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System Dynamics approach to assess the investments impact of the Dubai Logistics Corridor

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Sommario

INTRODUCTION

Origin of the work

This work was born thanks to the contribution of the Polytechnic of Turin and the Zayed University of Dubai. During the collaboration between Professor Alberto De Marco, head of the project management course at the Polytechnic University of Turin and Professor Hussein Fakhry, head of the college of Technology innovation at Zayed University, there was a common agreement to include a polytechnic's student in the project of the Dubai logistic corridor, with the aim of contributing to the work and at the same time creating the conditions for making a master degree thesis.
The work lasted approximately seven months and was carried out through different phases.
The first phase was the study of the methodology, the approach of System Dynamics is not a subject of a master's degree, so a preliminary study of everything concerning complex systems was necessary, through textbooks, literature and similar works.
After acquiring the basics, the second and most intense phase of field research began.
The period of three months spent thanks to the hospitality of Zayed University has seen a period of study of the basic processes of the port and the airport of Dubai, essential for the realization of the work.
The theory behind it is Systems thinking, it is a discipline aimed at solving systemic problems in a holistic way, making use of the notion of feedback.

Then the data collection started, a part carried out on the field thanks to the availability of the entities, such as Al Maktoum airport, and the other one using the relevant literature.
Once the data were acquired, it was possible to move on to the Modeling of the problem, first with the choice of the main research objectives, then with the identification of the key variables.
We started from the modeling of the CLD Causal Loop Diagram, a qualitative part with the aim of identifying the relationships between the variables and the feedback or reinforcement feedback cycles.
The part of Stock and Flow S&F was then made thanks to the previous CLD. Thus the S&F model was populated with the data previously collected.
The last phase of Simulation through different scenarios was made on the return to Italy at the Politecnico, with a subordinate phase of iterative correction of the model until reaching the final one. As a result, the model was validated with historical data to verify its accuracy.
Finally, the draft of the final elaborate. The System Dynamics model is developed in order to study management policies that could lead to an increase in capacity of the Dubai Logistics Corridor thanks to investments and port profits.

The thesis is structured as follows: Chapter 1 presents the theory that underlies system dynamics, from its origins to the functioning of them. To be able to understand the model it is essential to have the underlying theory in mind.

In Chapter 2 the methodology is reduced in cases related to transport and logistic commerce, works are very similar to this of the Dubai Logistics Corridor in particular concerning the study of Ports and consequently we try to compare them to find out the similarities and differences.

Chapter 3 presses an introduction and an overview of the Emirate of Dubai first and then explains in detail what the Dubai Logistics Corridor consists of, with its components such as the Jabel Ali Port and the Al Maktoum Airpot.

The work carried out for the creation of a System Dynamics model for the simulation of trade logistics flows as well as the validation phase of the same is the subject of Chapter 4. This model is then used using data from field research and those found through literature and sitography.

Chapter 5 is dedicated to the conclusions, elaborated following the results of Chapter 4. The benefits that this work has generated, the limitations encountered during the journey and the steps that can be undertaken in the future are illustrated. This thesis therefore represents a first step, for the Dubai Logistics Corridor, in the final chapter there are also some future steps to improve it.

The development of Dubai as Logistics hub

The reason why Dubai is becoming one of the major logistics and transportation hubs in the world are several, over the past decade the emirate of Dubai has emerged as a leading transport and logistics center serving not only the Middle East and North Africa (MENA) region, but also Russia, Europe, Asia and the Far East. This has been driven by concerted and far-sighted government initiatives which since the mid-1970s have sought to diversify an economy underpinned by oil revenues, but with an otherwise limited domestic resource base. With little arable land and a very small and un-skilled population, Dubai was a pearling port and regional entrepot based around shipping until the discovery of oil in the 1960s. A succession of formal government plans has introduced incentives and inducements aimed at encouraging Free Zone based companies to set-up operations in the emirate with the aim of fast-tracking the establishment of a modern, service-based economy. Initially the planning focus was on establishing the finance, tourism and property sectors as well as on significant expansion and upgrading of traditional trading activities. More recently the emphasis has broadened to incorporate more technology-intensive service industries. The phased development of Dubai's transport and logistics sector over the past several decades has culminated in the establishment of a major regional multi-modal commercial and transport hub, a so-called 'transtropolis' that includes the Dubai

Logistics Corridor. Although a work-in-progress, several stages of this long-term project are already operational and construction remains ongoing.

The main problem of policy resistance

One of the fundamental aspects dealt with in the model is undoubtedly the investment choice that underlies the growth of airport and port capacity to face the significant increase in demand base that the Dubai logistics hub is facing. When you find yourself in choices whose fruits are seen in the long run, decision makers often due to uncertainty tend to under-invest or make non-rational decisions, this is just one of the problems of policy resistance.

Public policy problems have several characteristics that impede resolution using traditional non- simulation approaches.

The first characteristic of public policy problems is the complexity of the environment in which problems arise and in which policies are made. Such complexity leaves policies highly vulnerable to “policy resistance” (Forrester, 1971b; Sterman, 2000). Policy resistance occurs when policy actions trigger feedback from the environment that undermines the policy and at times even exacerbates the original problem. Policy resistance is common in complex systems characterized by many feedback loops with long delays between policy action and result. In such systems, learning is difficult and actors may continually fail to appreciate the full complexity of the systems that they are attempting to influence. Often, the most intuitive policies bring immediate benefits, only to see those benefits undermined gradually through policy resistance (e.g., Repenning and Sterman, 2002). As Forrester (1971b) notes, because of policy resistance, systems are often insensitive to the most intuitive policies.

Policy resistance often arises through the balancing feedback loops that numerously exist in social systems. Traditional tools that lack a feedback approach may therefore fail to anticipate the best policy actions.

A second characteristic of public policy problems is the importance and cost of experimentation with proposed solutions. Experimentation is important because the stakes are high, and it is costly because, once implemented, policies are often not reversible. Experimentation is natural to the functioning of all organizations and social systems. People and organizations take actions, evaluate results and learn from results in an attempt to improve future performance (Cyert and March, 1963). Experiential learning (Denrell and March, 2001) is fundamental to public policy as well: policymakers, when dealing with complex problems, will implement policies, observe behaviors, and adjust policies accordingly.

A final characteristic of public policy problems is the tendency that decision makers have to attribute undesirable events to exogenous rather than endogenous sources. An endogenous perspective is necessary for individual and organizational learning. Individuals who attribute adverse events to exogenous factors and believe “the enemy is out there” lack the ability to learn from the environment and improve their behavior (Senge, 1990). Experimental research in the system dynamics tradition has confirmed that the lack of a fully endogenous perspective in decision tasks is both common and also a major reason for suboptimal performance

In summary, public systems and public policy problems have numerous characteristics that inhibit both the making and implementation of effective policies.

The Research objective

At the beginning of the work the research objectives were not so clear as the project was in an early stage and for this reason not really detailed.
Over time several objective emerged, some of them could be classified as main objectives, others as secondary.
Some of the objectives could be carry on thanks to the data availability, the others are in a work in progress situation and will be treated as open points for the future.

Hera are listed all of the main research objective:

- Forecast of the future demand and capacity of the port and airport trade, calculated as TEUs for the port and Tons for the airport, thanks to forecasting models, statistics model and literature data;

- The Amount of the optimal investments required to cover the increased demand.
  Calculated thanks to the creation of a several different scenarios;

- The existence of a capacity bottleneck that avoids the increasing of the overall capacity and doesn't allow the increasing of profit;

- The existence of an empirical relationship called super-additive function between the port and airport attractiveness concerning the increasing of the overall demand;

- The detection of a transport bottleneck in the Dubai Logistics corridor;

- The avoiding of the under investing because of the policy resistance;

- Many others.

Chapter 1

System Dynamics: History, Methodology, Transport & Logistics Application

1.1 Origin of System Dynamics

System dynamics was created during the mid-1950s by Professor Jay Forrester of the Massachusetts Institute of Technology. In 1956, Forrester accepted a professorship in the newly formed MIT Sloan School of Management. His initial goal was to determine how his background in science and engineering could be brought to bear, in some useful way, on the core issues that determine the success or failure of corporations. Forrester's insights into the common foundations that underlie engineering, which led to the creation of system dynamics, were triggered, to a large degree, by his involvement with managers at General Electric (GE) during the mid-1950s. At that time, the managers at GE were perplexed because employment at their appliance plants in Kentucky exhibited a significant three-year cycle. The business cycle was judged to be an insufficient explanation for the employment instability. From hand simulations (or calculations) of the stock-flow-feedback structure of the GE plants, which included the existing corporate decision-making structure for hiring and layoffs, Forrester was able to show how the instability in GE employment was due to the internal structure of the firm and not to an external force such as the business cycle. These hand simulations were the start of the field of system dynamics.

During the late 1950s and early 1960s, Forrester and a team of graduate students moved the emerging field of system dynamics from the hand-simulation stage to the formal computer modeling stage. Richard Bennett created the first system dynamics computer modeling language called SIMPLE (Simulation of Industrial Management Problems with Lots of Equations) in the spring of 1958. In 1959, Phyllis Fox and Alexander Pugh wrote the first version of DYNAMO (DYNAmic MOdels), an improved version of SIMPLE, and the system dynamics language became the industry standard for over thirty years. Forrester published the first, and still classic, book in the field titled Industrial Dynamics in 1961.

From the late 1950s to the late 1960s, system dynamics was applied almost exclusively to corporate/managerial problems. In 1968, however, an unexpected occurrence caused the field to broaden beyond corporate modeling. John F. Collins, the former mayor of Boston, was appointed a visiting professor of Urban Affairs at MIT. The result of the Collins-Forrester collaboration was a book titled Urban Dynamics. The Urban Dynamics model presented in the book was the first major non-corporate application of system dynamics.

The second major noncorporate application of system dynamics came shortly after the first. In 1970, Jay Forrester was invited by the Club of Rome to a meeting in Bern, Switzerland. The Club of Rome is an organization devoted to solving what its members describe as the "predicament of mankind" that is, the global crisis that may appear sometime in the future, due to the demands being placed on the Earth's carrying capacity (its sources of renewable and nonrenewable resources and its sinks for the disposal of pollutants) by the world's exponentially growing population. At the Bern meeting, Forrester was asked if system dynamics could be used to address the predicament of mankind. His answer, of course, was that it could. On the plane back from the Bern meeting, Forrester created the first draft of a system dynamics model of the world's socioeconomic system. He called this model WORLD1. Upon his return to the United States, Forrester refined WORLD1 in preparation for a visit to MIT by members of the Club of Rome. Forrester called the refined version of the model WORLD2. Forrester published WORLD2 in a book titled World Dynamics.

1.2 Systems Thinking

Systems thinking is a discipline aimed at solving systemic problems in a holistic way, making use of the notion of feedback. An inherent assumption of systems thinking is that problems (and their solutions) are internally generated. There are multiple perspectives from which we can view and understand the world. There are four different perspectives we can use, from a systemic perspective, to classify those views of the world: events (the things we encounter on a day to day basis); patterns of events (accumulated memories of events); systemic structure (event generators); and shared vision (systemic structure generators). The end goal of a systems thinking is to go from an events or patterns of events perspective to one that focuses on system structure and, from that, to build a shared vision perspective, in order to address problems proactively (or generatively) rather than reactively. For a Systems Thinking approach to have a higher leverage degree, a generative level of understanding should be sought. The basic tools of systems thinking are: causal loop diagrams, behavior over time graphs, and systems archetypes.

1.2.1 Causal loop diagrams

A causal loop diagram (CLD) is a graphical representation of the causal relationship between variables. A CLD takes the form of a closed loop that depicts cause-and-effect linkages between variables. Causal loop diagrams constitute a means to represent the feedback structures present in a system (Sterman, 2000).

The causal influences (or causal links) among the variables are denoted through the use of arrows pointing from the independent to the dependent variable (see Figure 0.1).

The polarity of a causal link can be positive (+) or negative (−), depending whether an increase of the independent variable causes the dependent variable to increase (positive link) or decrease (negative link).

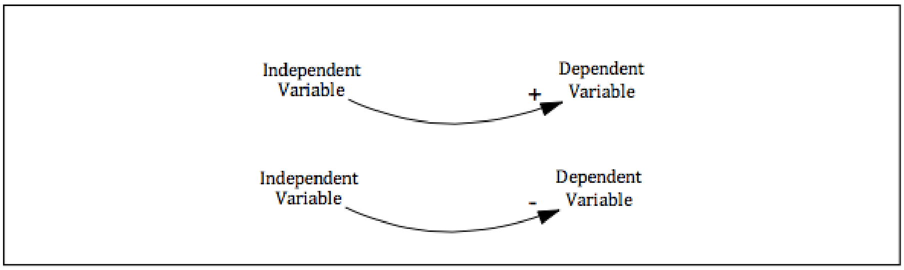


Figure 0.1 The causa links

A feedback loop is present when information resulting from some action (a change in one variable) travels through the system and returns in some form to its point of origin (as a change in that same variable), potentially influencing future action. So, a set of causal links which constitute a closed circle, with all the arrows pointing clockwise or all the arrows pointing counter clockwise is called a feedback loop (the name comes from the fact that any variable in a loop feeds back upon itself, either increasing or decreasing its value, depending on the polarity of the loop).

A positive loop (also called reinforcing loop and denoted by a (+) or a (R)) means that if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been. In other words, if the tendency in the loop is to reinforce the initial action, the loop is called a positive or reinforcing feedback loop.

A negative loop (also called balancing loop and denoted by a (−) or a (B)) means that if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been. To put things in another way, if the tendency is to oppose the initial action, the loop is called a negative or balancing feedback loop.

Both types of feedback loops are represented in figure 0.2.

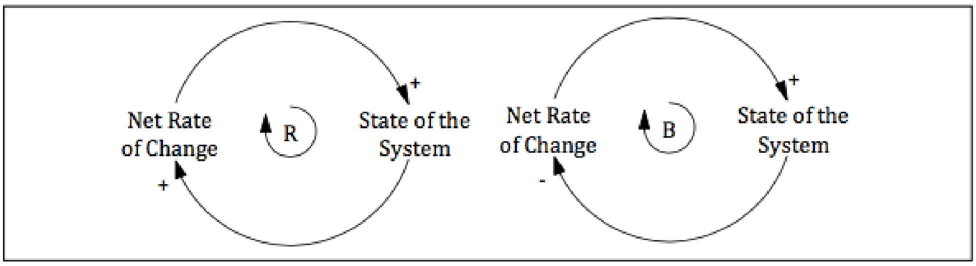


Figure 0.2 The Feedback loops

Thanks to a simple rule it is possible to see that, whenever the number of negative links in a loop is even, the loop is positive (reinforcing), and when the number of negative links is odd, the loop is negative (balancing).

Balancing loops can be variously characterized as goal-seeking, equilibrating, or stabilizing processes. They can sometimes generate oscillations, as when a pendulum seeking its equilibrium goal gathers momentum and overshoots it (for oscillations to appear, some form of delay must be present in the system). Reinforcing loops are sources of growth or accelerating collapse; they are not equilibrating and destabilizing. Combined, reinforcing and balancing circular causal feedback processes can generate all sorts of dynamic patterns (Richardson, 2011).

An important fact to bear in mind is that feedback and circular causality are not enough to understand the systems behavior. The notion of active structure and loop dominance is crucial to explain the dynamics of a system whose behavior is likely to change over time. For example, initially a reinforcing loop may dominate the systems behavior, while at a later phase a balancing loop may become stronger and as a consequence, may cause the system's behavior to change. As the complexity of a system increases (more loops present), several shifts in loop dominance can be expected.

Only nonlinear models can endogenously alter their active or dominant structure and shift loop dominance. From a feedback perspective, the ability of nonlinearities to generate shifts in loop dominance and capture the shifting nature of reality is the fundamental reason for advocating nonlinear models of social system behavior (Richardson, 2011).

1.2.3 Systems archetypes

Systems archetypes capture generic patterns of behavior that commonly occur in systems. Systems archetypes or their combination allow the representation of virtually all existing systems. The archetypes include causal loop diagrams that depict the dynamic behavior that drives the problems and a set of strategies to address them, with actions that use the least amount of effort to produce the desired change in the system.

The archetypes are: limits to success; success to the successful; tragedy of the commons; growth and underinvestment; fixes that fail; shifting the burden; drifting goals; and escalation.

As explained in the next section, one of the fundamental steps of the Systems Thinking approach is to try to identify the system's structure. The use of the Systems archetypes is particularly useful since they (either alone or in combination) allow the representation of virtually all existing dynamic systems. So a basic knowledge of all the archetypes is necessary for a correct choice of the ones we believe may be responsible for the observed behavior of the system.

1.3 System Dynamics

In a general sense, System Dynamics can be regarded as the translation of the systems thinking language into a mathematical one.

Richardson (1999) defines System Dynamics as a "...computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems - literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality".

Sterman (2000) views simulation as an essential step of the problem solving process since mental models (our assumptions about the system at hand) have several flaws: they are dynamically deficient, and they omit feedbacks, time delays, accumulations, and nonlinearities. But even after a systems thinking approach has been undertaken, the result is merely qualitative, showing causal relationships but omitting parameters, functional forms, external inputs, and initial conditions needed to fully specify and test the model. Simulation is the only practical method to test these models.

The field of System Dynamics developed from control theory, through the work of Jay W. Forrester.

1.3.1 System Dynamics models

A system dynamics model consists of a system of coupled, nonlinear, first-order differential equations. When simulation is carried out, the value of state variables is calculated through numerical integration, by splitting time into discrete intervals of length dt. System Dynamics is a state-determined approach. In other words, the value of the state variables after computation depends not only on their net rate of change, but also on the previous values.

Other approaches make use of unidirectional cause-and-effect relationships. The fact that, when solving a system of coupled first-order differential equations, the initial condition (the state variable at t0) determines the solution is in line with the systems thinking notion of feedback - the fact that it is the state of the system that determines its future evolution and not some external input with no regard for the system condition itself. The typical application of System Dynamics is in policy analysis and design. The concept of endogenous change is fundamental to the system dynamics approach. Exogenous disturbances are seen at most as triggers of system behavior (Richardson, 2011).

1.3.2 Stock-and-flow diagram

An important drawback of causal diagrams is their inability to generate dynamic behavior. In other words, it is not possible to study the actual behavior of the variables of interest through the use of causal diagrams alone. A way to overcome this shortcoming of causal loop diagrams is to make use of Stock-and-flow diagrams.

There are five components in a Stock-and-flow diagram: stocks, flows, auxiliary variables, sinks/sources, and information links (see Figure 0.3).

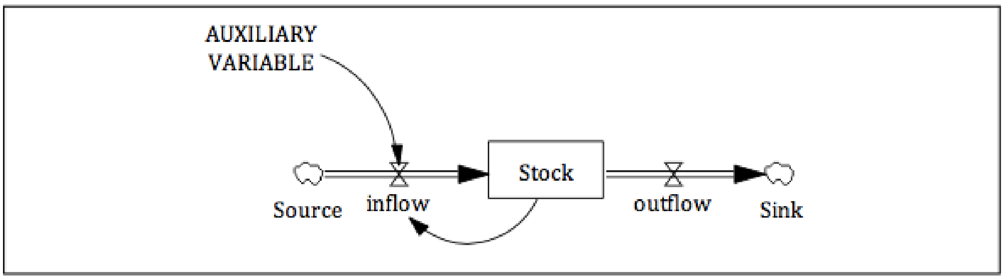


Figure 0.3 Stock and Flows

Stocks are accumulations, and as such, they are modelled as integrals. They characterize the state of the system and generate the information upon which decisions and actions are based (stocks correspond to state variables). Stocks give systems inertia and provide them with memory. Stocks create delays by accumulating the difference between the inflow to a process and its outflow. By decoupling rates of flow, stocks are the source of disequilibrium dynamics in systems.

Flows are quantities per unit of time entering (inflow) or leaving (outflow) the stocks, i.e., flows are the rates at which the system's state variables (the levels or stocks) change. So the flows associated with a given stock must be measured in the same units of the stock per time period. Quantity can also refer to something intangible such as "perception", "quality", or "satisfaction" (the possibility of modeling such variables is one of the differences between SD and other modeling approaches). The net flow (i.e. the algebraic sum of all the flows affecting a given stock) into the stock is the rate of change of the stock. The quantity in any stock is the accumulation of the flows in less the flows out. Stocks accumulate or integrate their flows.

The flows (i.e. the quantity per unit of time entering or exiting the stocks) are controlled by valves. The action of valves can in turn be controlled by eventual causal loops and auxiliary variables through causal loops and information (any constants and exogenous variables).

Change in information is represented through arrows in the flow and stock diagram.

A source is an origin of a flow outside the boundary of the system. A sink is the destination equivalent to the source. Both sources and sinks are assumed to have infinite capacity and, so, they never impose a limit on flows originating from them or directed to them.

Sterman (2000) defines the diagramming notation for stocks and flows:

- Stocks are represented by rectangles (suggesting a container holding the contents of the stock). Inflows are represented by a pipe (arrow) pointing into (adding to) the stock.
- Outflows are represented by pipes pointing out of (subtracting from) the stock (it should be noted that an arrow pointing into the stock but with a negative flow associated is equivalent to having that arrow, with the same absolute value, pointing out of the stock) .
- Valves control the flows.
- Clouds represent the sources and sinks for the flows.
- In the stock-and-flow representation there is a distinction between the flows through the stock-and-flow network and the information feedbacks that couple the stocks to the flows and close the loops in the system.
- The contents of the stock-and-flow networks are conserved in the sense that items entering a stock remain there until they flow out. When an item flows from one stock to another the first stock loses precisely as much as the second gains (in other words, quantity is conserved).

Stocks can represent tangible quantities such as people, money, and materials. Stocks can also represent intangible variables including psychological states, perceptions, and expectations such as employee morale, the expected rate of inflation and perceived inventory (soft variables). The theory of System dynamics takes a state-determined system or a state variable approach. The only way a stock can change is via its inflows and outflows. In turn, the stocks usually determine the flows through information feedbacks about its state. Figure illustrates the representation of a system using a Causal loop diagram notation (on the left) and a stock-and-flow diagram (on the right).

So, under the System Dynamics stock-and-flow representation, systems consist of networks of stocks and flows linked by information feedbacks from the stocks to the rates. Only the initial value of the stocks (the initial condition for the differential equation) and their rates of change (flows) are necessary for a complete mathematical description of a system because stocks change only through their rates of flow. There can be no causal link directly into a stock, since stocks only accumulate the difference between inflows and outflows.

Model testing

Sterman (2000) describes the tests a system dynamics model should be submitted to and succeed in. These include: boundary adequacy, structure assessment, dimensional consistency, parameter assessment, extreme conditions, integration error behavior reproduction, behavior anomaly, family member, surprise behavior, sensitivity analysis and system improvement.

Chapter 2

System dynamics approach in Logistics and transport fields

The greater evidence that can come from this analysis of the literature on the methodology in question is how even today we make an important use of the dynamical systems to study complex systems, the non-professionals could label the metrics as 'dated' because it dates back to studies carried out in the 50s, but from the use that still exists today it seems to be still very current. Moreover, as anticipated, one of the advantages of metrology is to find application in many different fields, to cite only some of the challenges present on Business Dynamics (Sterman 2000), it finds space in problems of microeconomics as "the tragedy of the commons", in the energy field with "The oil crises of 1970s", in finance with "the speculative Bubbles" on in medicine with "Modelling HIV / AIDS epidemic". Today one of the fields that most uses SD is certainly that of logistics and transport, there are many challenges that the researchers of this field are trying to solve, among the most recent achievements we find that of the Fields Medal of the Italian Alessio Figalli, rewarded thanks to his work on optimal transport.

This section describe how SD can be used in order to assess transportation and logistics problem, for this purpose a list of conference papers will be cited and described especially those involved in the port transportation for the similarity with this work. Then will be analysed the main differences and similarities between these papers and the work of the Dubai Logistics Corridor.

- **Ruutu** (2008). National sea transport demand and capacity forecasting with system dynamics. Espoo: s.n., 2008.
  In his work uses the System Dynamics methodology in order to forecast the national sea transport demand and the concerning capacity. A comparison between System dynamics approach and Time series methodology or statistics tools like Regression model is made to understand the accuracy of the different approaches. In this case the national sea transport referred is the Finland one.

- **Sebo** (1995). A System Dynamics approach to intermodals at the Port of Lewiston. Idaho National Engineering Laboratory, 1995. A systems dynamics model of intermodals at the Port of Lewiston has been developed to highlight leverage points, hidden assumptions, second order effects resulting from feedback loops and system drivers. Intermodals is the interconnections among modes of transportation like road, rail, water, and air. The development of an effective and efficient intermodal transportation system requires the identification of barriers to intermodal transportation and the investigation of the impact of proposed changes in infrastructure development, policies, regulations, and planning. A systems approach is necessary to adequately represent the interaction between the sometimes incompatible concerns of all modes and stakeholders.

- **Briano, E., et al**. 2009. A System Dynamics decision cockpit for a container terminal: the case of Voltri terminal Europe. International journal of mathematics and computers in simulation. 2009, pp. issue 2, vol. 3. Adopts SD decision for the case of Voltri terminal Europe sited in Italy, Genova. The purpose of this paper is to design a model of the port performance metrics for improving the quality in ports by integration of six sigma and system dynamics (SD) approach

- **Carlucci, F. and Cira, A**. 2009. Modelling a Plan for Seaport Investments through a System Dynamics Approach. Pomorstvo: Scientific Journal of Maritime Research. 2009, p. vol.23 no.2.
  Respectively PhD at University of Salerno and University of Messina, they modelled through SD approach a plan for seaport investments. This paper is focused on a dynamical approach for analysing a small sized seaport. Its main advantage is the ability to linearly depict the several relationships occurring amongst the different subjects involved, with increased advantages as opposite to more traditional approaches, like the "Costs-Benefits" model, or the "Multi-criteria" techniques.

- **Castillo, J. I, López-Valpuesta, L. and Aracil, M. J**. 2004. with Dynamising economic impact studies: the case of the Port of Seville. Seville: Centro de Estudios Andaluces, 2004. simulates the decision making process of vessels carrying merchandise whose final destination is the province of Seville. A forecast is obtained for Port of Seville traffic, highlighting how public investment influences this entrance decision via improvements in Port of Seville infrastructure and so a reduction in its costs.

- **De Marco A., Rafele, C., Cagliano, A C**.,2007 with the work named "Strategies for the complexity of logistics and transportation. case-study: simulation models for the "dry harbour" problem."
  this work aims at proposing a simulation model as a strategic tool for policy making. In particular, the case of logistics and transportations in Piedmont is considered with reference to the "back-port" of Genoa, in particular the decision to assign the back-port of Genova to Alessandria, Novara or both of them.

- **Pinhal dos Santos M**., Analysis of investment policies for the Port of Lisbon with a System Dynamics model.
  A System Dynamics model is developed in order to study management policies that could lead to an increase in throughput in Port of Lisbon. Additional objectives include assessing port profits and investments associated with each management policy, as well as their implications to the regional economy. The impact of the port activity on regional employment, trade and GDP is used to measure the beneficial effects associated with each policy.

A check of whether the results obtained from the System Dynamics model might be improved by using econometric techniques ruled against the latter.
Analysing these studies, it can be seen that most of the objectives that the authors have set themselves are present in the previous part of the 'research objectives' of the introductory chapter.
The demand forecast, the optimization of port capacity and the analysis of investments are in fact objectives often sought in this area, as often linked to cost savings or greater profitability, without neglecting the competitive advantages in long-term strategies that they follow.
It may therefore seem "" the fact that the study on the case of the Dubai Logistic Corridor present many research objectives that are individually treated in other works, but a clarification is necessary, while the above works focus on detailed and circumscribed problems, the work in this case it is in an embryonic phase and therefore at a minimum level of detail, consequently all the resulting conclusions will be only the input of future studies that will lead to more precise evidences. In other words, the study looks at the various phenomena from a macro point of view, and then leaves space and time for more detailed considerations in the future.
One aspect that cannot be left out is the geographical area pertaining to the work not yet surveyed. In fact, as we can see from the other works mentioned above, there is a huge literature in Europe and in other parts of the world as the United States unlike the Middle East in which no work has yet been published on logistic transport with SD metrics. One of the reasons may be the recent expansion of the United Arab Emirates, which started to have a noteworthy logistic conformation starting from the 90s. Unlike the studies already present in the literature, the paper does not focus on logistics and port transport, but attempts to study a major phenomenon as a whole logistics hub. The Jabel Ali port is in fact only one of the parts of the Dubai Logistics Corridor, it is

connected to Al Maktoum Airport via the logistic corridor of the JAFZA Free Zone. The privilege of being able to consider a multitude of different ways of transport (by air, by land and by sea) in the model is for sure the strategic conformation of the territory of Dubai. As we will see in the appropriate section, the proximity between Airport and Port allows us to study their behavior, leaving out complications and being able to make assumptions that we would never have dreamed of doing in different situations.

Chapter 3

UAE and Dubai: Overview and History

3.1 Country overview

The United Arab Emirates (UAE) is a federation of seven emirates, each governed by its own monarch. The seven Emirates - Abu Dhabi, Ajman, Dubai, Fujairah, Ras al-Khaimah, Sharjah, and Umm al-Quwain - jointly form the Federal Supreme Council, which chooses a president every five years. Since independence from Britain in 1971, the ruler of Abu Dhabi has been elected as the president, while the ruler of Dubai has been elected as the Vice President and Prime Minister. Abu Dhabi serves as the capital and each emirate enjoys a high degree of autonomy. The country is strategically located in the Middle East, bordering the Persian Gulf, the Arabian Sea, Oman and Saudi Arabia. It occupies a total area of 83,600 km2 with around 1,318 km of coastline. The population is estimated to be 9.3 million in 2015 with only 13% nationals.

Figure 2.1Dubai

3.1.2 UAE Economic Performance

The UAE is an oil rich country, with most of its oil and gas production coming from Abu Dhabi. The country was ranked eighth worldwide in terms of oil and gas production in 2012 and seventh in terms of reserves. Since the UAE's establishment, oil revenues have been used strategically to develop basic infrastructure and provide UAE citizens with government services including subsidized utilities, free education, and medical services. As a result of oil price fluctuation, the country has understood the importance of diversifying away from this resource and started to develop its petrochemical sector. During the 1990s, the UAE government implemented different economic reforms to liberalize trade and investment to further reduce dependence on oil. The strategy has resulted in reducing the oil contribution to GDP to 33%, and having real estate, trade, transport and communications grow to become the country's other main economic sectors. In 2009, the country was affected by the financial crisis because of its deep integration with the global economy and had negative GDP growth for the first time since its establishment. In 2012 the country recovered mostly thanks to the tourism and trade sectors. As a result, the government decided to focus on transitioning to a knowledge-based economy. In 2014, the Prime Minister launched a National Innovation Strategy that aims to make the UAE among the most innovative nations in the world within seven years. Currently, the UAE enjoys a relatively high level of income with a GDP per capita of US$ 24,077 (constant prices) in 2012 and is considered the second largest economy in the Middle East. In addition, the country is the second least dependent on oil among GCC countries and the second most attractive in terms of foreign direct investment.

The UAE has a strong fiscal and monetary outlook. The currency is pegged to U.S.D., which reduces the risk of currency fluctuation. The UAE also has 3 sovereign funds with substantial wealth, including the Abu Dhabi Investment Authority (one of the largest in the world), Mubadalah, and the Dubai Investment Corporation. Although the UAE has succeeded in reducing the oil sector's contribution to GDP, fiscal revenues are still highly dependent on oil revenues.

Among many positive factors of the business environment, the UAE is considered a tax haven with no profit tax, and an average tax lower than the regions. The country was ranked second in economic freedom amongst GCC countries, with a score higher than the world average. It was also ranked third in infrastructure according to the 2014 GCI index. Besides that, labour cost is relatively low due to the immigrant labour force. The level of investor protection, however, is considered low.

Talking about Political stability and cultural tolerance, despite the turbulent nature of many countries in the Middle East, the UAE remains an example of complete political stability in the region. It is also one of the biggest donors to developing countries across the world and a major contributor to UN peace keeping initiatives globally.

The country's decision-making model, both at federal and local emirate level, allows for sustainable economic and infrastructure growth. This has led to the levels of economic diversification and foreign direct investment we see today.

Culturally, the Emirates is a melting pot with more than 200 nationalities hailing from all corners of the globe. Cultural tolerance is actively promoted across the Emirates. As a result, there is minimal tension, either culturally or from a religious point of view. The multicultural aspect of the UAE means that many businesses also comprise a wide range of nationalities, bringing a valuable resource of diverse knowledge, experience and innovation, and driving the country's spirit of entrepreneurship that has made it a regional and global business hub.

In an environment of stability, cultural tolerance and warm Arabian hospitality, the UAE has become well-known as a place where expats can feel at home and enjoy a high quality of life when living and working in the Emirates, with all the education and healthcare facilities, leisure amenities and more that they might expect in their home country. Because of its political stability, the UAE remains one of the safest countries in the world with extremely low crime rates compared to most other major cities.

3.2 DUBAI OVERVIEW

Dubai has a long history of openness to trade, being a natural harbour. It has been called the gateway between East and West, connecting China, India, the Middle East, and Africa. All these regions are important suppliers of manufactured goods redistributed through Dubai. The Dubai government has always been eager to support free flow of labour and capital, in an effort to diversify away from oil revenues from neighbouring Abu Dhabi and maintain its position as an important trade hub. Dubai is the second largest of the seven states of the United Arab Emirates (UAE) and its main port and commercial center. With an area of 3,885 square kilometers, it is located on the two banks of the Dubai Creek, an inlet from the Arabian Gulf. It is one of the world's few locations where modern city life, sandy beaches and the desert are all within easy reach.

The city has built its wealth mainly on its traditional role as an international trading center, and it is less dependent on oil revenue than the other Emirate states. Dubai's government is now heavily promoting the city for international investment, commercial and industrial development, and, more recently, tourism. Fifteen free trade zones are being developed, including the world's first e-business free zone.

Dubai also has a tradition of implementing vast development projects which have included building the tallest hotel in the world, as well as the latest Palm Islands development, a major reclamation project which will include numerous new hotels and residential properties of the highest standard, as well as shopping malls, entertainment facilities, a marine park and around 75 miles of new beaches.

The main trading center of the region, Dubai has developed into a truly cosmopolitan city, with up to four-fifths of its population at any one time being expatriates from around the world. With the continuing promotion of favorable conditions for trade and investment, there is likely to be a continuing influx of expatriate companies and workers wishing to take advantage of these benefits.

Expatriates can enjoy an excellent standard of living in Dubai. The city has an extremely low crime rate, and received the Conde Nast Traveler award for the safest holiday destination in 2003. There are a vast number of world-class hotels, luxury accommodation at reasonable cost, and very good leisure, entertainment and sporting facilities. It is also a shopper's paradise, with imported goods from around the world available in the numerous high quality shopping malls, and bargains available in the many traditional souks and gold stores. For those with children, there a wide range of excellent international schools. English is widely spoken, and street signs and menus are printed in English as well as Arabic. As an added bonus, foreign workers pay no tax in Dubai, and goods are sold tax-free.

Despite its cosmopolitan nature, Dubai still retains its Arabic heritage and culture, along with the more western aspects of life which have developed here. Traditional souks, mosques and traditional merchant's houses are interspersed with ultra-modern skyscrapers, shopping malls, hotels and office blocks. Along the creek, traditional dhows - though now motor-powered - are moored, whilst water-taxis ferry passengers from one bank to other at all hours of day and night. The city is very family-friendly, with playgrounds in virtually shopping mall, restaurants which welcome children, and a wealth of family-oriented festivals and activities.

There are some lifestyle restrictions in Dubai relating to its Islamic laws and traditions. During Ramadan, there is a ban on eating and drinking in public during daylight hours. Alcohol is only sold in hotels and restaurants which possess a liquor license, and a license is also required for the purchase of alcohol for private consumption.

3.2.1 Key trends for UAE & Dubai

Growing Population: Based on IMF Data, the UAE is expected to witness a 2.9% CAGR rise in its population between 2014 & 2019

Per Capital Income: The UAE’s GDP per capital is higher than that of the US and major European economies - Increased spending on high-value international products

Increase in Tourism: Dubai is the leading tourist destination in the Middle East with more 5 star hotels than any other market globally.

Increase business competitiveness: The UAE has been recognized as the No. 1 Country in the MENASA region for the ease of doing business

Diversification in Economy: With little petro carbon wealth Dubai has diversified in to other key industries such as Finance, Tourism and Transport

Key Regional facts on how the World Bank ranked Dubai

- No.1 quality for transport infrastructure 2014- 2015
- No.1 for industry output as a proportion of total GDP at 59%
- Lowest total business tax rate at 14.8%
- No. 1 in the MENASA region for ease of doing business

- No.1 hotel keys per 1,000 population
- No.2 for global air freight transport

3.3 The Dubai Logistics Cluster

As already mentioned in the introductory part, the model used for the study with the system dynamics approach treats the Dubai Logistics Corridor as the protagonist. This chapter aims to explain in detail this logistic cluster, the different parts that involve it and the advantages that derive from it.

3.3.1 The Dubai Logistics corridor

The Dubai Logistics corridor has been implemented to drastically improve the trade process affecting the Dubai Logistics in its entirety, whether it involves air or sea transport. The DLC is made up of three main parts:

- The Jabel Ali port, governed by an institution called DP WORLD
- Al Maktoum Airport, reporting to DUBAI WORLD CENTRAL
- the free zone area of Jabel Ali, known by the acronym JAFZA (Jabel Ali Free Zone Area)

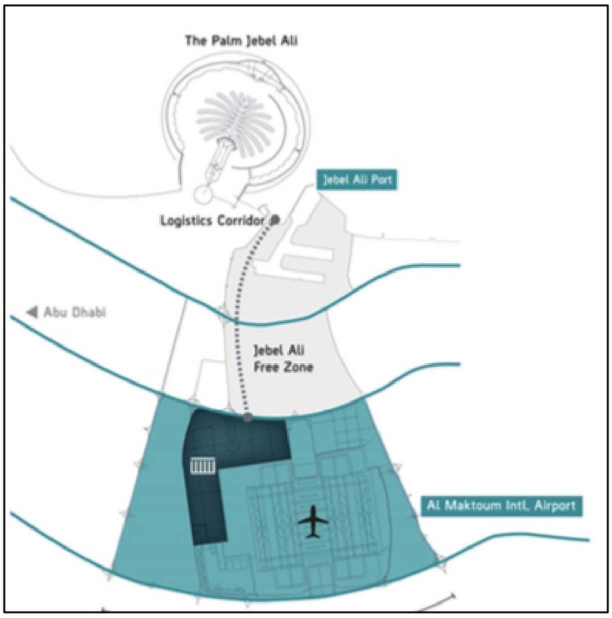


Figure 2.2 The Dubai Logistics Corridor

In the context of logistics management, when any consignment moves from one free zone to another it has to undergo various procedures of customs and legal compliance, which is not only time consuming but also cost incurring. However, with the formation of Dubai Logistics Corridor (DLC), the products travelling within DP world, JAFZA and DWC i.e., the sea-road-air cargo route, will have to go through the customs only once at the first point of entry. After that travel within the corridor will be relaxed as the shipment has complied with the stipulated regulation. This globally unique system has made it possible to process transports more quickly and in a cost-effective manner than ever before.

Its innovative policy initiatives spell out that building a business in Dubai is consistently straightforward and constantly monitored with the advice and guidance of the ruler. Therefore, beyond room for any doubt, the synergistic effect is bound to give a new impetus to the sector.

3.3.1.2 Reducing the response time

Further, the time taken to unload shipment at DP World, clear the containers and transport them to the Al Maktoum International Airport in DWC would just be a matter of a few hours, say approximately four hours. Prior to the formation of the DLC, a lot of documentation and customs work had to be complied, once the goods left JAFZA for the DWC. Completing all these documentation and compliance of various formalities could stretch over 2-3 days and thus the clearance of the whole shipment from the port to the airport would perhaps take about 4 days. Thus the DLC business model would help the companies to reduce their lead times and be able to enjoy more responsive logistics, while not compromising on maintaining operational efficiency.

3.3.1.3 Cost of Handling

Generally, in order to enhance the logistics responsiveness, huge expenditure is incurred. However, the implementation of innovative trade solutions by the DLC corridor provides a win-win situation for all the stakeholders - the shipper, the carrier and the consignee. It increases the responsiveness while reducing the costs for the companies. Several documents were needed for customs clearance, which was laborious and time consuming apart from being expensive. Further, at each and every custom point, financial guarantees needed to be produced for the cargo to go through. In the case of DLC and the single custom based zone, such charges are incurred only once and thereafter the movement in the DLC is custom free which cuts the costs for the companies in particular and logistics overall.

3.3.1.4 Policies and Regulations

Inevitably, state-of-the-art transportation infrastructure is the backbone of a modern competitive international logistics hub. However, the efficiency and seamless connectivity between the administration and customs are equally important. In addition to this, clearance of goods should be least costly with the fastest possible speed and accuracy. In UAE, it has been observed that the trade facilitation and shipment handling services are not available 24/7 and are highly complex compared to benchmarking cities like Singapore. Transportation of goods by trucks is also restricted during peak hours in order to avoid road blocks; thus increasing the lead times taken by road freight during the wee hours of business. The clearance time without inspection takes almost one day and the numbers of agencies involved can be as high as 3 agencies involved in importing and exporting as opposed to to Singapore (0 days and 1 agency). Furthermore, it takes a longer time to import and export goods in UAE (2 days) than in Hong Kong (1 day) and is more expensive than in Singapore and Hong Kong. However, transparency of the customs clearance and other border agencies along with the timely and adequate provisioning of information on regulatory changes is lesser compared to Singapore and Hong Kong.

3.3.2 DP World and Jebel Ali Port

DP World is a leading enabler of global trade and an integral part of the supply chain. It operates multiple yet related businesses – from marine and inland terminals, maritime services, logistics and ancillary services to technology-driven trade solutions.

It has a portfolio of 78 operating marine and inland terminals supported by over 50 related businesses in over 40 countries across six continents with a significant presence in both high-growth and mature markets. Its aims to be essential to the bright future of global trade, ensuring everything we do has a long-lasting positive impact on economies and society.

Container handling is the company's core business and generates more than three quarters of its revenue. In 2017, DP World handled 70 million TEU (twenty-foot equivalent units) across its portfolio. With its committed pipeline of developments and expansions, the current gross capacity of 88 million TEU is expected to rise to more than 100 million TEU by 2020, in line with market demand.

Figure 2.3 The Jabel Ali Seaport

Jabel Ali Port operated by DP World UAE Region, is the largest marine terminal in the Middle East and the flagship facility of DP World's portfolio of over 65 marine terminals across six continents.

Strategically located in Dubai, Jebel Ali port is at the crossroads of a region providing market access to over 2 billion people. As an integrated multi-modal hub offering sea, air and land connectivity, complemented by extensive logistics facilities, Jebel Ali Port plays a vital role in the UAE economy. It is a premier gateway for over 90 weekly services connecting more than 140 ports worldwide. Expansions currently underway at the Port will bring total handling capacity to 22.1 million TEU by 2018.

Jebel Ali port has been voted "Best Seaport in the Middle East" for 20 consecutive years and is ranked the 9th largest container port worldwide. It has the world's largest man-made harbour. DP World UAE Region portfolio includes Jebel Ali Port, Mina Rashid Cruise Terminal and Coastal Berth, and Al Hamriya in Dubai city.

The Jebel Ali Port plays a significant role in serving the gulf, Indian Subcontinent, and African Markets. The diversity of the region and the markets served through Jebel Ali Port are reflected in the nature of the cargo imported and exported. The port is strengthened by the high degree of specialization in the storage and handling of all kinds of cargo at its facilities including bulk, breakbulk, and RoRo.
Jebel Ali's General Cargo facility covers a total storage area of over 1.4 million sqm consisting of 26 berths. This includes 928,499 sqm of open storage and 71,501 sqm of covered storage area.
Jebel Ali Port combines unparalleled access by sea, air and land with a multitude of modern facilities, a wide choice of logistics service providers and excellent connections with the hinterland.

Jebel Ali Port operates a refrigerated storage facility located centrally in the port area. The facility covers a total area (cool and cold storage) of 65,000 cbm and a floor space of 9,272 sqm
DP World UAE Region's Cool Stores at Jebel Ali Port provide customers' with the ideal storage solutions for all kind of perishable products ranging from chocolates, fruits and vegetables, alcohol and cigarettes to pharmaceutical products, photographic films and cosmetics.

Container Freight Station facility located outside Gate 2 at Jebel Ali Port covers a total area of 134,343 sqm which includes a covered storage area of 11,900 sqm and an uncovered storage area of 122,443 sqm.
Container Freight Station provides an array of services based on the customers' requirements which include:

- LCL (Less than Container Load)
- Handling Transshipment Cargo
- FCL Un-stuffing/ Stuffing
- Rework/ Consolidation Operations
- Cross Stuffing
- Weight Reduction of Containers
- Export Stuffing
- Storage -Open/ Covered
- Delivery of Cargo which comprises
- Inter Port Transfer (IPT)
- Internal Shifting
- Additional Services Inspection of Containers

3.3.3 Dubai South (DWC) and AL Maktoum airport

Dubai South (formerly known as Dubai World Central) is an economic zone to support a number of activities including logistics, aviation, commercial, exhibition, humanitarian, residential and other related businesses around Al Maktoum International Airport with the planned annual capacity of 12 million tons of cargo and 160 million passengers.[2] The construction area is 140 square kilometers, almost two times the size of Hong Kong Island. The location is estimated to be the future home of 900,000 people.[3] The Dubai World Central combined with the Al Maktoum International Airport is expected to draw additional tourism to the Middle East, designed to handle 20 million visitors a year by 2020.[4] The development has been designed on the basis of three key factors: Dubai's geographic location, increasing importance of airports in the Middle East region, and the region's booming aviation sector.

Dubai World Central–Al Maktoum International was first announced back in 2004 as part of an extremely ambitious plan to develop the world’s biggest airport

The development consists of the following sub-development projects:

- Dubai World Central Residential City
- Dubai World Central Logistics City
- Dubai World Central Enterprise Park
- Dubai World Central Commercial City
- Dubai World Central Aviation City
- Al Maktoum International Airport (DWC)
- Dubai World Central Staff Village
- Dubai World Central Golf City

Figure 2.4 The Al Maktoum Airport

3.3.2.1 ABOUT AL MAKTOUM AIRPORT

The Al Maktoum International Airport (IATA: 'DWC'), operational since 2010, is the largest airport in the world in the making. The airport will feature five Airbus A380 compatible runways capable of simultaneous operations.
Al Maktoum International Airport is located 40km from Dubai International Airport. It has a capacity of over 12 million tonnes of cargo a year and 160 million passengers a year. It is capable of handling all new-generation aircraft such as the A380 superjumbo.

The airport construction is part of the Dubai World Central project (DWC). DWC is the Dubai Government’s single largest urban land development project and comprises six clustered zones. The project is estimated to cost $33bn.

DWC started its first phase of operation when DWC-Al Maktoum International Airport opened for cargo operations in June 2010. General aviation operations were launched in April 2011. Passenger operations begin in 2012 and the airport is scheduled for completion in 2020. Dubai Aviation City Corporation integrates DWC and the Dubai Airports Company.

The airport will consist of a number of terminals, five runways, a large area for cargo and two main entrances.

3.3.4 Free Zone structure and JAFZA

Beginning with the opening of Jebel Ali Free Zone in 1985, there are now more than 35 free trade zones across the UAE, where significant proportion of business and trading activities takes place. They also provide a major source of business for the imports, exports and re-exports sector.
Each free zone is strategically located near a transportation hub, reducing the timescales and logistics needed for cargo and shipping. Jebel Ali Port, for example, is very close to Dubai World Central, poised to be the world s largest logistics hub. Jabel Ali Port, within Jebel Ali Free Zone, is also the largest container port between Singapore and Rotterdam.
For the main part, each is set up to cater for a particular industry or economic sector, creating a community for companies operating within similar or complementary fields and further developing the nations entrepreneurial business culture
All offer a number of distinct advantages. Unlike onshore companies in the UAE, where there is a requirement for a 51 per cent Emirati ownership stake, free zone companies can be 100 per cent foreign-owned, and expats are free to repatriate all capital and profits. There is no corporate, personal or capital gains tax, neither are there any currency restrictions. Each free zone has excellent infrastructure and communications, and can supply residency visas along with the company's trade license.
The free zone business model was set up with the intention of streamlining trade and logistics activities across the countries. This model has been instrumental in boosting the country's economic growth by extending various tax exemptions such as corporate tax exemptions, 100% foreign ownership, 100% tax exemptions on imports and exports etc. Each free zone is governed by its own Free Zone Authority (FZA) and mandated business policies of the federal government. As of now, the UAE government has managed to establish a total of 38 free zones across the country (see Exhibit 9) in various formats and the number is likely to swell. Some of the strategic advantages for logistics companies operating in Dubai Free Zones are:

- 100% ownership
- Tax exemption for corporate
- Purpose-built office or warehouse facilities
- Liberal VISA policies
- No Import or Export custom duties
- Abundant availability of space and energy

3.3.4.1 JAFZA

As part of the vision of the late ruler of Dubai Sheikh Rashid Bin Saeed Al Maktoum, Jafza has matured into an ever expanding business platform that is ready for today. Overtime it has grown from a small operation of just 19 companies into a thriving business community with over 7,000 companies that continues to expand. Today, Jafza is a dynamic base for thousands of businesses, from over 100 countries, sustaining over 135,000 jobs and attracting more than 20% of the UAE's foreign direct investment; all the while exceeding 50% of Dubai's total exports, with an phenomenal value for trade of $69 billion. Jafza is located in an Over 78 Sq-km Industrial & Logistics Zone.

The main goal of this Free area Zone are:

- Hub for logistics companies
- Base for global companies
- Hassle-free & cost effective business setup
- Smooth cargo movement
- Sea-air connectivity within customs-bonded transport corridor

Chapter 4

The case study: System Dynamics model of the Dubai Logistics Corridor

After introducing the SD methodology and describing all the components of the Dubai logistics cluster, this chapter deals with the case study and theof modeling the Dubai Logistics Corridor through the System Dynamics approach.
It is the crucial part of the work, carried out in the field of Dubai where both modeling and research data have been done in alternating phases but with an iterative approach up to the final model. Like any model it tries to simulate the logistic behavior of the various parts that compose it, albeit with simplifications and adopting different assumptions in order to make the model not too complex and elaborate.
The level of detail of the model is minimal, in fact it is in an embryonic phase and sets macro objectives and then is divided into more detailed problems in the future.
As mentioned in the introductory part it counts with five macro phases:

- Preliminary phase: in this phase it was possible to study the logistic behavior that identifies both the port and the airport as a protagonist in terms of trade.We began to outline the key variables and to test the possibility of using them through a preliminary phase of data research.

- The Causal Loop Diagram CLD: qualitative part of the model with the aim of highlighting the causal relationships between the variables involved and the feedback loop of reinforcement and balancing.

- The Stock and Flow S&F model: a quantitative part where, once the relationships between the variables are found, the equations that underlie their behavior are explained. Furthermore, the variables involved are quantified through the imput of initial data, collected through field research and use of the underlying literature.

- The simulation phase, through the use of scenarios to compare the different solutions.

- The validation phase of the model, to assess whether the results obtained are actually consistent with reality. Usually to do this we choose a time horizon that starts from the past and arrives at the future, and compares the differences in results with what has actually been achieved.

4.1 Preliminary phase

System Dynamics requires a good knowledge, as well as the tool itself, also the simulation process and the variables involved. The first phase was therefore to verify how much and what data were available. Fortunately, most of the data searched was made available, thanks to the data archive of the parties involved, to the literature that had previously done similar research and thanks to research data on the field such as that carried out during the visit to the airport Al Maktoum (later explained in detail). At the end of this phase a first draft of a casual loop diagram was formulated, which was then submitted to the interested parties in order to receive feedback, suggestions, observations and critiques, with the aim of obtaining a result that is as close as possible to reality. Again, the experience and knowledge of those working in the field and the contributing experts have led to several changes in the initial loop. The next section describes the steps that led to the final CLD. Subsequently we proceed to illustrate in detail the elements present in the final stock and flow diagram and the first results of the simulations carried out.

4.2 The Causal Loop Diagram

The first casual loop diagram was created with the most global view possible of the process, and essentially comprised all the flows, variables and stocks in the DLC. Such a high level of simulation is not recommended as it makes it difficult to focus on single issues, but the CLD has been specially set up in this way in order to encourage discussion with experts. Through continuous comparisons, the focus of the diagram is gradually narrowed, eliminating step by step those flows or variables that are difficult to simulate or not particularly significant. One advice was to not make the model too complicated, willing to overdo it when people do not have too much experience in the SD can lead to errors and complications from which it is difficult to extricate.

4.2.1 The CLS Model

As mentioned before the model counts two part, the Seaport and the Airport, both connected with a Land Transport. In the two Figure below we can see the small differences between the port and the airport model.

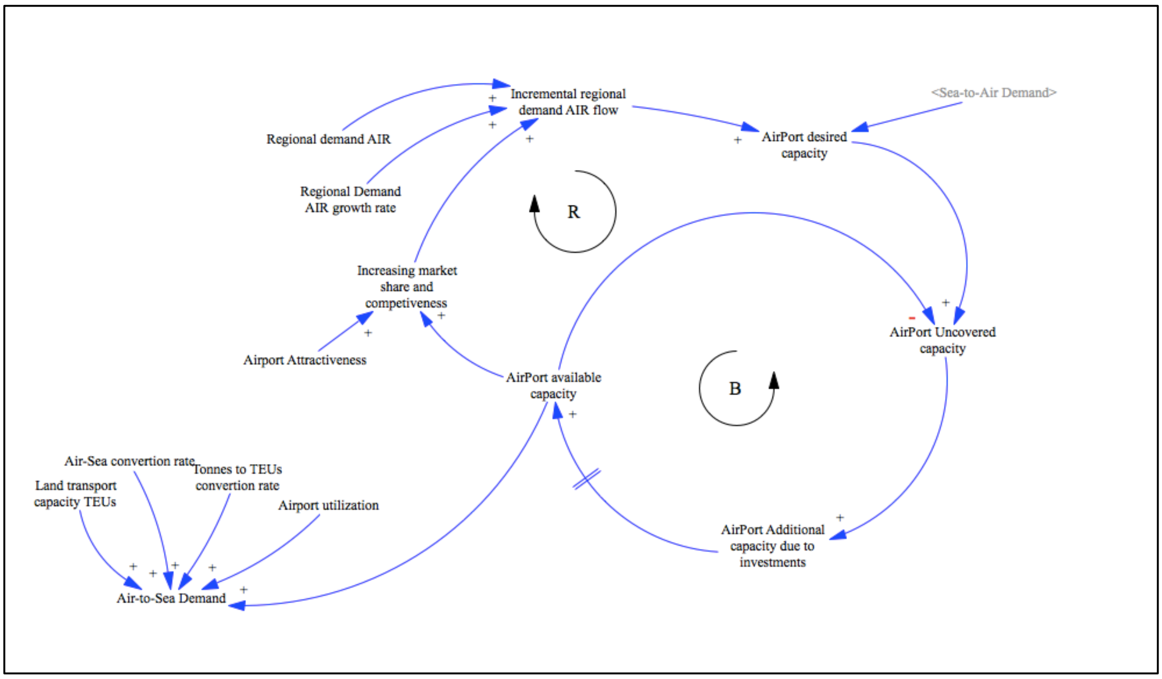


Figure 3.1The Airport Causal Loop Diagram

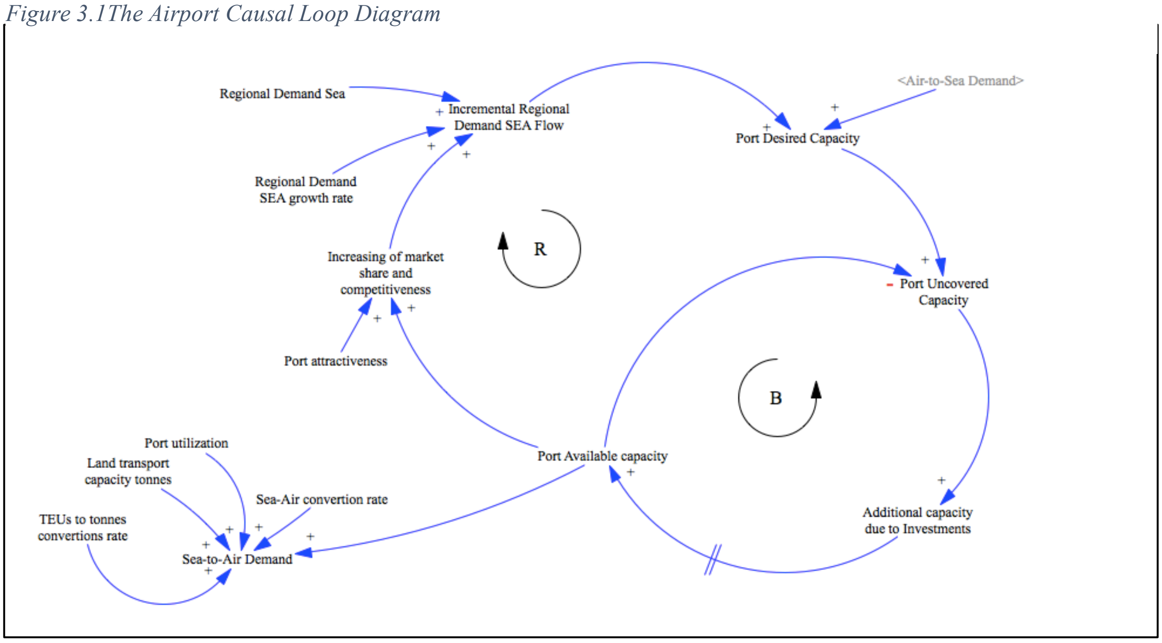


Figure 3.2 The Seaport Causal Loop Diagram

For the explanation of CLD we start from the Incremental Regional Demand SEA Flow, it is the monthly increase in capacity demand expressed in TEUs, it is the product of the regional demand of the UAE port multiplied by a monthly percentage growth coefficient called Regional demand SEA growth rate. As will be explicitly indicated in the part of the assumption, the literature and the professionals estimate that there is a perpetual growth of the demand for items shipments in the emirates for a decade, due to the strategic position, investments and growth of the trading itself. As a result, the incremental growth in capacity demand generates a shortfall in port

capacity, called Port Uncovered Capacity. It is easy to understand how this capacity uncovered is the difference between the desired capacity and the available capacity.
If it is positive then we will have an actual lack of capacity that coincides with the non-sale of the commercial services, the so-called stock out in the production area.
If it is negative then there will be excess capacity, therefore the supply of production capacity is greater than the demand, it is common called overstock.
It is clear that as the capacity for discovery increases, the stakeholders will be encouraged to invest and consequently increase production capacity. This additional capacity is called 'additional capacity due to investments' and is going to add to the capacity available.
This investment choice follows precise criteria and to quantify the amount of additional capacity, the underlying logic will be explained in the qualitative part of the S&F.

The increase in available capacity has two double effects which will then determine the feedback loops explained later. On the one hand they will decrease the Uncovered Capacity that by definition has as subtracting the available capacity, on the other hand it increases a size that is defined under the name of competitiveness and increased market share.
We will see in the assumptions of the model how to estimate the competitiveness of the port, one of the key indicators is the available capacity. As this increases, the service offered by the port improves and consequently the competitiveness, this is taken into account in the CLD and especially in the S&F through a positive percentage coefficient that raises the demand even more. So far the model of the port is totally disconnected with the model of the airport, the reader could ask how the two will interact.
The interaction between the 2 Macro systems is found in the variable 'Sea to air demand' and in the similar 'Air to Sea demand'. In these variables are taken key factors and key assumptions that are fundamental in the model, that is the possibility of neglecting control and travel times between the port and the airport thanks to the Free area zones and according to the synergy existing between the two ports, thanks to this synergy there is an increase in the demand for both because considered intertwined (that is, part of the demand for one transits also in the second one generating a greater need). Evaluating whether a super additive function exists in the model is one of the primary research objectives.
From the figures of the 2 models we can see how they are practically specular, if not for some subtle differences. The decision not to enter the specific and to treat the DLC at the Macro level allowed to do a parallel job and to treat Port and Airport in the same way, at this level of detail it is possible to assert that the behavior of the trade by sea and via air is approximated as analogous. Obviously the differences exist, as the unit of measurement to indicate the capacity. For the port it is measured in TEUs, or twenty feet equivalent units. The unit of measurement for the airport model is instead in Tons, or tons. The reader can easily guess how the first measure a volume while the second a mass, in fact in the model there are coefficients to convert one with the other in such

a way as to make the quantities homogeneous. It is also necessary to add that the Dubai Emirate is about to design a system of railway lines, which is currently lacking, this in the future could be a factor to be added in the model to make it evolve into something more complete. It is clear that such an addition would only improve the logistics efficiency of the logistics corridor.

4.2.2 The feedback loops

As explained by Sterman previously, a causal loop diagram is a graphical representation of the causal relationship between variables. A CLD takes the form of a closed loop that depicts cause-and-effect linkages between variables. Causal loop diagrams constitute a means to represent the feedback structures present in a system. A feedback loop is present when information resulting from some action (a change in one variable) travels through the system and returns in some form to its point of origin (as a change in that same variable), potentially influencing future action. So, a set of causal links which constitute a closed circle, with all the arrows pointing clockwise or all the arrows pointing counter clockwise is called a feedback loop.

In the Dubai Logistics Corridor model there are four feedback loops, two in the Airport part and two in the Seaport part. In this section will be mentioned the Seaport feedback loops only, the other part of the model is pretty similar so there is no reason to explain it. The entire model will be explained properly in the S&F section.

4.4.2.1 Reinforcing Loop

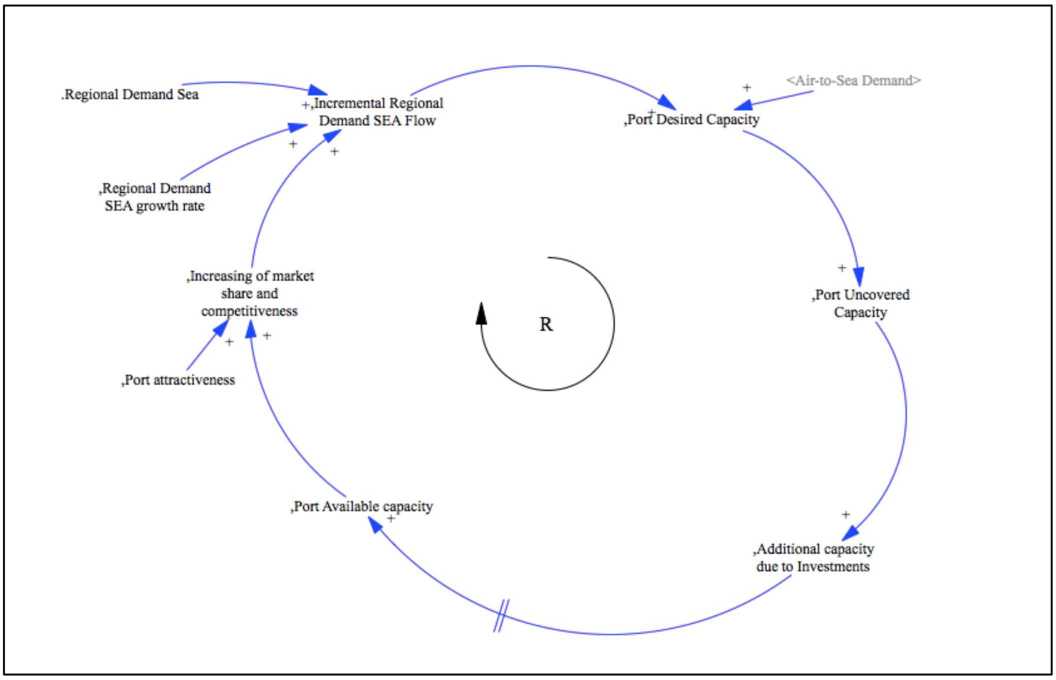


Figure 3.3 The Seaport Reinforcing Loop

The one represented in the Figure is the Reinforcing Loop of the part of competence of the Seaport, in fact we can distinguish an arrow that follows the clockwise direction with a R in the center, which is really to mean Reinforcement. All the variables are linked together by oriented arcs (arrows) and by signs that can be positive if there is a directly proportional relationship between the arrows and vice versa negative if the relationship is inversely proportional. Specifically, it can be noted that all the signs of the loop are positive, it distinguishes the reinforcing loops. A positive change in the Incremental Regional Demand causes a variation in the variable that is defined as Port Desired Capacity, i.e. the capacity that stakeholders would like the port to have to face the demand. Obviously, due to constraints, it does not always coincide with the capacity available, here a shortfall of capacity is created called Port Uncovered capacity. It grows with the growth of the Port Desired Capacity and in turn increases the Additional Capacity variable two to investments that coincides with the additional capacity created thanks to investments. Obviously not all the discovered capacity is always transformed into additional capacity and later the logics will be explained. Consequently, the additional capacity with a delay (signaled by the two strips perpendicular to the arrow) is added to the available capacity, one of those parameters that well approximates the quality of the service perceived by the customers.

A higher available capacity tends to make a high level of service perceive and therefore increases the competitiveness and the market share of the port, competitiveness that is reflected in a further increase in regional demand, thanks to the greater market share taken away from the competition. It will further increase the desired capacity which in this way closes the loop. It seems obvious that the reinforcing behavior, taken individually, increases all the variables exponentially causing them to reach infinity asymptotically. However, there is a brake on this phenomenon, which makes it possible to converge the analyzed metrics and to stabilize the logistic behavior of the Dubai Logistics Corridor, it takes the name of balancing loops and is explained hereinafter.

4.4.2.2 Balancing Loop

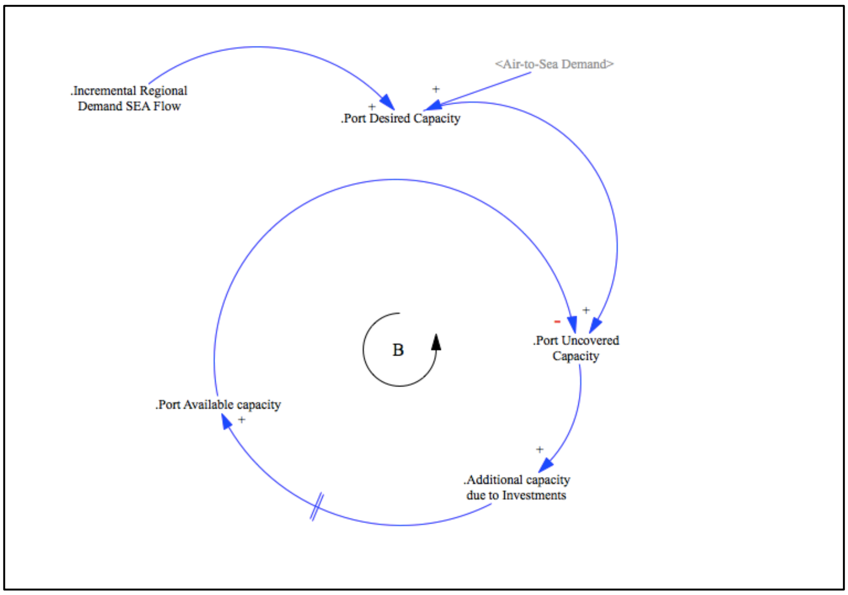


Figure 3.4 The Seaport Balancing Loop

The one shown in the figure is the second Loop, in particular that of balancing the Port. You can see how a variable is taken as a reference point (Eg: Port Uncovered Capacity) by following the arrows, through the other variables the first variable will be reached. In other words, we can deduce how the variable taken into consideration influences itself, the basic concept of system thinking. In this case we find ourselves in front of a Rebalancing Loop, which precisely rebalances the model. If it were not for the rebalancing of this loop and having already mentioned that of reinforcement, the model would grow asymptotically to infinity. To verify that it is actually a balancing loop, as previously explained in the chapter of the methodology it is enough to count the number of negative signs of the cycle. If it is even (zero included), then it will be a cycle of reinforcement, vice versa if it is odd it will be a balancing cycle. In this case it is easy to verify how the number of negative signs is odd (one only). Entering specifically in the model, we start from Uncovered Capacity, it positively influences the Additional Capacity two to investments variable (as capacity increases, the stakeholders will have more incentive to invest to fill this gap). In turn, investments that generate capacity will increase Available Capacity, but it will increase with a delay since generating new production capacity is not an instant task and requires considerable time. An increase in the available capacity will in turn decrease the Uncovered Capacity, and here we are back to the initial variable by closing this loop. It can therefore be said that the Uncovered Capacity influences itself, an increase of it determines with the delay a simultaneous decrease.

4.3 The Stock & Flow Diagram

An important drawback of causal diagrams is their inability to generate dynamic behavior. In other words, it is not possible to study the actual behavior of the variables of interest through the use of causal diagrams alone. A way to overcome this shortcoming of causal loop diagrams is to make use of Stock-and-flow diagrams. There are five components in a Stock-and-flow diagram: stocks, flows, auxiliary variables, sinks/sources, and information links.

Each component has the precise purpose of trying to simulate the behavior of the Dubai logistics corridor in the most truthful way. Each of these variables is populated with data that have been collected, some of them precise and punctual, others estimated through assumptions and finally macro data have been used, they do not refer to the DLC in particular but to overall averages. the variable will be explained rigorously in the appropriate part before the simulations.

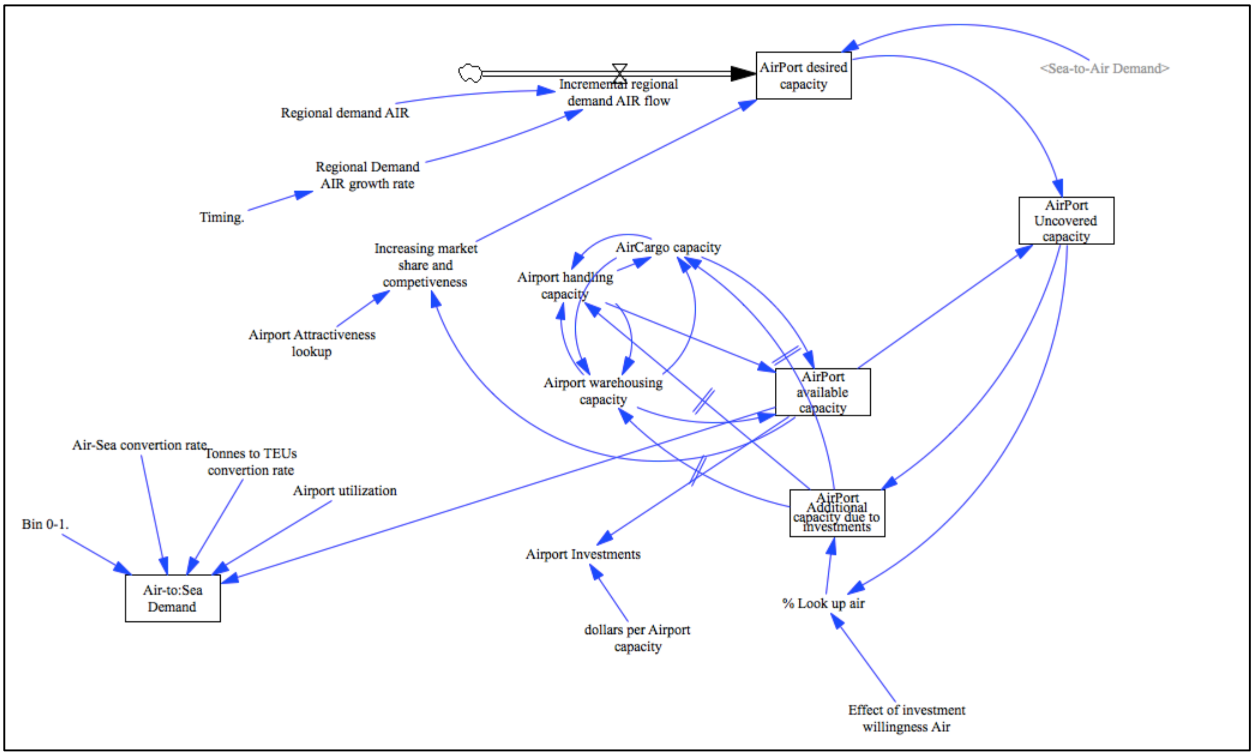


Figure 3.5 The Airport Stock & Flow Diagram

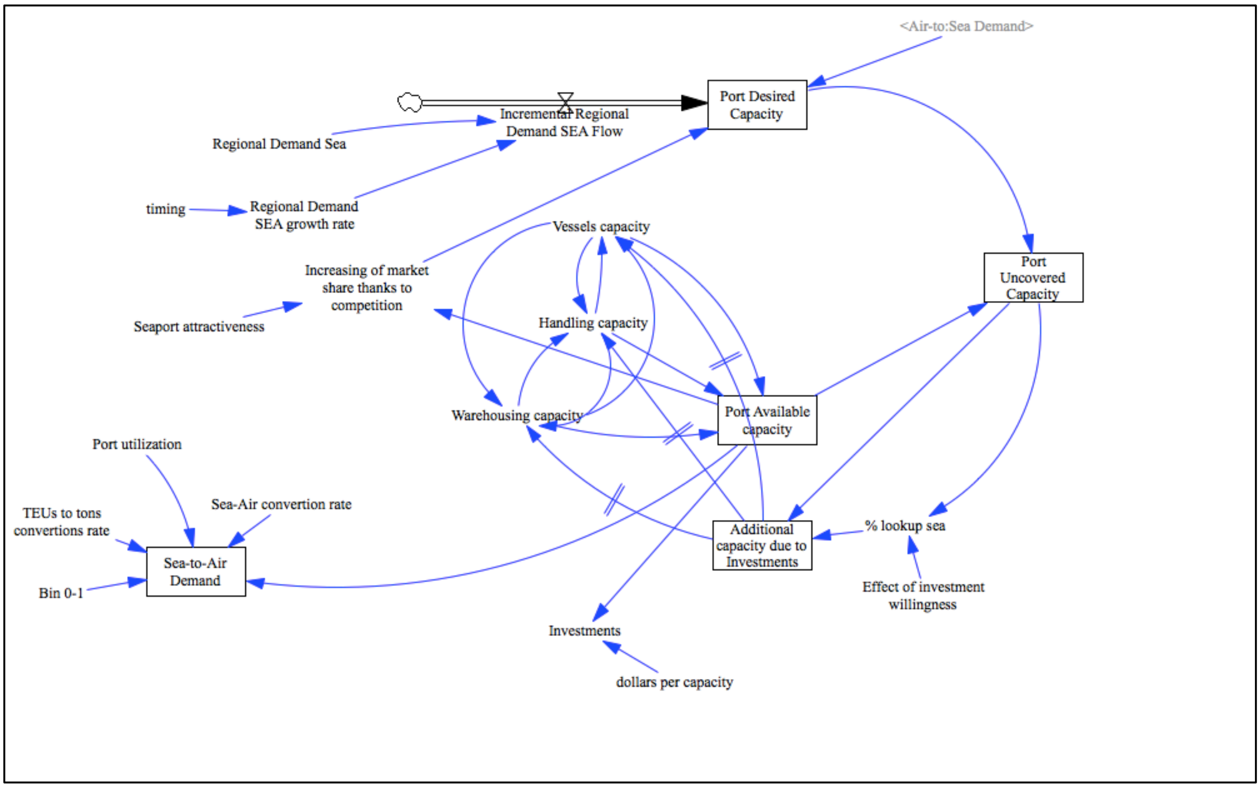


Figure 3.6. The Seaport Stock & Flow Diagram

4.3.1 The model, the time horizon and the explanation of the variables

An S&F diagram should be the alter ego of the Causal Loop Diagram, consequently the two should look as much as possible since one is a representation of qualitative behavior (CLD) while the other through quantitative data and equations must confirm the trend.

In the case in question we can see how the two models are almost similar, with the difference that in the second some auxiliary variables have been added to facilitate the explanation of the underlying equations, this is the case for example of the Table Lookup which have the task of following the variables having chosen before a behavior. In addition, a focused reader may notice that some basic CLD variables have become compound variables and exploded into underlying variables such as Available Capacity, which is the result of the minimum between Handling, Warehousing and Vessels capacity.

4.3.1.1 The time horizon

The model has made the clear choice to unite a medium-term time horizon. A 96-month Time Step has been taken into consideration, coinciding with 8 years, this because a period of this kind is not too short to give a minimum of strategic vision to the project and it is not too long in order to be able to predict the behavior with an acceptable error, given that more is expected in the future and more likely to incur future errors. The reference timeframe is the one that starts from the beginning of 2015 until the end of 2022, the year zero has not been taken in the past at random, the first 3 years up to the present will be fundamental for the validation of the model as available data and expected data.

4.3.1.2 The variable explanation

In this part all the variables present in the model are explained, since there is a certain redundancy between the part of the seaport and that of the airport will be explained all the variables of the Seaport and those that differ from the Airport. For each of the Variables the type (stock, flow, auxiliary), the unit of measure (month, Teus, dmnl), the underlying equation that binds to the others and a short explanation will be explained

- **Regional Demand SEA [MTeus / Month]**
  Type: Initial
  Equation: /

  Ideally, it is the maximum demand of the entire CCG region that Dubai could absorb if it had no capacity constraints and there was no competition from other Regional CCG ports.
  If Dubai were Monopolist, it would coincide with the variable 'port desired capacity'.

- **Regional Demand SEA growth rate [Dmnl]**
  Type: Auxiliary
  Equation: (1+growth monthly percentage) ^ Timing

  Is the rate of monthly growth of the TEU demand of the Seaport, according to the literature in the coming years the demand will greatly exceed the current capacity of the commercial ports of Dubai, thanks to strategic positioning, DLC synergy, big events like Expo 2020 and the trade global growth itself.

- **Timing [Month]**

Type: Auxiliary
Equation: initialize at 0 and increase +1 every month

This variable takes into account the monthly Time step, so in every month it represents the current month.

- **Incremental Regional Demand SEA Flow [MTeus]**
  Type: Flow
  Equation: (Regional Demand Sea*Regional Demand SEA growth rate) - Regional Demand Sea

  This variable in the monthly increment of the regional Demand, it represents the incremental amount of Demand thanks to the growth rate, if in the Time Step i there is no growth the i-result will be 0.

- **Port Desired Capacity [MTeus]**
  Type: Stock
  Equation: Incremental Regional Demand SEA Flow*1+Increasing of market share thanks to competition+ "Air-to-Sea Demand"

  It is the amount of capacity that the Seaport could absorb if there is enough available capacity. It is similar to the Potential Demand but without competition among the other region. If the Port Desired Capacity is greater than the Available there is a stock out and missed sales of potential capacity.

- **Port Uncovered Capacity [MTeus]**
  Type: Stock
  Equation: Port Desired Capacity-Port Available capacity

  It is the difference between the desired capacity and the total available capacity. If it is negative it coincides with an excess of capacity else is the explication of the missed sales of capacity.

- **Additional capacity due to Investments [MTeus]**
  Type: Stock
  Equation: IF THEN ELSE (Port Uncovered Capacity>0, "% lookup sea"*Port Uncovered Capacity ,0)

  As the uncovered capacity increases, coinciding with the lack of sales, the willingness of the stakeholders to invest in order to increase capacity also grows. Consequently, if the Port Uncovered Capacity will be negative, no investment maneuvers will be undertaken, opposite, if it is positive, investments will be granted to increase the available capacity. The additional capacity generated by the investments is contained in this variable, the

Additional capacity due to Investments. Obviously, depending on the investment availability, a more or less high amount will be covered, probably will be not sufficient to cover the entire capacity discovered.

- **% lookup sea [Dmnl]**
  Type: Auxiliary
  Equation: Effect of investment willingness (Port Uncovered Capacity)

  This variable is nothing more than the output of a function dependent on Port Uncovered Capacity. It represents the percentage of Port Uncovered Capacity that the stakeholders want to cover, if it is equal to 0 means that no investments will be granted, the opposite case is if it is equal to 1 where there will be investments to fully cover the shortfall in capacity discovered. In the intermediate cases, on the other hand, the decision maker decides to cover only a part of the capacity discovered, a more truthful situation.

- **Effect of investment willingness [Dmnl]**
  Type: Table Lookup

  This variable of type Lookup has been inserted to model the behavior of the 'policy makers' in front of the question of investments according to the variable Port Uncovered Capacity.
  In the model it is considered an auxiliary variable that can change according to the decision-maker's propensity to invest, in this case three different cases will be analyzed.

  Risk Adverse: the decision makers' willingness decrease with the growth of Port Uncovered Capacity, this because investments would always weigh more on the increase of the shortfall, making investments intensively increase.

  Risk Neutral: The willingness of the decision maker is always constant and does not vary with the variation of Port Uncovered Capacity, a simpler but less truthful situation.

  Risk Inclined: The willingness of the decision maker grows with the growth of Port Uncovered Capacity, in this case the significant investments could generate more profits as a larger amount of coverage would be captured.

- **Total Additional capacity [MTeus]**
  Type: Stock
  Equation: INTEG (Additional capacity due to Investments)

This variable takes into account the entire additional capacity generated by investments, beyond where they are placed.

- **Dollars per capacity [B$/Mteus]**
  Type: Constant
  Equation: /

  Indicate how many dollars it takes to generate a MTeus of capacity.

- **Investments [$]**
  Type: Auxiliary
  Equation: dollars per capacity*Total Additional capacity

  The variable is an output of the model, it indicates the amount of Dollars spent on the investments made.

- **Warehousing capacity [MTeus]**
  Type: Stock
  Equation: INTEG (IF THEN ELSE (Warehousing capacity = MIN (MIN (Handling capacity, Vessels capacity), Warehousing capacity), + DELAY1 (Additional capacity due to Investments, 2), +0))

  Warehousing capacity coincides with the capacity of the warehouse to receive goods entering and leaving the Port. If it is minimal compared to other capacities, then the additional capacity investments will be allocated in this for the bottleneck principle. The formula includes a component that refers to the Delay, in fact it is assumed that once invested in the chosen capacity there is a delay of 2 months coinciding with a lead time to consider it available. In the part of the data collection it will be explained how a space quantity can be estimated in TEUs.

- **Seaport Handling capacity [MTeus]**
  Type: Stock
  Equation: INTEG (IF THEN ELSE(Handling capacity=MIN(MIN(Handling capacity , Vessels capacity) , Warehousing capacity) , + DELAY1(Additional capacity due to Investments , 2) ,+0))

Handling capacity coincides with the ability to handle or move the goods, from the warehouse to the ships and vice versa. Despite having large amounts of storage capacity and shipping or arrival through the banners there is certainly a need for adequate handling of items.
It is estimated through the number of Cranes in the port, where global performance parameters are used to estimate the corresponding TEUS capacity. If it is minimal compared to other capacities, then the additional capacity investments will be allocated in this for the bottleneck principle. The formula includes a component that refers to the Delay, in fact it is assumed that once invested in the chosen capacity there is a delay of 2 months coinciding with a lead time to consider it available.

- **Vessels capacity [MTeus]**
  Type: Stock
  Equation: INTEG (IF THEN ELSE(Vessels capacity=MIN(MIN(Handling capacity , Vessels capacity) , Warehousing capacity) , + DELAY1(Additional capacity due to Investments , 2) ,
  +0))
  The capacity of the banners is that which is properly measured in Teus, that is the unit of measurement of the container. It corresponds to the shipping and arrival capacity of ships at the port. Among those analyzed is certainly the most expensive capacity as to increase it must have more ships owned or rented by intermediaries. If it is minimal compared to other capacities, then the additional capacity investments will be allocated in this for the bottleneck principle. The formula includes a component that refers to the Delay, in fact it is assumed that once invested in the chosen capacity there is a delay of 2 months coinciding with a lead time to consider it available.

- **Port Available capacity [MTeus]**
  Type: Stock
  Equation: INTEG (MIN(MIN(Handling capacity, Vessels capacity) , Warehousing capacity))

  As already mentioned, the Port Available capacity is the minimum among the three capacities just explained, namely the Warehousing capacity, Handling Capacity and Vessels Capacity.
  In fact, for the bottleneck theory the resulting capacity of a process is the one with the lowest capacity. This variable is the key variable of the model, in fact it is present in both the Feedback loop of the Causal Loop Diagram.

- **Seaport attractiveness [Dmnl]**
  Type: Table Lookup
  This lookup is conceptually different from the one seen previously for investments. In this case the Seaport Attractiveness is a function of the

Available Capacity, in fact to estimate the attractiveness and competitiveness of a port, it is a good indicator. This variable calculates the growth percentage of the Market share based on the available capacity.

- **Increasing of market share thanks to competition [Dmnl]**
  Type: Auxiliary
  Equation: 1+ Seaport attractiveness (Port Available capacity)

  This variable is the direct consequence of Seaport Attractiveness. It represents the monthly growth rate of the market share thanks to the competitiveness of the port and consequently increases the desired demand.

- **Sea-Air convertion rate [Dmnl]**
  Type: Constant
  Equation: /

  Sea-Air conversion rate is the first of the variables that determine the exchange of goods between the port and the airport. It represents the percentage of goods arriving at the port and then being redirected to the airport.
  This is a very important variable in the simulations, as it is subject to multivariate analysis to analyze how the output changes as it changes, consequently different percentage values are hypothesized to understand what is best for the logistics behavior.

- **Port utilization [Dmnl]**
  Type: Constant
  Equation: /

  The seaport like the airport does not make full use of its available capacity, this is a choice that is made not to create too much congestion or simply because the demand has some peaks in some months and remains more stable in others. This constant expresses on average the use of port capacity and is the ratio between capacity used on available capacity.

- **TEUs to Tons conversions rate [Tons/TEUs]**
  Type: Constant
  Equation: /

  It represents the conversion rate from Teus to Tons. This constant is essential to be able to estimate a passage of goods from the port to the airport as the two ports do not have the same units of measurement to measure the traded loads. Obviously for the opposite case there is an opposite conversion rate. This rate is not accurate but it is a good estimate as it tries to approximate a mass unit (tons) with a volumetric (Teus).

- **Bin 0-1 [Dmnl]**
  Type: Boolean
  Equation: /

  Bin 0-1 is a Boolean variable used in scenarios. It is set to 0 in the scenario in which one does not want to consider cross-subsidization, 1 in the case where one wants to take into account an effect between the capacities of the ports.

- **Sea-to-Air Demand [Tons]**
  Type: Auxiliary
  Equation: Port Available capacity*Port utilization*TEUs to tons conversions rate*"Sea-Air conversion rate"*"Bin 0-1"

  It represents the total demand that is added to the desired capacity of the airport. A similar variable of the airport model flows into the desired capacity in the same way. In the equation we find the available capacity that is adjusted with coefficients such as using the conversion rate and the exchange rate between the port and the airport. This variable is the only connection that exists between the model of the port and that of the airport, therefore it is a variable core of the model.

4.4 Main assumptions of the model

4.4.1Capacity variables:

They are overall capacity of:

-Import;
-Export;
-Re-export;

Assumption made to greatly simplify the model and take into account the Land-Sea-Air interactions.

4.4.2 Neglecting of time to move goods from port to airport

Thanks to the Dubai Logistics corridor, a road that interconnects the port to the airport and the JAFZA (Jabel Ali Free Trade Zone) that allows you to avoid to submit the goods double security checks and bureaucracy, the items passing through each other in time really fast, an average of four hours was measured. Considering this, it was decided to simplify the model of being able to obscure these times as if compared to the benchmarks are really omitted.

4.4.3Minimum level of detail

It was decided to keep the level of detail of the model as low as possible, for two reasons:

1. The study of the project is at an early stage, so it is better not to go into detail immediately
2. To remain in little detail has allowed enormous examples to manage to treat both the port and airport parts in a mirror-like manner.

4.4.4 Data collection

For data collection, we tried to obtain the most realistic data possible. The data collection carried out on the field at Al Maktoum airport allowed to have quantitative but also qualitative data from the stakeholders of the institution, so they could be used considering the maximum reliability. The collection of official data through bibliography and sitography has given an important help for the success of the work. In this case the reliability lies in the official publications of the institutions. Where it was not possible to find the precise data, macro data were used as world averages or benchmarks of analogous situations in order to avoid having to make false assumptions.

4.5 Simulations through the Different scenarios approach

In this section, after having fully explained how the underlying stock and flow model works, the simulations made through different scenarios and the results that derive from them will be described. This is the properly operational part where it will be assessed whether the chosen research objectives have been really achieved.
The first step will describe all the data that populate the equations of the variables described above, the assumptions behind and from where they were extracted.
Consequently, the outputs of the various simulations and the first evidences will be explained.
The conclusions and implications deriving from this section will be described in the appropriate final chapter after the validation of the model.

4.5.1 Data Collection

As already described above, the data that populate the model have different nature, some are precise data, others are macro data dropped in reality, another part are based on assumptions and finally there are qualitative data such as interviews given to experts and professionals

For the data collection of the Al Maktoum airport it was possible to visit the site, to talk with the referents and to extract good ideas and authentic data.
For the data collection of the Jabel Ali port, the same treatment was not granted, therefore all the reference data are public data contained above all in the online archive of the institution.

Here then the explanation of all the data, as they were obtained, the sources and the assumptions at the base, being specular will be described at the same time.

- **Regional Demand Sea**

Total Annual Demand of GCC in 2014: 52 Mteus
Total Monthly Demand of GCC in 2014: 4.4 Mteus
Dubai Market share: 29%
Attackable Demand: 2/3
Monthly Regional Demand Sea: **2MTeus / Month**

Fonte: Analysis of the Competition of Ports in the Middle East Container Ports Using HHI, Osama. F. Elbayoumi & Ahmed Dawood (2016)

	2009			2010			2011		
Port	Throughput (1000) TEU	Market Share (%)	HHI	Throughput (1000) TEU	Market Share (%)	HHI	Throughput (1000) TEU	Market Share (%)	HHI
Dubai (Jebel Ali)	11,124	23.111	0.053414	11,600	23.259	0.054098	13,000	26.465	0.070041
Khore Fakkan	2,750	5.713	0.003264	3,023	6.061	0.003674	3,230	6.576	0.004324
Salalah	3,340	6.939	0.004815	3,620	7.258	0.005268	3,201	6.517	0.004247
Jeddah	4,561	9.476	0.008980	4,738	9.500	0.009025	4,010	8.164	0.006664
Suez Canal C. Terminal	3,524	7.322	0.005360	3,646	7.311	0.005344	4,272	8.697	0.007564
Elsokhna	403	0.837	0.000070	597	1.197	0.000143	585	1.191	0.000142
Damietta	1,213	2.520	0.000635	1,096	2.198	0.000483	1,200	2.443	0.000597
Aqaba	674	1.400	0.000196	605	1.213	0.000147	338	0.688	0.000047
Beirut	995	2.067	0.000427	950	1.905	0.000363	1,034	2.105	0.000443
Khalifa Bin Salman	280	0.582	0.000034	368	0.738	0.000054	375	0.763	0.000058
Hodeida	6,311	13.112	0.017192	6,402	12.837	0.016478	5,446	11.087	0.012292
Bandar Abbas	56	0.116	0.000001	68	0.136	0.000002	87	0.177	0.000003
Shahid Rajaei	2,206	4.583	0.002101	2,592	5.197	0.002701	2,389	4.864	0.002365
Latikia	621	1.290	0.000166	586	1.175	0.000138	524	1.067	0.000114
Haifa	1,357	2.819	0.000795	1,372	2.751	0.000757	1,235	2.514	0.000632
Djibouti	519	1.078	0.000116	600	1.203	0.000145	634	1.291	0.000167
Aaden	62	0.129	0.000002	68	0.136	0.000002	73	0.149	0.000002
Dammam	1,659	3.447	0.001188	1,622	3.252	0.001058	1,492	3.037	0.000923
Jubail	121	0.251	0.000006	124	0.249	0.000006	167	0.340	0.000012
Sohar	145	0.301	0.000009	142	0.285	0.000008	150	0.305	0.000009
Ambarli	3,378	7.018	0.004926	3,097	6.210	0.003856	2,686	5.468	0.002990
Ashdod	893	1.855	0.000344	1,018	2.041	0.000417	1,039	2.115	0.000447
Alexandria	1,508	3.133	0.000982	1,500	3.008	0.000905	1,490	3.033	0.000920
Port Sudan	432	0.898	0.000081	439	0.880	0.000077	464	0.945	0.000089
Total	48,132	100.000	0.1051	49,873	100.000	0.1052	49,121	100.000	0.1151

	2012			2013			2014		
Port	Throughput (1000) TEU	Market Share (%)	HHI	Throughput (1000) TEU	Market Share (%)	HHI	Throughput (1000) TEU	Market Share (%)	HHI
Dubai (Jebel Ali)	13,270	25.960	0.067390	13,641	26.595	0.07073	15,249	29.034	[illegible]084298
Khore Fakkan	3,996	7.817	0.006111	3,800	7.409	0.00548	[illegible]	[illegible]	[illegible]05235
Salalah	3,482	6.812	0.004640	3,490	6.804	0.004630	3,034	5.777	0.003337
Jeddah	3,830	7.492	0.005614	3,091	6.026	0.003632	3,034	5.777	0.003337
Suez Canal C. Terminal	3,631	7.103	0.005046	4,100	7.994	0.006390	3,959	7.538	0.005682
Elsokhna	452	0.884	0.000078	534	1.041	0.000108	587	1.118	0.000125
Damietta	760	1.487	0.000221	1,300	2.535	0.000642	807	1.537	0.000236
Aqaba	817	1.598	0.000255	413	0.805	0.000065	403	0.767	0.000059
Beirut	1,041	2.036	0.000415	1,117	2.178	0.000474	1,210	2.304	0.000531
Khalifa Bin Salman	525	1.027	0.000105	595	1.160	0.000135	331	0.630	0.000040
Hodeida	7,237	14.157	0.020043	6,257	12.199	0.014882	6,578	12.525	0.015686
Bandar Abbas	91	0.178	0.000003	105	0.205	0.000004	95	0.181	0.000003
Shahid Rajaei	2,258	4.417	0.001951	2,147	4.186	0.001752	1,842	3.507	0.001230
Latikia	342	0.669	0.000045	194	0.378	0.000014	254	0.484	0.000023
Haifa	1,264	2.473	0.000611	1,357	2.646	0.000700	1,196	2.277	0.000519
Djibouti	681	1.332	0.000177	735	1.433	0.000205	773	1.472	0.000217
Aaden	95	0.186	0.000003	111	0.216	0.000005	135	0.257	0.000007
Dammam	1,333	2.608	0.000680	1,250	2.437	0.000594	1,748	3.328	0.001108
Jubail	245	0.479	0.000023	257	0.501	0.000025	278	0.529	0.000028
Sohar	198	0.387	0.000015	208	0.406	0.000016	227	0.432	0.000019
Ambarli	2,540	4.969	0.002469	3,378	6.586	0.004337	3,488	6.641	0.004410
Ashdod	1,181	2.310	0.000534	1,165	2.271	0.000516	1,250	2.380	0.000566
Alexandria	1,350	2.641	0.000697	1,508	2.940	0.000864	[illegible]	3.195	0.001021
Port Sudan	499	0.976	0.000095	538	1.049	0.000110	565	1.076	0.000116
Total	51,118	100.000	0.1172	51,291	100.000	0.1163	[illegible]	100.000	0.1278

- **Regional demand AIR**

Total Annual Demand of GCC in 2014: 16 Mteus
Total Monthly Demand of GCC in 2014: 1.3 Mteus
Attackable Demand: 2/3
Monthly Regional Demand AIR: **0,9 MTeus / Month**

Source: www.dubaiairports.ae

Fast Facts

- Once completed, DWC will accommodate more than 240 mppa.
- DWC will have a final cargo capacity of 16 million tonnes per annum.
- The airport will have a total of five parallel runways, 4.5km long, each separated by a minimum of 800m.
- The central terminal area (of the main terminal) will incorporate basements which will house a fully automated baggage handling system capable of handling around 240 million bags per annum.
- Located near the Jebel Ali Port and Free Zone, DWC will make air-sea connectivity achievable in four hours
- DWC is designed to support aviation, tourism, and logistics well into the future.
- Costs for the entire DWC development (including all clusters) has been estimated more than US$ 32 billion (approx. AED 120 billion).

- **Regional Demand SEA growth rate**
  Annual Growth: 5.7%
  Using the compound rate formula to bring it in months:
  Monthly Growth rate: 0.351%
  Source: www.thenational.ae

DP World's gross container volumes grew by 5.7 per cent year-on-year on a reported basis, ahead of the industry estimate of 2.6 per cent throughput growth for the first quarter of the year, beating estimates from Egyptian investment bank, EFG Hermes. Its terminals around the world handled 16.4 million TEU between January and March compared with 15.5 million TEU a year earlier. On a like-for-like basis, which does not include volumes from newly opened terminals, the throughput grew 5 per cent in the first quarter.

- **Regional Demand AIR growth rate**
  Annual Growth: 6.7%
  Using the compound rate formula to bring it in months:
  Monthly Growth rate: 0.541%

  Source: www.dubaiairports.ae

Dubai Airports Strategic Plan 2020

Dubai Airports announced a US$7.8 billion (28.8 billion AED) airport and airspace expansion programme which will boost capacity at Dubai International from 60 million to 90 million passengers per year by 2018.

Designed to deliver aviation infrastructure which will support the continuation of the sector's impressive growth, facilitate Dubai's economic expansion and generate an estimated 22 per cent of total employment and 32 per cent of the emirate's GDP by 2020.

The SP2020 responds to a ten-year traffic forecast for Dubai International (DXB) and Dubai World Central (DWC) that projects international passenger and cargo traffic will increase at an average annual growth rate of 7.2 per cent and 6.7 per cent respectively.

Port Available capacity: MIN(MIN(Handling capacity, Vessels capacity) , Warehousing capacity)

- **VESSELS capacity: 15.5 MTeus / year**
  Source: Dubai Statistics Center

GOVERNMENT OF DUBAI

Dubai Statistics Center

الحاويات التي تم تسليمها في ميناء جبل علي

Containers Handled at Jebel Ali Port

(2016 - 2014)

(Unit: 20 Foot Equivalent Units الوحدة: بمقياس حاوية 20 قدم)

Table (11 - 06) جـدول

Title	2016	2015	2014	البيـــــان
Discharged Containers	2,505,552	2,574,993	2,504,352	حاويات مفرغة
Loaded Containers	1,392,349	1,345,109	1,372,428	حاويات مشحونة (محملة)
Other Containers*	10,868,618	11,664,663	11,363,619	حاويات أخرى*
Total	**14,766,519**	**15,584,765**	**15,240,399**	**المجموع**

- **Handling capacity** (based on the number of cranes)
  Number of Jebel Ali Cranes: 97
  Hour per Month: 720h
  Lift per Cranes per hour: 10 Lift / h
  Teus per Lift: 1.75 Teu / Lift
  Annual Handling capacity: 14.4 MTeus / year
  Source: DPWorld

Vessel Size TEU	6,000	8,000	10,000	12,000
Cranes	4	5	6	6
Lifts per Hour	Vessel Turnaround Time, Hours			
20	96	103	107	129
30	64	69	71	86
40	48	51	54	64
50	39	41	43	51
60	32	34	36	43
Parameters: 1.75 TEU per lift. Turnover 75%. Two eight hour shifts/day.				

- **WAREHOUSING capacity**
  Capacity in m squared: 134343m^2
  Conversion rate Teus/m^2= 14.6 Teus /m2
  Day in port: 0.87→ 26 days
  0.134Mm2/14.6Teus=9178 Teus
  9178*26=0.239 Mteus /Month
  levels: 5
  0.239*5=1.195 MTeus / Month
  Annual Warehousing Capacity: **14.34 MTeus**
  Source: DPWorld & Marina Traffic

Terminal Infrastructure

- Container Terminal
- General Cargo – Bulk, RO-RO and Break-bulk
- Tank Terminal
- Multi-modal Capabilities- Sea, Air and Land

Logistics Capabilities

- Container Freight Station
- Cool Port - Cold and Cool Storage Facilities
- Warehouses
- Haulage Services

Facility	Capacity	Details
Container Terminal	15 million TEU (19 million TEU 2014)	23 berths (6 berths under development) / 78 cranes (19 cranes on order)
General Cargo RO-RO	Over 1.4 million sqm storage facility	26 berths
Container Freight Station	135,000 sqm	LCL goods and consolidation cargo
Cool Store	Over 3,900 sqm	+10°C to +20°C
Cold Store	Over 5,765 sqm	-29°C to +13°C
Tank Terminal	11 berths	Petroleum and petrochemical products

Table 4.5. Average time in port: Container vessels, 2016

Country	Days in port	Total arrivals
China	0.83	60 795
Japan	0.29	38 415
Republic of Korea	0.49	23 545
United States	0.97	19 844
Taiwan Province of China	0.40	16 895
Singapore	0.80	16 159
Malaysia	0.93	15 678
Germany	0.46	14 784
Spain	0.51	14 018
Netherlands	1.14	12 264
World total	**0.87**	**445 990**

Source: Marine Traffic, 2017.
Note: Average time in port is equivalent to the average of median per port per country.

AirPort available capacity: MIN(MIN(Airport handling capacity, AirCargo capacity) , Airport warehousing capacity)

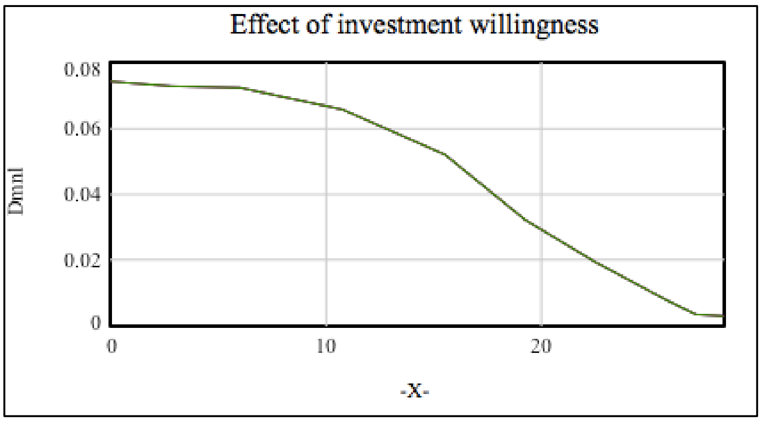
- **AirCargo capacity= 0,89 Mtones**
  Source: www.dubaiairports.ae

Traffic 2015/14

- DWC handled 888,714 tonnes of freight in 2015, up 7.7 per cent from 824,933 tonnes recorded during 2014.
- DWC welcomed 463,236 passengers during 2015, a contraction of -45.2 per cent compared to 845,046 recorded during the corresponding period in 2014.
- The slump is due to the surge in volumes created by the temporary relocation of 300 weekly flights while the runway refurbishment programme was conducted at Dubai International in 2014.
- Aircraft movements in 2015 totalled 42,055 compared to 47,655 movements during the same period last year, a decrease of 11.8 per cent.

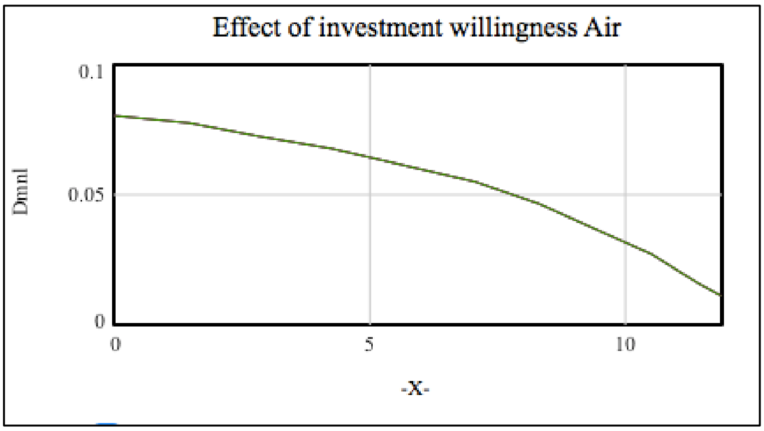
- **Airport handling & Airport warehousing capacity** (interview)
  = 16 M Tones both
  In agreement with Al Maktoum airport up to the maximum capacity of the 2020 masterplan the only constraint is the aircargo capacity, warehouse and handling already equipped.
  Source: Al Maktoum Logistics coordinator

Effect of investment willingness SEA (assumption)
Assumption of RISK ADVERSE stakeholder



The model with risk-inclined stakeholders will also be simulated as a different scenario.

Effect of investment willingness AIR (assumption)
Assumption of RISK ADVERSE stakeholder



The model with risk-inclined stakeholders will also be simulated as a different scenario.

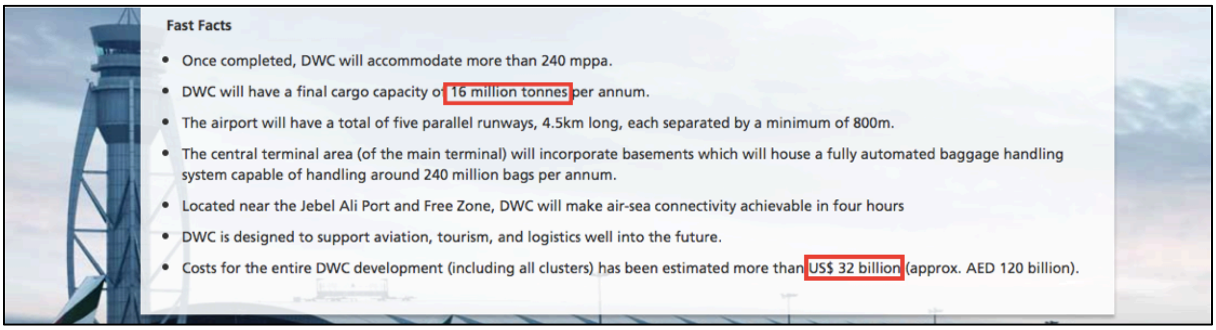
- **Seaport Dollar per Capacity (to increase all the capacity together)**
  Dollar invested in Jabel Ali terminal 4: 1.6 B$
  Increasing in capacity involved: 3.1 MTeus
  Dollar per Capacity: **0,516 B$ /MTeus**
  Source: DPWorld

DP World may revive US$1.6 billion Jebel Ali terminal 4 expansion next year

DP World announced in 2015 that it would add 3.1 million TEU in Jebel Ali by building phase one of the fourth terminal, increasing overall capacity to 22.1 million TEUs by 2018.

- **Airport Dollar per Capacity**
  Dollars invested in Al Maktoum Cluster Project: 32B$
  Cluster divided in 5 parts:
  1. Dubai Logistics City (DLC)
  2. Commercial City
  3. Residential City
  4. Aviation City
  5. Airport

  Dollars invested in Al Maktoum Airport only 32B$ /5 =6,4 B$
  Increasing in capacity involved: 16 MTeus
  Dollar per Capacity: **0,4 B$ /MTeus**
  Source: DUBAI SOUTH

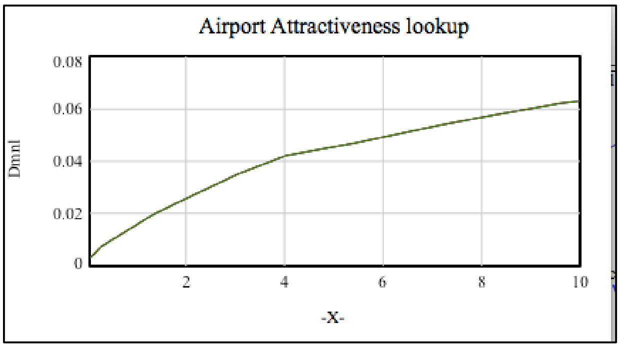


Fast Facts

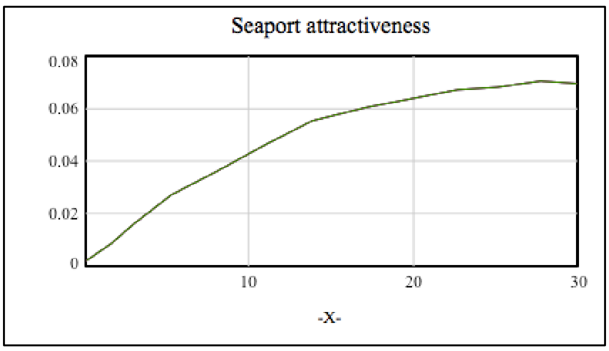
- Once completed, DWC will accommodate more than 240 mppa.
- DWC will have a final cargo capacity of 16 million tonnes per annum.
- The airport will have a total of five parallel runways, 4.5km long, each separated by a minimum of 800m.
- The central terminal area (of the main terminal) will incorporate basements which will house a fully automated baggage handling system capable of handling around 240 million bags per annum.
- Located near the Jebel Ali Port and Free Zone, DWC will make air-sea connectivity achievable in four hours
- DWC is designed to support aviation, tourism, and logistics well into the future.
- Costs for the entire DWC development (including all clusters) has been estimated more than US$ 32 billion (approx. AED 120 billion).

- **Increasing of market share thanks to competition**

AIRPORT:

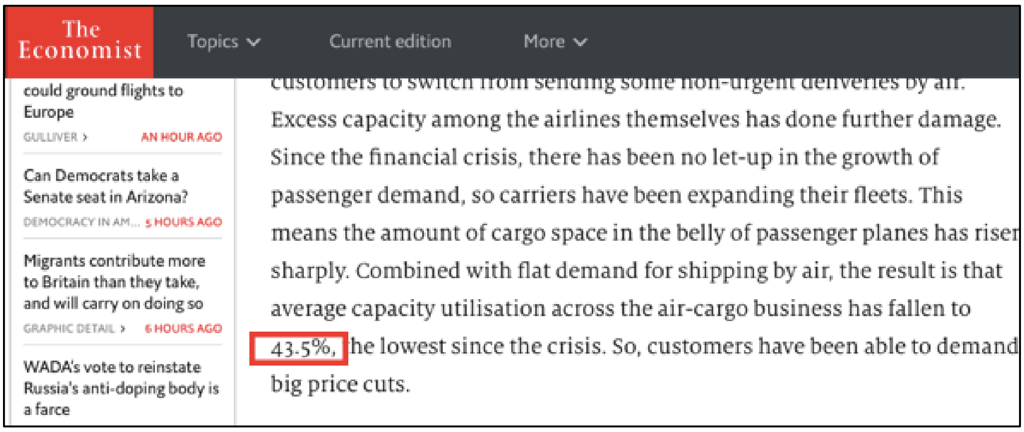


SEAPORT:



Air-To-SEA Demand: Air-Sea conversion rate*AirPort available capacity*Airport utilization*"Bin 0-1."*Tonnes to TEUs conversion rate

- **Tonnes to TEUS conversion** =0.588
- **Bin 0-1** = 0 or 1
- **Utilization**=0.435
- **Conversion rate:** 0.15 or 0.2 per different scenarios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could ground flights to Europe
GULLIVER › AN HOUR AGO

Can Democrats take a Senate seat in Arizona?
DEMOCRACY IN AM… 5 HOURS AGO

Migrants contribute more to Britain than they take, and will carry on doing so
GRAPHIC DETAIL › 6 HOURS AGO

WADA's vote to reinstate Russia's anti-doping body is a farce

customers to switch from sending some non-urgent deliveries by air. Excess capacity among the airlines themselves has done further damage. Since the financial crisis, there has been no let-up in the growth of passenger demand, so carriers have been expanding their fleets. This means the amount of cargo space in the belly of passenger planes has risen sharply. Combined with flat demand for shipping by air, the result is that average capacity utilisation across the air-cargo business has fallen to 43.5%, the lowest since the crisis. So, customers have been able to demand big price cuts.

SEA-To-Air Demand: Port Available capacity*Port utilization*TEUs to tons conversions rate*"Sea-Air conversion rate"*"Bin 0-1"

- **TEUS to Tons conversion** =0.588
- **Bin 0-1** = 0 or 1
- **Utilization**=0.84
- **Conversion rate:** 0.15 or 0.2 per different scenarios

GCC container port throughput and capacity 2015–17

	Throughput (thousand teu)			Maximum capacity			Capacity utilisation		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Bahrain	425	422	400	1,000	1,000	1,000	42.5%	42.2%	40.0%
Kuwait	985	1,020	1,095	1,180	1,180	1,180	83.5%	86.4%	92.8%
Oman	3,106	3,944	4,785	5,800	6,000	6,500	53.6%	65.7%	73.6%
Qatar	530	532	800	590	790	1,290	89.8%	67.3%	62.0%
Saudi Arabia	7,890	7,725	8,106	13,150	14,600	15,150	60.0%	52.9%	53.5%
UAE	21,471	20,280	19,344	25,555	26,055	28,405	84.0%	77.8%	68.1%
Total	**34,407**	**33,923**	**34,530**	**47,275**	**49,625**	**53,525**	**72.8%**	**68.4%**	**64.5%**

Source: Drewry Shipping Consultants

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4.6 Simulation: The base case

Simulation is the ultimate goal of creating a System Dynamics model. However, it is also an effective control tool: when one of them starts, Vensim returns an error message if problems are found, which may be incorrect equations, incorrect syntax, logical errors etc…
This is the first of a series of scenarios that will then be compared to derive the implications and conclusions, therefor it is called base case.

In all the simulations, the time horizon is set at 96 months, corresponding to 8 years, where the year zero is 2015.
The base case contains all the data that has just been explained in the previous section with the following control variables:

- **Bin 0-1** = 1 for port and airport both.
- **SEA - AIR Conversion Rate** = 15%
- **AIR – SEA Conversion Rate** = 15%
- **Effect of investment willingness AIR:** stakeholder with risk adverse behavior
- **Effect of investment willingness SEA:** stakeholder with risk adverse behavior

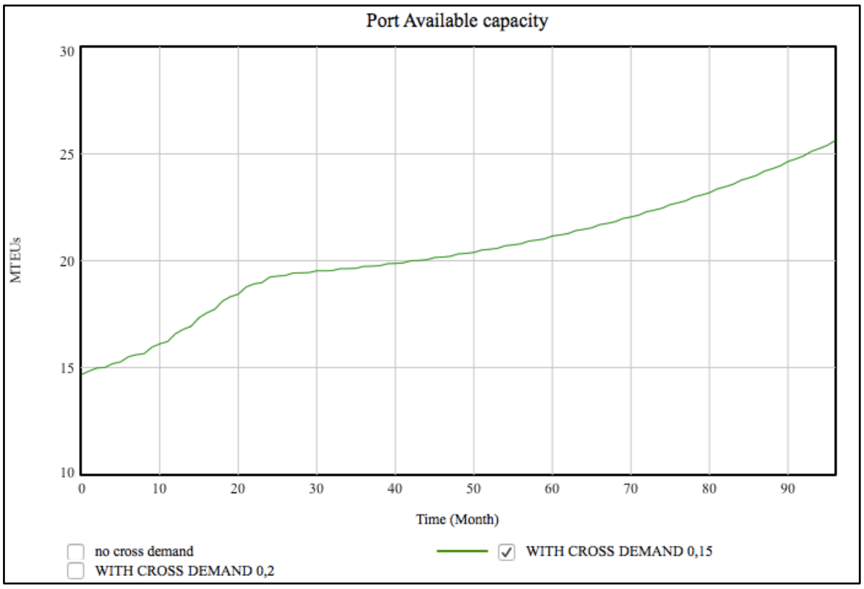
As we can see from the control variables, it has been assumed that there is interaction between the Seaport Model and the Airport Model and that the exchange of goods between the two is equal to 15%. The stakeholders in the investment decision take a cautious attitude, inherent in risk aversion.

Following are the main results of the first simulation for the SEAPORT part:

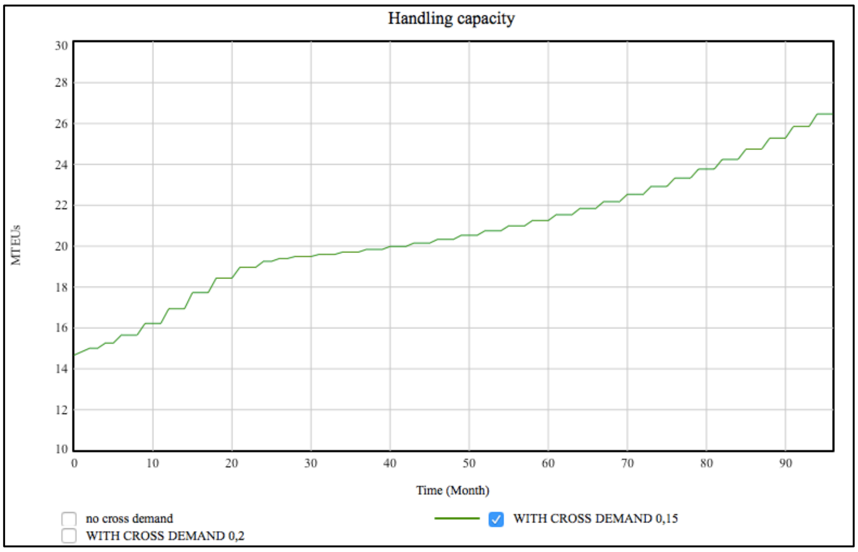
- **Port Available capacity**: It grows as a step function because of its equation which is the result of the minimum of the 3 micro capacities described extensively.
  We can see how in 2015 it is equal to about 14.5 million Teus to finish after 8 years at about 25 million, undergoing a growth of over 10 million resulting capacity.

- **Vessels capacity** & **Warehousing capacity** & **Handling capacity**:
  The three capacities that make up the resulting available capacity also follow a step-by-step function for taking the bottleneck. We can see how the three graphs take on a role of policy making tool because they simulate the history of capacity increase, so the stakeholders following this could know what is the optimal time to invest and in which of the different capacities to optimize investments. It can be noted that the starting point for all of them is very similar, this means that in reality the institution brought in 2015 already uses the notion of bottleneck as the capabilities seem well balanced.

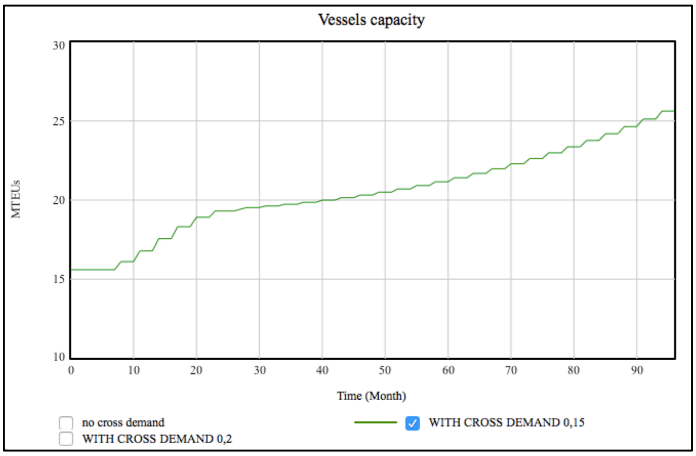
- **Investments**: The investment chart shows the history of the investments required to generate the available capacity previously described. It can be seen that in order to create over 10 million Teus in the 8 years an outlay of about 6 Billions of dollars is required. Obviously this data takes into account an average expense, therefore the value could be higher or lower.



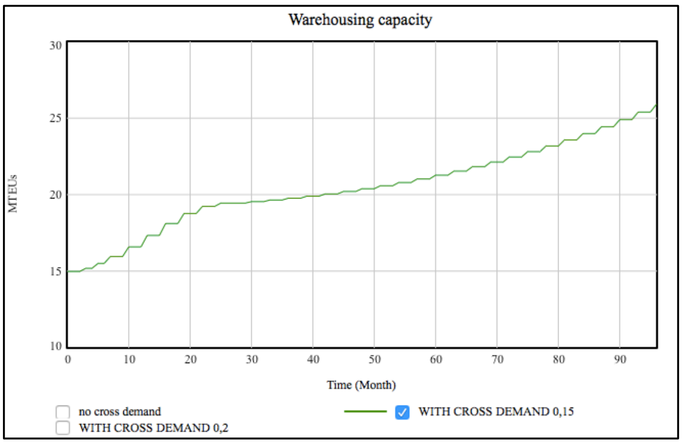
Port Available capacity
MTEUs
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



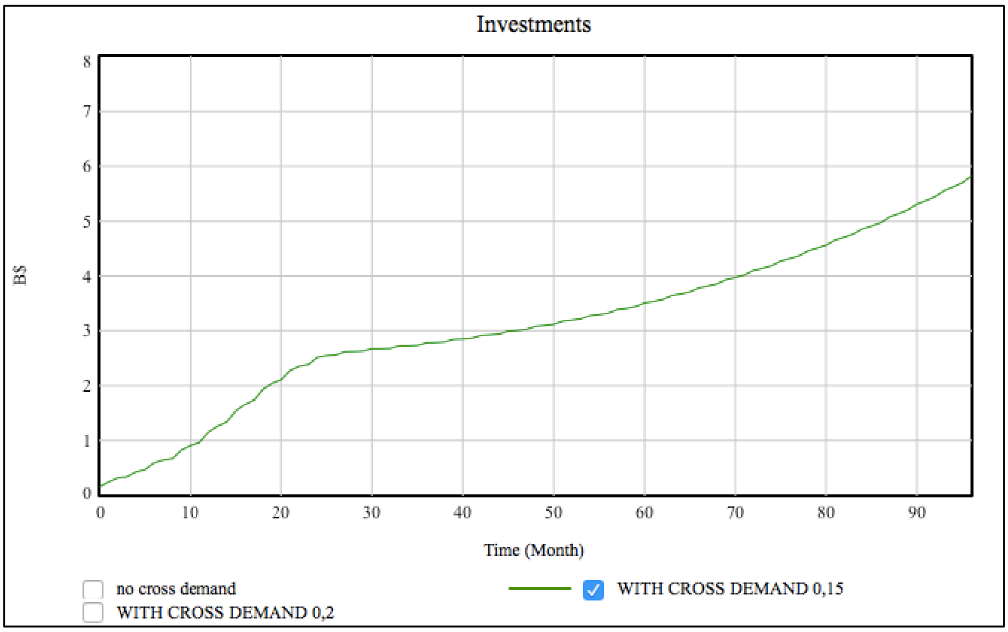
Handling capacity
MTEUs
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



Vessels capacity
MTEUs
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



Warehousing capacity
MTEUs
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15

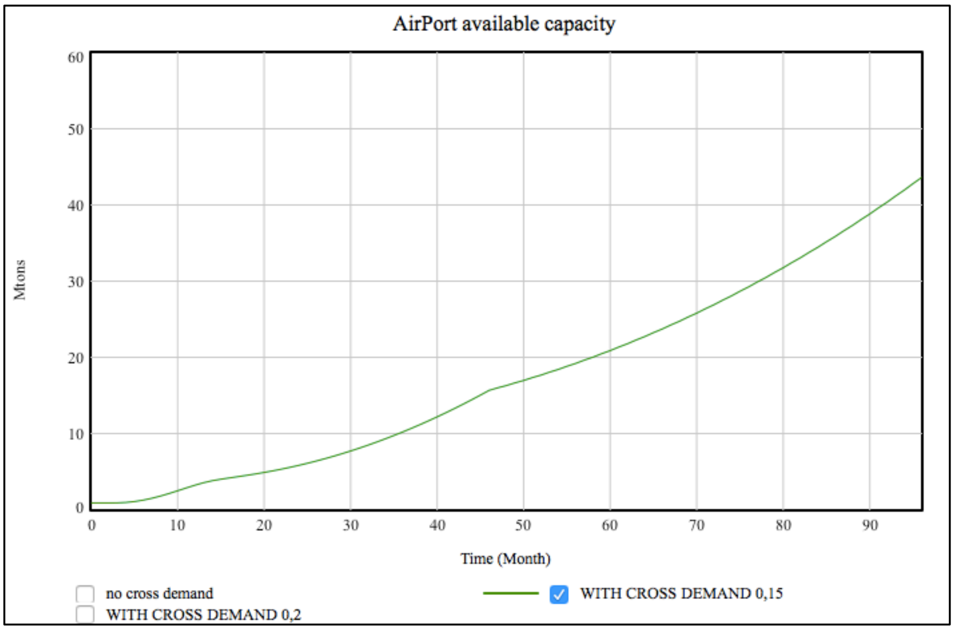


Below are the main results of the first simulation for the AIRPORT part:

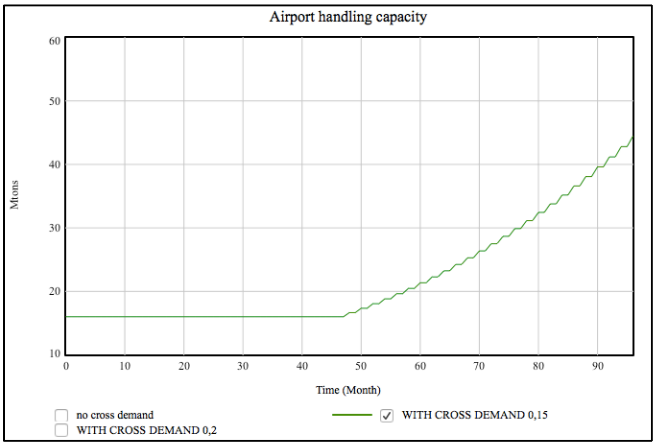
- **AirPort Available capacity**: It grows as a step function because of its equation which is the result of the minimum of the 3 micro capacities described extensively.
  We can see how in 2015 it is equal to about 0.9 million Tons to finish after 8 years at about 43 million, undergoing a growth of over 40 million resulting capacity.

- **Air cargo capacity** & **Warehousing capacity** & **Handling capacity**:
  The 3 capacities that make up the resulting available capacity also follow a step function for the assumption of the bottleneck. We can see how the three graphs take on a role of policy making tool because they simulate the history of capacity increase, so the stakeholders following this could know what is the optimal time to invest and in which of the different capacities to optimize investments. It can be seen that, unlike the Seaport model, there is no clear balance of the 3 capacities. Handling and Warehousing are already calibrated to satisfy a large capacity (around 16 MTons) while Air Cargo starts almost from scratch. The reason is explained, for the moment a large capacity of Cargo is engaged in the other airport of Dubai the DXB and soon will be transferred in the new one, thus separating the function of Trading and passenger transport.

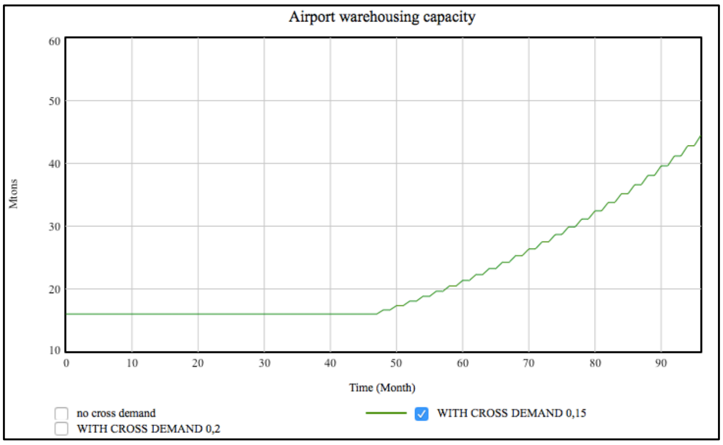
- **Investments**: The investment chart shows the history of the investments required to generate the available capacity previously described. It can be seen that in order to create over 40 Millions of Tons in the 8 years a disbursement of about 18 Billions of dollars is required. Obviously this data takes into account an average expense, therefore the value could be higher or lower.



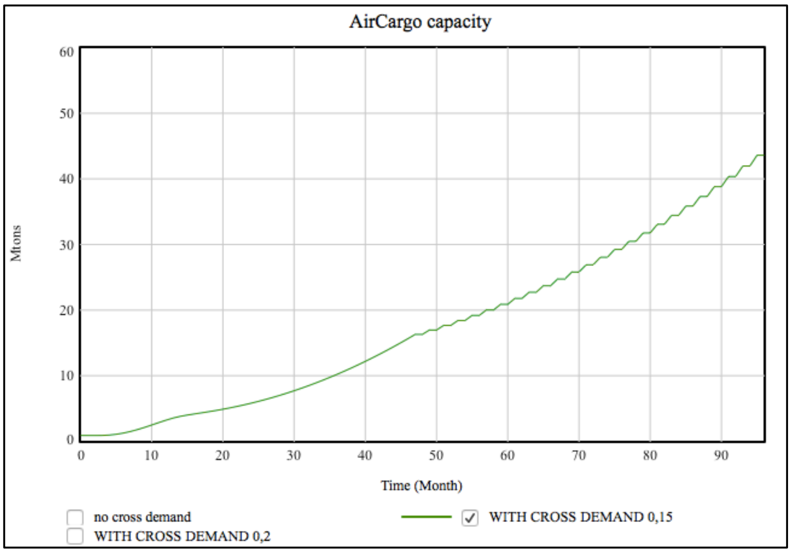
AirPort available capacity
Mtons
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



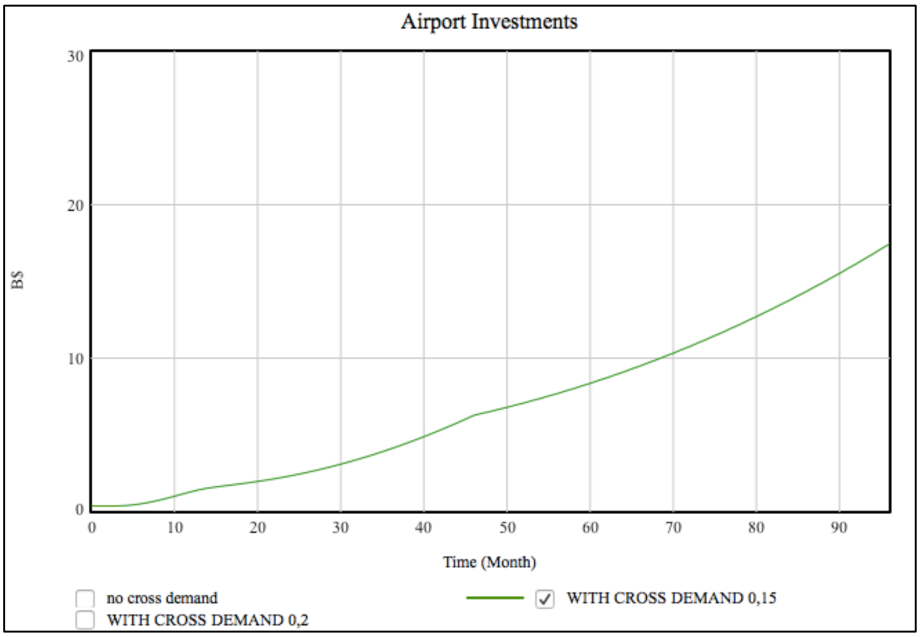
Airport handling capacity
Mtons
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



Airport warehousing capacity
Mtons
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



AirCargo capacity
Mtons
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



4.6 Comparison of different scenarios (Risk Adverse)

After seeing the results of the basic case we can now compare them with the other two scenarios used in the work. They are diametrically opposed to the case study, and the behavior of the stakeholders that will subsequently vary in another scenario remains unchanged. The new scenarios have the following features:

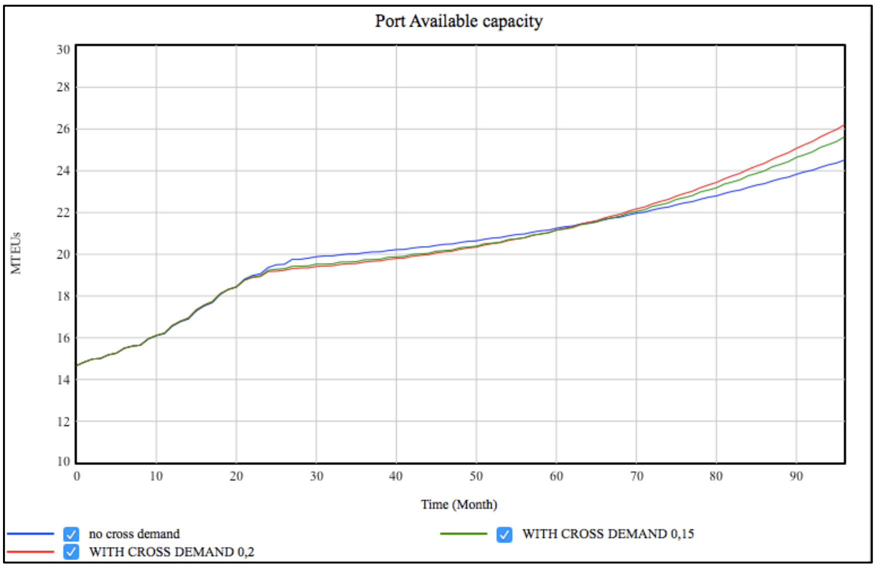
- **WITH CROSS DEMAND 0.2**: In this case the conversion rate between SEA and AIR is equal to 20% rather than equal to 15% (base case).

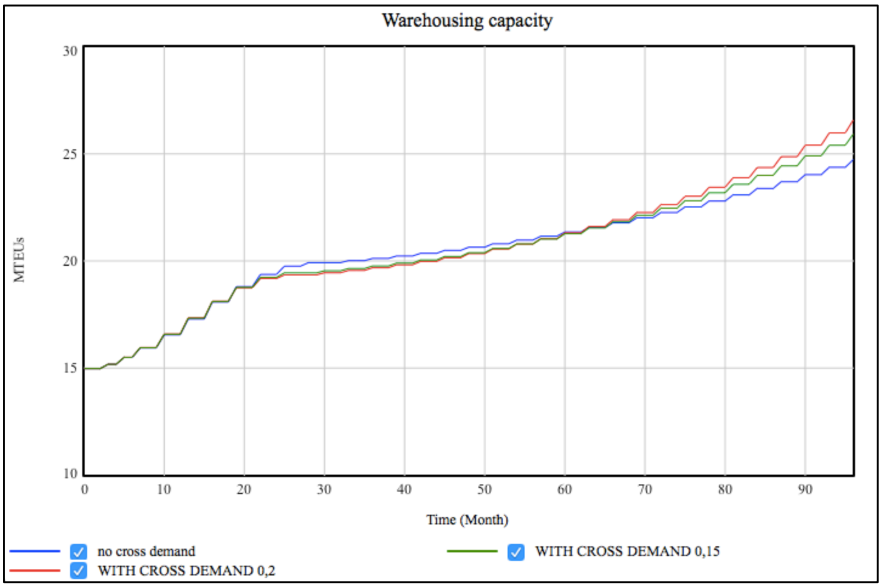
- **no cross demand**: the variable bin 0-1 is set equal to zero, ie there is no subsidy between the demand for the port and that of the airport, and their capacities are independent of each other.

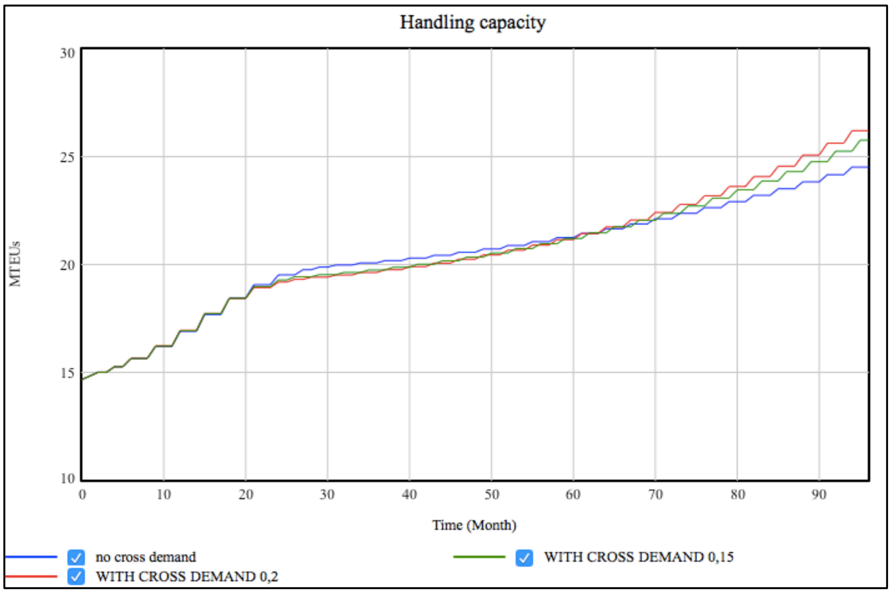
Through the simulation in the different scenarios these are the main results of the Port among them comparable:

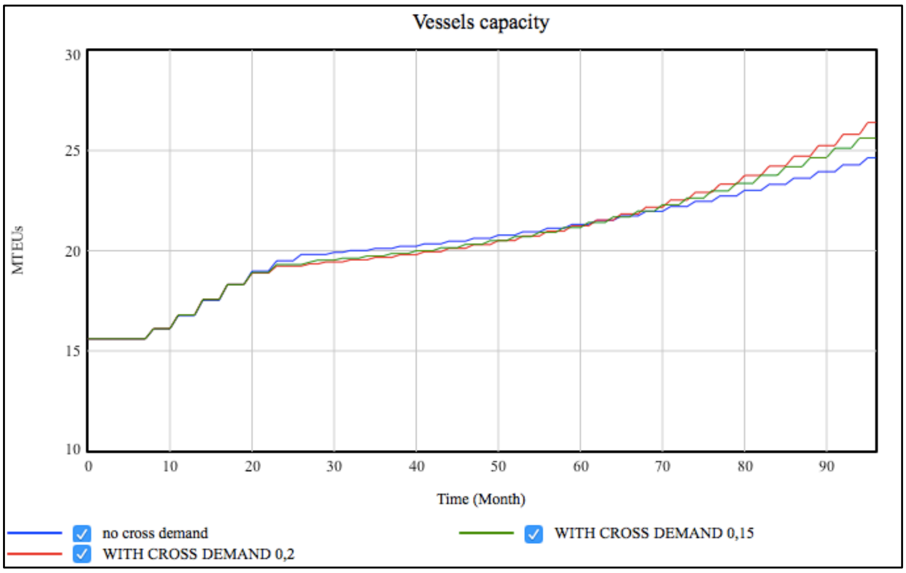
- **Port Available capacity**: We can see how the behavior of the three simulations over a certain period of time (about 20 months) is almost identical, and then from the month 21 to the month 60 something unexpected happens.
  The simulation without cross-effect of the demand generates a capacity slightly greater than the others, rationally it should happen the contrary as to the increase of the desired capacity one would have to invest more.
  The motivation is found in the prudent behavior of the stakeholders modeled by the lookup described above, ie we prefer to invest more when the demand gap is lower. This behavior is one of the assumptions of the model, so it must be taken as such and the reader can be in agreement or not.
  Once the 60-month threshold is over, the expected behavior returns, the simulations with demand crossing generate more demand for available capacity. At the end of the simulated 8-year period, the simulation 0.2 generates 26.2 Mteus, the simulation 0.15 generates 25.3 and finally the simulation without a 24.2Mteus question crossing.
- **Vessels capacity** & **Warehousing capacity** & **Handling capacity**:
  The three capacities that form the Available capacity behave obviously in the same way as the resultant. For all three, the simulation initially did not show appreciable differences, in the following the 'no cross demand' emerges on the others and then finally look at a countertrend where the two simulations WITH CROSS DEMAND end up above the first mentioned. Also in this case it is worth underlining how, once determined which of the three simulations behave more truthfully, it can be used as a policy making tool to evaluate how much and when to invest and above all where to go to act in order to balance the capacity in order to optimize the investments and returns generated by it. It is recalled that a Delay function was used in order to take into consideration the time between the investment expenditure and the actual availability of the related capacity.

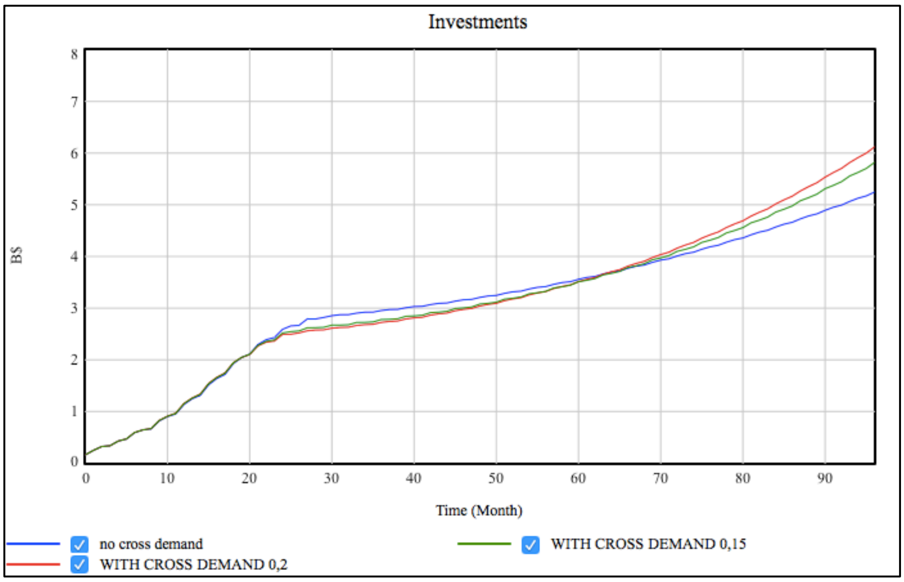
- **Investments**: The figure of investments from an operational point of view is fundamental because it shows the outlay of investments in total to generate the corresponding capacity that includes all three capacities. Remember that once the investments have been generated, the same capacity will not immediately be generated due to the Delay function used.
  It can therefore be noted that the most expensive simulation (because it generates greater capacity) is that of the DEMAND 0.2 which requires an outlay of about 6 billions of dollars to generate a surplus of about 12 MTeus. Next we find the CROSS DEMAND 0.15 and finally the 'no cross demand' which compared to the first one costs 1 Billion less to generate a capacity less than about 2Mteus.


Port Available capacity
MTEUs
30
28
26
24
22
20
18
16
14
12
10
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15


Warehousing capacity
MTEUs
30
25
20
15
10
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15


Handling capacity
MTEUs
30
25
20
15
10
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15





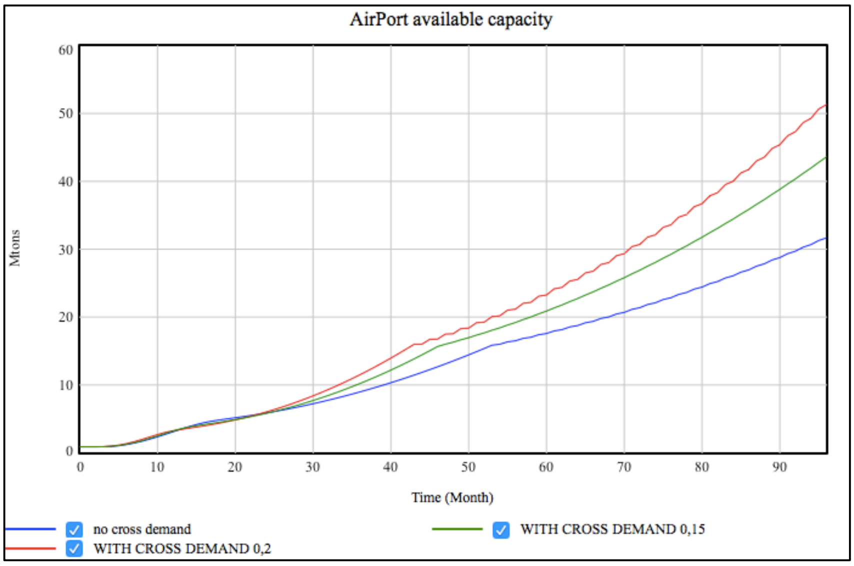
Through the simulation in the different scenarios these are the main results of the Airport among them comparable:

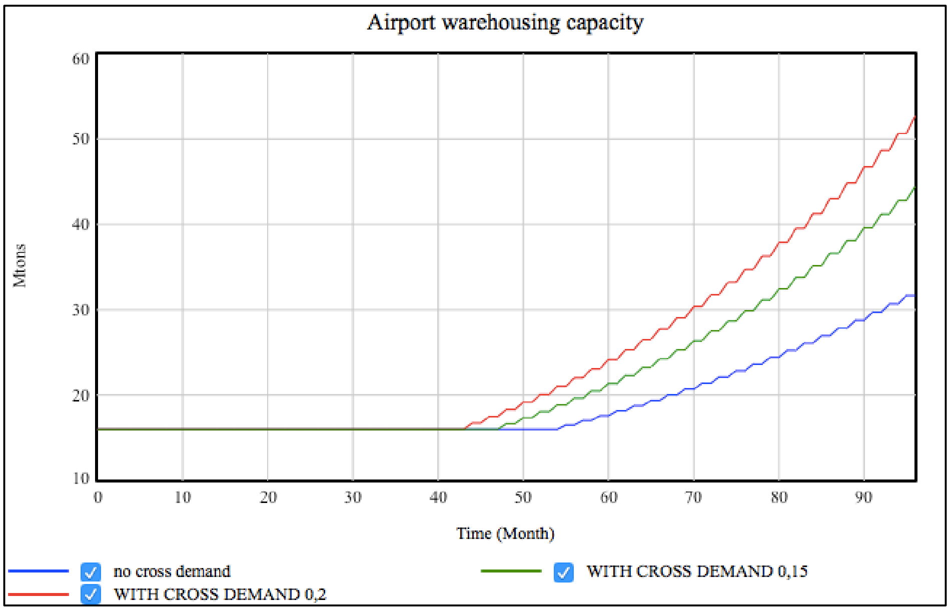
- **Airport Available capacity**: We can see how the behavior of the three simulations over a certain period of time (about 25 months) is almost identical. Once the 25-month threshold is over, the expected behavior returns, the simulations with demand crossing generate more demand for available capacity.
  Also in this case 'WITH CROSS DEMAND 0.2' is the one that in the long run generates more productive capacity. In this case the growth rate is really important, in fact in the intermediate case of part in the month 0 from almost 1 million Tons and then reach 43 million Tons. The important growth is mainly

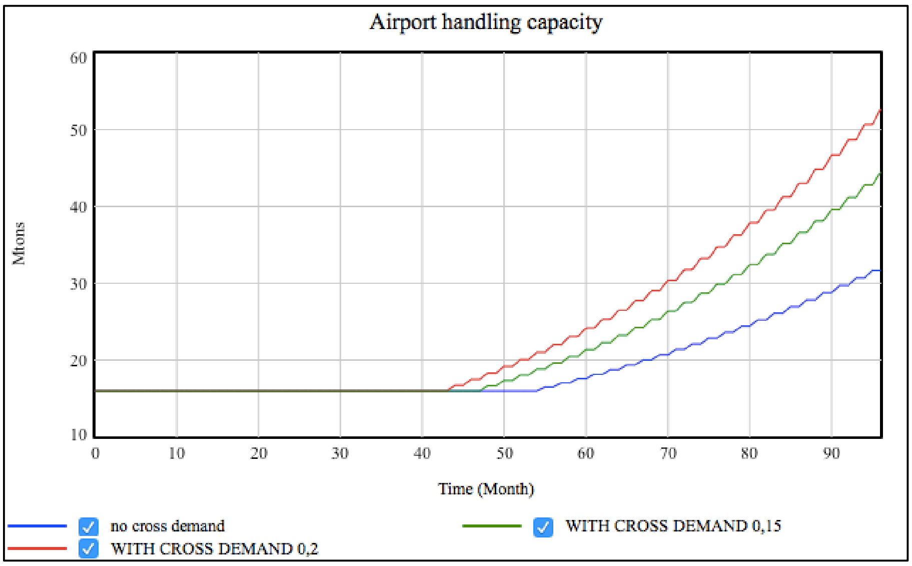
due to the fact that the airport is getting ready to meet an important level of capacity for the project is really ambitious. It is sufficient to think that the totality of Air cargo's capacity that is now at the Dubai International Airport (DXB) will be totally transferred to the Al Maktoum Airport and the first mentioned will become only passenger transport.

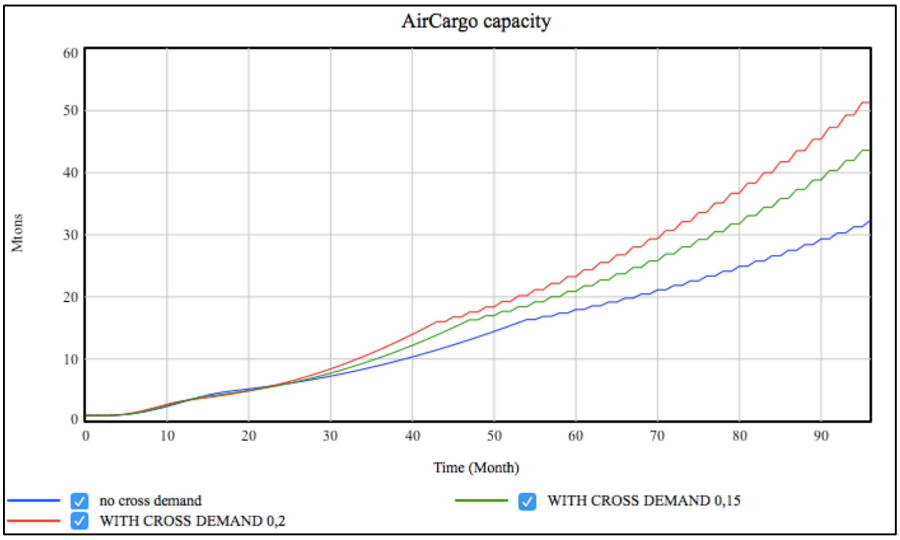
- **Air cargo capacity** & **Warehousing capacity** & **Handling capacity**:
  The three capacities that form the Available capacity behave obviously in the same way as the resultant.
  As already mentioned, Warehousing capacity and Handling capacity start from much higher capacity, therefore they start to increase later.
  Regarding the comparison between the three simulations up to the month WITH CROSS DEMAND 0.2 is the first to grow the two most capable variables as it is the one that exceeds before the 16 MTons already widely discussed.
  Also in this case it is worth underlining how, once determined which of the three simulations behave more truthfully, it can be used as a policy making tool to evaluate how much and when to invest and above all where to go to act in order to balance the capacity in order to optimize the investments and returns generated by it. It is recalled that a Delay function was used in order to take into consideration the time between the investment expenditure and the actual availability of the related capacity.

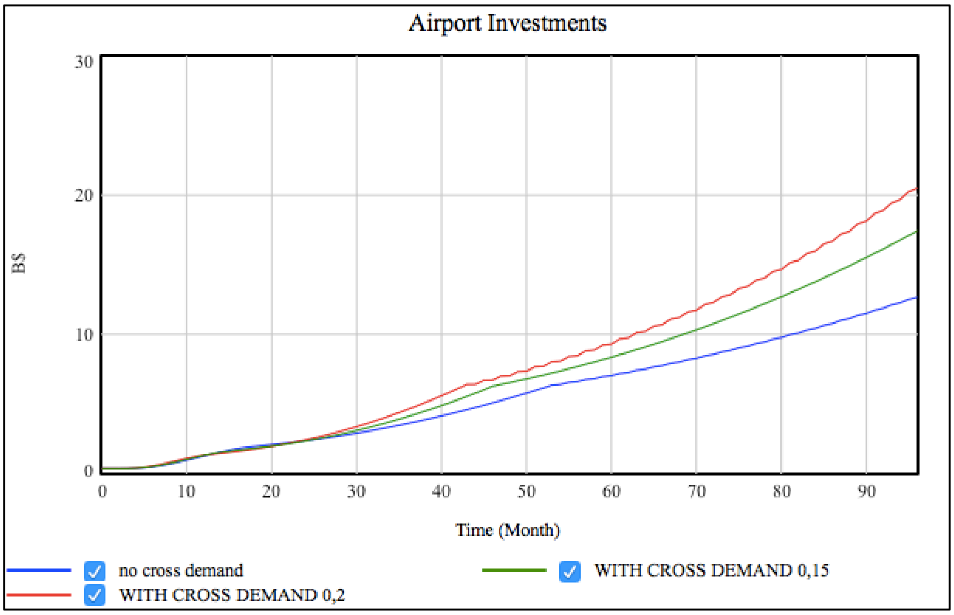
- **Investments**: t can therefore be noted that the most expensive simulation (because it generates greater capacity) is that of the DEMAND 0.2 which requires an outlay of about 20 Billions of dollars to generate a surplus of about 50 MTons.
  CROSS DEMAND 0.15 instead is a slightly cheaper but less performing solution, with an outlay of 17 dollar Billions to generate a capacity of 42 Million Tons.



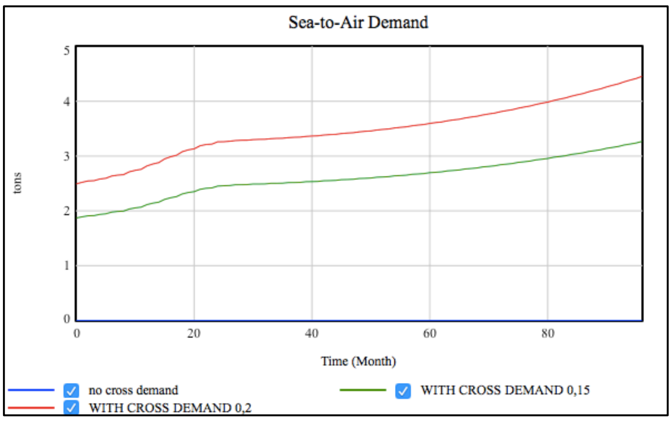

Airport warehousing capacity
Mtons
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15

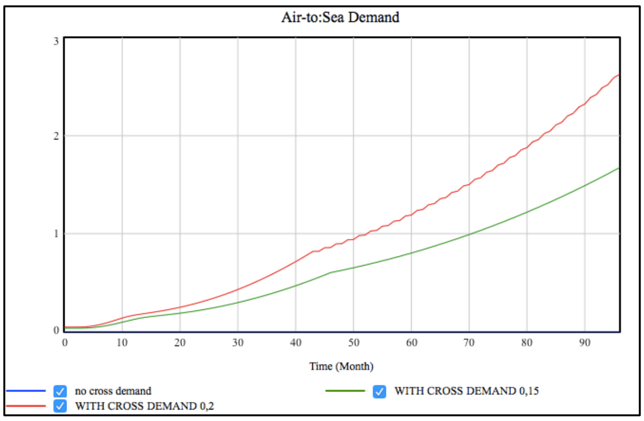

Airport handling capacity
Mtons
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15


AirCargo capacity
Mtons
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Time (Month)
no cross demand
WITH CROSS DEMAND 0,2
WITH CROSS DEMAND 0,15



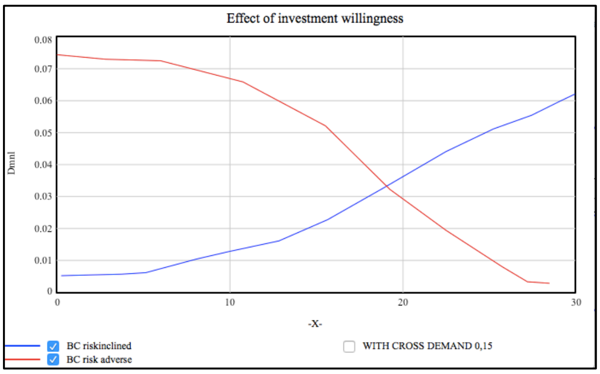
After having seen the main evidences resulting from the results of the simulations of the Port and the Airport taken individually it is right to add some comments regarding the interaction between the two models. It can be noted that the rate of growth of the Available Capacity is much higher than the other, but this should not be misleading as the 2 capacities have different units of measure, so the Tons must be related to the Teus with the right precautions. Furthermore, it should be remembered that initially the cross-effect makes many more benefits at the airport rather than at the port, as the initial capacities of the port are already important while those of the airport in its early stage are small. We can therefore note in the figure the growth of the AIR-TO-SEA demand and SEA-TO-AIR demand capacities, which affect the desired capacity and consequently the uncovered capacity. The demand from the port that has an impact on the Airport is already very high thanks to the already available capacity, and it has cautious growth rates just like the growth in available capacity. The demand that flows into the port, on the other hand, starts practically from zero and then grows in a more vertiginous way.

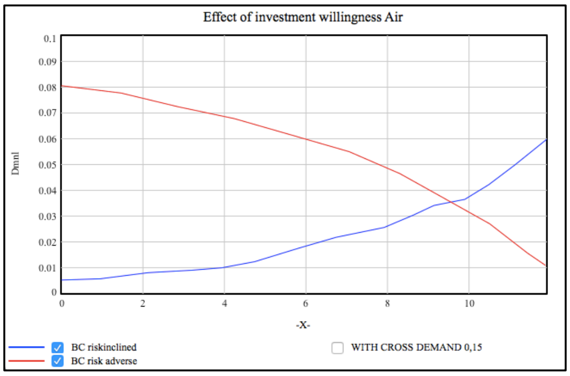




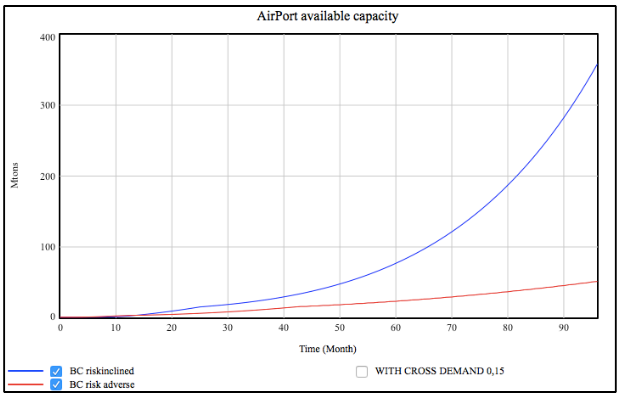
4.7 Case-based comparison between risk adverse and risk inclined

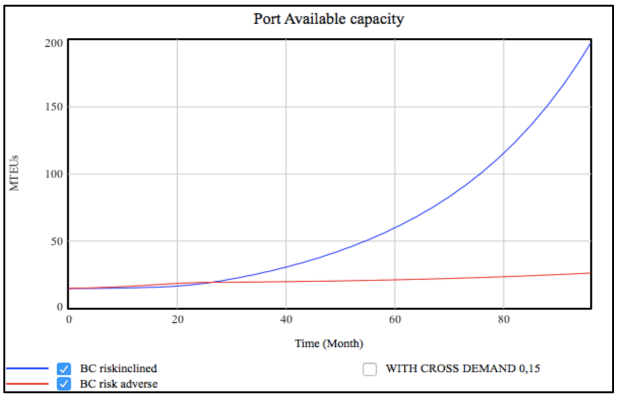
In addition to the simulations already seen, it was thought that it would make sense to go and see what changed if a Lookup function was used in the model, which was inherent in stakeholders with a good propensity to risk. Contrary to that used the comparative function will invest a low percentage for lower and higher Uncovered capacity for increasing uncovered capacity. The figures below show precisely these functions.





We can see how what could have been expected in the images that represent the results of this simulation: The capacities with risk inclined increase exponentially while those already tested remain somewhat acceptable.
In effect, assuming that governing bodies take very risky decisions is very unintended. This suggests that the choice to use a cautionary behavior function for this model was the best choice. In fact, a form of risk inclined can be married to the figure of a private entrepreneur who thinks instinctively and not with stakeholders representing a large part of interested parties.

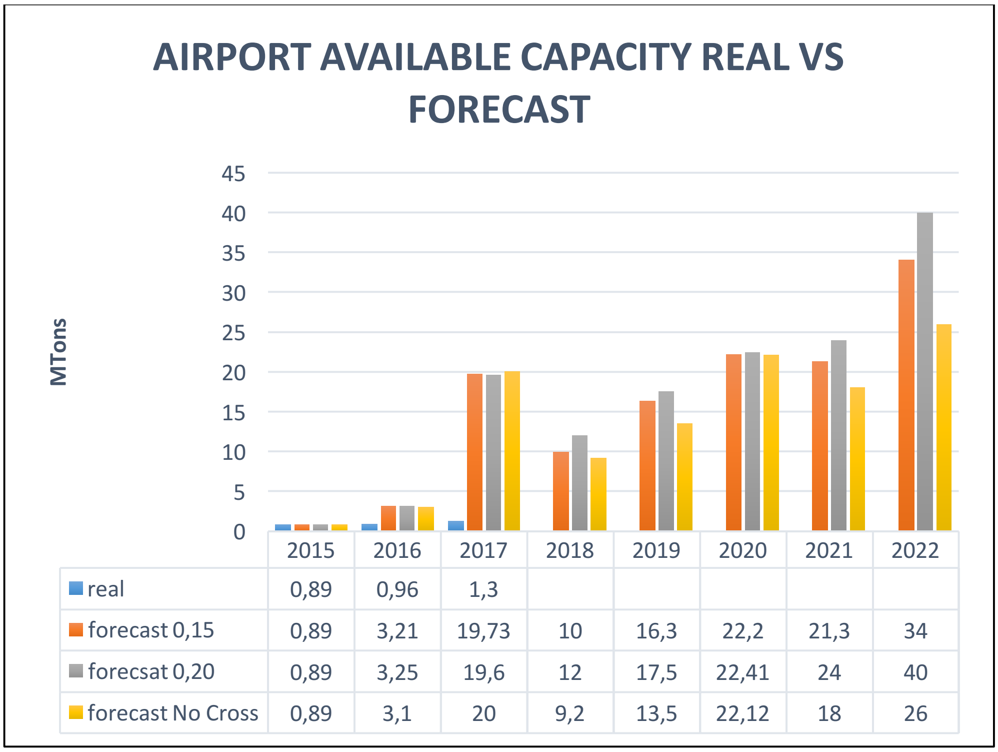




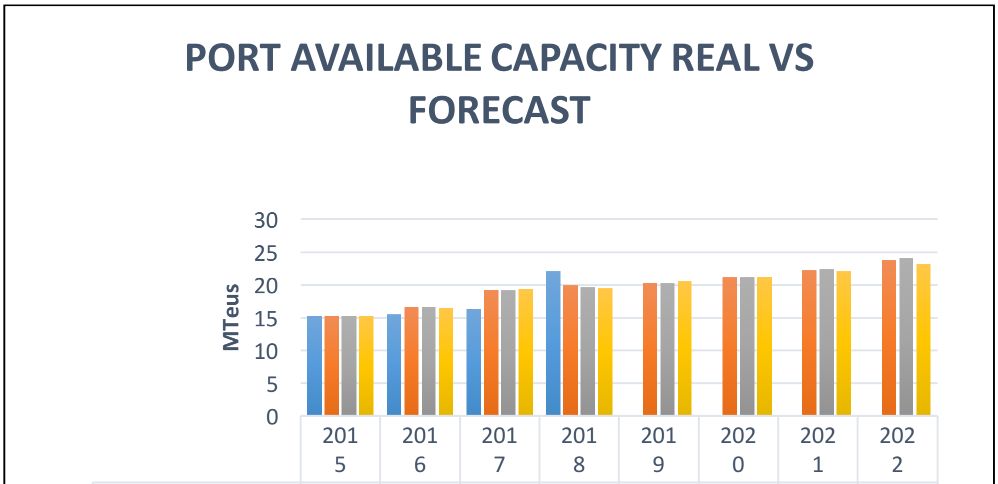
4.8 The Model Validation

The validation phase of the model is crucial to reality. We look forward to seeing the future from the past and coming to the future.
In this case, as mentioned several times, an 8-year time horizon is used starting from 2015. In this way, the years up to now, i.e. the 2015-2017 three-year period available for real data, will be compared with the forecasts made through the simulations.
We will try to understand accordingly if the model is valid in the face of reality.

Below in the graphs we can analyze the results obtained:



	2015	2016	2017	2018	2019	2020	2021	2022
real	0,89	0,96	1,3					
forecast 0,15	0,89	3,21	19,73	10	16,3	22,2	21,3	34
forecsat 0,20	0,89	3,25	19,6	12	17,5	22,41	24	40
forecast No Cross	0,89	3,1	20	9,2	13,5	22,12	18	26



	2015	2016	2017	2018	2019	2020	2021	2022
real	15,24	15,58	16,36	22,1				
forecast 0,15	15,24	16,58	19,23	19,9	20,3	21,15	22,2	23,7
forecsat 0,20	15,24	16,6	19,17	19,6	20,24	21,15	22,41	24
forecast No Cross	15,25	16,55	19,3	19,41	20,56	21,24	22,12	23,2

As far as the Airport model is concerned, the validation seems to be consistent until 2016, after which the forecasts undergo an important increase that seems not to be followed by reality. In defense of the model, however, the Dubai World Central has inferred that by 2020 the resulting capacity will reach 16 MTons. A large share of this increase in capacity is due to the acquisition of all the production capacity of Air Cargo at the DXB airport, which will consequently become purely a passenger transport provider. It follows that it is not the model that seriously misrepresents the forecast but the airport that is lagging behind the Master Plan outlined. For this reason it is difficult to compare the simulations and therefore to assert which of these seems to be more coherent.

Moving instead to the Seaport model graph we can see how all three simulations behave in a way that is coherent with respect to reality.

More precisely, if we compare the data of 2018 that are the most current today, we can see that the most accurate prediction with the minor error is with CROSS DEMAND 0.15. Depending on this it is possible to state with due precaution that it seems to be a synergy between Airport and Seaport, something confirmed by several articles on the Re-Export of the Dubai Trade.

Chapter 5

Conclusions

The chapter in question is the last and consequently the final one of the work.
In this section we find a part of conclusions and implications of policy making that summarizes the results to which we have arrived.
Later we will talk about the limitations of the model, as for the assumptions considered there are some aspects that are probably left out.
Finally, we will talk about the so-called future steps, where we can improve the model and what could be added later to improve its validity.

5.1 Conclusions and implications of policy making

The work was intended to be a support tool for the investments of the Dubai Logistics Corridor, as mentioned in the introductory part is part of a father project, financed by the Government of Dubai, to which the department of the College of technological Innovation of Zayed University is working to release software that supports Policy Making decisions.
Following the end of the work, the student is fully satisfied with the results achieved, as the main research objectives have been focused fairly precisely.
It is emphasized that even though the simulations give an operative answer to the questions posed, the only construction of the model through the system dynamics approach is already the source of a focused goal with which the Add in can be made later to get more specific in the problem.
Through this work it was possible to foresee the future capacity in terms of Teus and Tons of the airport which consequently acts as a good predictive tool to encourage to make operational decisions.
The second objective of the model is to be able to detect the bottlenecks of their respective capacity, so as to be able to act principally on them to optimize the choice of investment and in what timing, as we remember that as output we provide the amount disbursement of investments, the consequent amount of capacity generated and the timing in which it must be used to be available in the right timing.
Finally, the problem was posed on the positive externalities generated by the respective satisfactions of Seaport and Airport, if they are really correlated and generate positive externalities as a super-productive production function. The validity of this statement has been partly satisfied thanks to the comparison with reality, especially as regards the port model. In addition, the response had already been anticipated by the interviews at the airport Maktoum where the stakeholders had definitely confirmed the thesis.

5.2 Limitations of the model

Like any model that can be defined as such, this also presents a series of limitations that must be taken into consideration.
All the assumptions made simplify the work done a lot and without them probably would not have been able to carry on the work at all. However, it must be stressed that as the assumptions grow, the model loses validity, so the model to which it has arrived can be called pseudo-real.

Among the various assumptions, what is right to mention are:

- Assumption of perpetual growth in the time horizon.
- Minimum level of detail of the model
- Capacity utilization as aggregate of Import-Export and Re-Export.

In addition to this, it was noticed that in the model it would be possible to add a relationship on the investments that generate other investments through the proceeds. In the model it was assumed that the investments are made only by disbursements, but the aspect of using the profits for cars to finance the invests has not been considered. This could be one of the Add in of the model.

5.3 Open point and future steps

There are some future steps that could later be added to the work, obviously overtime the amount of data available will grow, therefore some assumptions and approximations made for lack of precise data could be improved. As already mentioned, a self-financing of investments could be subsequently included, with this however should be added variables that take into account costs and revenues to arrive at determining the undistributed profits.
Finally, in the future a railway line currently absent in the Gulf countries will be built, it could be added as a third macro part of the model that would take into account sea, water and rail movements.

Acknowledgments

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I thank my parents for economic support and for moral support, I love you.

Bibliography and sitography

- **Alanood Bin Kalli, Camila Fernandez Nova, Hanieh Mohammadi, Yasmin Sanie-Hay, Yaarub Al Yaarubi:** The Dubai Logistics Cluster (2013)
- The Dubai Government: UAE Imports and Export Guide (2016)
- **Balan Sundarakani**: Transforming Dubai Logistics Corridor into a Global Logistics Hub (2017)
- **Carlucci, Cirà**: modeling a plan for seaport investments through a system dynamics approach (2009)
- **Adriano Miguel Pinhal dos Santos**: Analysis of investment policies for the Port of Lisbon with a System Dynamics model (2012)
- **Alberto De Marco, Carlo Rafele, Anna Corinna Cagliano**: strategie per la complessità della logistica territoriale. Caso-studio: modelli di simulazione per la questione del "porto secco"
- **John D. Sterman**: System Dynamics Modeling, Tools for learning in a Complex World
- **Capt. Osama. F. Elbayoumi and Capt. Ahmed Dawood**: Analysis of the Competition of Ports in the Middle East Container Ports Using HHI (2016)
- **Michael A. Jordan**, S.E., Liftech Consultants Inc: quay crane productivity (2002)
- **J. W. Forrester**: Industrial Dynamics
- **John D. Sterman**: Business Dynamics
- **Castillo, J. I, López-Valpuesta, L. and Aracil, M. J:** Dynamising economic impact studies: the case of the Port of Seville.
- **Briano, E., et al**. A System Dynamics decision cockpit for a container terminal: the case of Voltri terminal Europe (2009)
- **Ruutu:** National sea transport demand and capacity forecasting with system dynamics. Espoo (2008)
- **Sebo:** A System Dynamics approach to intermodalism at the Port of Lewiston (1995)

Sitography

- www.dpworld.ae
- www.dsc.gov.ae
- www.dubaicustoms.gov.ae
- www.gulfnews.com
- www.thenational.ae
- www.dubaiairports.ae
- www.economist.com
- www.dubaisouth.ae
- www.vensim.com