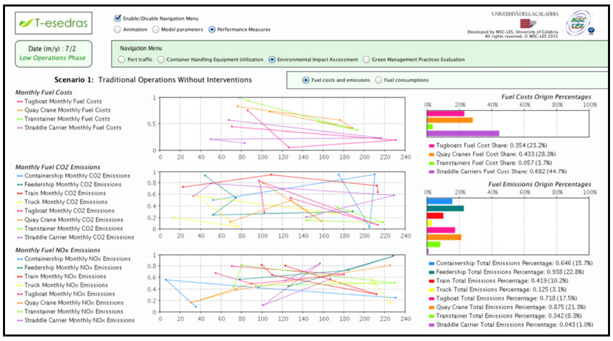

Figure 7: A view of environmental impact metrics

5. CONCLUSION

The continuing expansion of maritime transportation and the attendant environmental impacts provide powerful motivation for improving the sustainability of ports. As highlighted by Mittal and Baveja (in press), successful terminal operators with prior involvement in developing sustainability practices cannot rely on their past sustainability practices to remain market leaders. Instead they must innovate, deepen and deploy sustainability competencies as well as leverage new GMPs to ensure sustained success.

The strategic framework offered by the T-ESEDRAS simulation model can be useful in overcoming the abovementioned shortcomings, thereby improving the impact and extending the longevity of sustainability initiatives. Indeed, the T-ESEDRAS simulation model is proposed as a key tool to carry out environmental impact analyses of processes and activities performed in the course of the life cycle of port terminals. To this end, the simulation model can be used to simulate and compare alternative sustainability practices in terms of both environmental impact and technical and economic sustainability, thereby allowing terminal operators to work on continuous improvement of port economic efficiency and resource rationalization while maintaining an eco-friendly environment.

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ACKNOWLEDGMENTS
The research presented in this paper is part of the T-ESEDRAS project co-financed by the European Union, the Italian Government and Calabria Region under the program POR/FESR Calabria 2007/2013, Asse I, Ricerca Scientifica, Innovazione Tecnologica e Società dell'informazione.

The third author's work is supported by a grant from British Council's UK-India Education and Research Initiative (UKIERI) program and a Grant (# 49198-25-26) from the United States Department of Transportation (Via the University Transportation Research Center Program). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the sponsoring organizations.

BIOGRAPHIES

Francesco Longo is Director of the Modeling & Simulation Center – Laboratory of Enterprise Solutions (MSC-LES), a laboratory operating at the Department of Mechanical, Energy and Management Engineering of University of Calabria. He has published more than 200 scientific papers in international conferences and journals, and has participated as speaker and chairman in a broad range of international conferences. His research activities focus on innovative ways to use simulation paradigms (discrete event, agent based, distributed, etc.) and serious games to achieve new scientific advances in various application areas including Industry, Logistics, Defense and Cultural Heritage. He has also served as General Chair and Program Chair for the most prominent international conferences in the area of Modeling and Simulation (EMSS, SCS, I3M, etc.)

Antonio Padovano is currently conducting research in the area of green management and sustainability in marine ports at MSC-LES University of Calabria and in collaboration with Rutgers University where he spent a 3 months as guest scholar during 2015. He is expert in discrete event simulation and in developing simulation solutions as a service. He has been supporting the organization of the International Multidisciplinary Modeling & Simulation Multiconference since 2014.

Alok Baveja is Professor in the Department of Supply Chain Management at the Rutgers Business School – Newark and New Brunswick His research is in the area of Applied Operations Research and Supply Chain Management. Dr. Baveja has been associate editor for IIE Transactions on Scheduling and Logistics, and is currently an associate editor for Socio-Economic Planning Sciences. His research has been funded by grants from the National Science Foundation, the National Institute of Justice, U.S. Department of Transportation, The British Council, Centers for Disease Control and the New Jersey Department of Health and Senior Services. His biography has appeared in "Who's Who in America". He has been a Principal Investigator on a Port Operations *Partnerships for Innovation* grant from the National Science Foundation.

Benjamin Melamed is a Distinguished Professor at Rutgers Business School – Newark and New Brunswick, Rutgers University, Department of Supply Chain Management. His research interests include supply chain management, finance, modeling, analysis and simulation as well as homeland security, and especially port security. He has received many awards and honors and has served as Co-Director of the CAIT-DIMACS Laboratory for Port Security (LPS).