# Abstract

Most of the world economy is based on maritime freight transport and plays a key role in international trade, being a determining factor in the economic growth of countries. The steady and continuous increase in the demand for maritime freight transport in recent years (even in times of pandemic) brought consequences such as delays in operations due to congestion inside the terminal, congestion in the connection with the land transport network, unsuitable storage of containers, or due to human factors since these terminals operate 24/7 and it is necessary to manage work shifts to avoid unfortunate events.

On the other hand, the functional efficiency of a container terminal is no longer the primary goal of a terminal, since different sustainability goals are becoming of great interest and concern port operators, port authorities, decision makers, politicians, citizens.

The considerable increase in container volumes has increased the concerns on:

(i) the global environmental impacts from port emissions.
(ii) the environmental impacts on those urban areas which host several maritime ports because port operations can lead to environmental impacts on air, water, and land.
(iii) the social concerns for the health and safety of ports workers, due to accidents still depends on a wide range of human errors as be psychological fatigue despite the automation level reached nowadays,
(iv) the impacts of in/out traffic flows on the city congestion,
(v) the impacts on the liveability of the areas surrounding a port.

In this context, it is easily understandable why wide attention has been given by researchers to container terminals efficiency, and why terminal efficiency cannot be solely interpreted in terms of logistic efficiency, coherently with the United Nations in 2015 defined the Sustainable Development Goals (SDGs).

The first part of this thesis work is focused on the modelling and simulation of a container terminal through the combination of the two main known simulation techniques, on the one hand the discrete event simulation that allows solving large problems through discretisation and the agent-based modelling that allows to incorporate different behavioural logics, which allows to simulate complex and

different technological contexts. In this way, a hybrid simulation is obtained, in which both modelling approaches usually guarantee an efficient solution in time, adaptable solutions to changes in the problems and computational stability.

This research project simulates container terminal operations, highlighting the potential of this tool to model highly complex logistics systems, such as container terminals, without neglecting sustainability. AnyLogic is adopted as a simulation support tool. Specifically, a container terminal model is developed to assess the operations times, consumptions and emissions generated by handling means, where a descriptive approach will be used to assess the consequences of different actions in order to achieve environmental and energy efficiency. To test the flexibility of the tool in simulating any container terminal, a modelling framework is applied to a specific case study, the Salerno Container Terminal (SCT), then the validation is performed with real data provided by the terminal operator and available in the open literature, and a Well-to-Wheels analysis comparing different scenarios (with an increasing level of port electrification solutions).

The results of the Well-to-Wheels analysis show that if at the local level the solutions with the highest level of electrification allow a reduction in emissions, at the global level the energy sources used for electricity production are of vital importance to identify whether this scenario is still the one with the lowest environmental impact.

On the other hand, the internal efficiency of activities in a container terminal has a significant impact both on its competitiveness and its catchment area, as well as impacting (positively or negatively) on the city, and on the residents and economic activities that are located near the port. In other words, various stakeholders, different visions, and different objectives must be coordinated towards a single planning framework to achieve the best compromise.

Considering this complicated context, the second part of this thesis work focuses on emphasising the visions, positions, and corresponding objectives of the different stakeholders in relation to the issues presented above, using a multi-criteria analysis approach, which defines the preferences between alternatives according to their impact on the objectives that the decision-maker has identified how relevant. The specific approach used is the AHP (Analytic Hierarchy Process).

Firstly, a hierarchical structure was constructed with the macro-objectives, relating to functional efficiency and environmental, economic, and social impacts, both inside and outside the ports. At the lower level, sub-criteria or indicators were specified.

Through the construction of a survey, focusing on the pairwise comparison between the different macro-objectives, the weight of each macro-objective was defined for the different categories of stakeholders who participated in the survey. Interviews were held with people with different functions in the port sector, both technical and

decision-making, both in the public and private sectors, as well as with citizens directly affected by port activities.

The assessments carried out on an aggregate basis on the total sample, showed a strong focus on functional efficiency macro-objective and on the economic/social benefits induced on the territory. Less importance was attributed to the macro-objectives of energy efficiency and reduction of environmental impact, which were considered relevant mainly by citizens.

In the last phase of this thesis work, a simplified application of the full multi-criteria AHP procedure was developed on real intervention scenarios, reproduced through the simulation model created in the first part of this research project. These scenarios were implemented in the Salerno port model, for these, it was possible to calculate some of the indicators identified in the hierarchy constructed, which allowed a ranking of the alternatives to be established. However, this application does not intend to concentrate on the evaluation of the suitability of the alternatives, but rather to give an idea of the potential of applying the full procedure.