SAPIENZA
UNIVERSITÀ DI ROMA

Faculty of Civil and Industrial Engineering

Master Degree in Transport System Engineering

A.Y. 2016/2017

CONTROLLED TEMPERATURE SHORT SEA SHIPPING AS FEASIBLE AND SUSTAINABLE ALTERNATIVE TO ROAD TRANSPORT

Supervisor:
Stefano Ricci
External supervisor:
Adriana Diaz Alonso

Candidate:
Gabriele Pistilli

For the preparation and elaboration of this thesis, special thanks to:

- Adriana Diaz Alonso, Escola Europea – Intermodal Transport;
- Eduard Rodes, Escola Europea – Intermodal Transport;
- Viviana Zappa, Escola Europea – Intermodal Transport;
- Concha Palacios, Escola Europea – Intermodal Transport;
- Eva Marco, Escola Europea – Intermodal Transport;
- Marta Miquel, Escola Europea – Intermodal Transport;
- Xavier Lluch, Escola Europea – Intermodal Transport;
- Melanie Chhuan, MIT Massachusetts Institute of Technology;
- Carles Rua Costa, Port de Barcelona;
- Guim Compte, Port de Barcelona;
- Nathalie Thomas, Port de Barcelona;
- Juan Carlos Suari Aniorte, Universitat de Barcelona;
- Aida Boix Gregori, Port Authority of Alicante;
- Fernando Santamaria Libano, FRS;
- Jesus Pena Martin, Port Authority of Malaga;
- Santiago Muelas, GAM Grimaldi Agencies Maroc;
- Philippe Guillaumet, Port Authority of Marseille Fos;
- Francois Trouquet, Plateforme Multimodale MP^2;
- Juan Josè Aguilar Pacheco; Port Authority of Algeciras Bay.

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INTRODUCTION

In recent years, the consumer demand of fruits and vegetables has been growing constantly.

The worldwide growth of this particular industry is due primarily to the deregulation and liberalization of the market in many export countries, to the new preference of consumers for fresh, healthy, and natural products, and, most importantly, to the preference of consumers to have products available year-round instead of only seasonally.

All of this is currently possible thanks to the current development of the so-called *cold chain*. The logistics, tracking, packaging, containers and state-of-the-art reservation systems can deliver perishable products in record times while ensuring that they are always perfectly preserved and still able for markets.

Typical products that require this type of supply chain, in addition to fruit and vegetables, are pharmaceuticals, sea-related products, meat, cereals, milk and frozen goods.

These are all goods, which are capable of deteriorating over time or after exposure to adverse temperature, humidity, or other environmental conditions.

Protecting these valuable assets with proven, precise, and strict temperature control can save companies millions of dollars in lost inventory.

For this reason, more than 50% of the producers of perishable goods prefer to contract the process of delivery externally from specific transport companies. This choice can lead to an increase of shelf price of up to 90%.

Due to the growth of this market and the increase of value of these products, in the recent years the world of the reefer transports has seen a considerable growth, both in presence in the market, as well as in development of technology.

In the *cold chain*, the main mode of transport is the maritime one, especially for fruits and vegetables. This is due to their low unit value, which gives the possibility of optimizing between the costs of transport and the services offered.

In fact, for perishable products with higher unit values, like pharmaceuticals, it is usual to use more expensive, but faster, modes of transport, such as airplanes.

In the last few years, temperature controlled maritime transport has become a highly competitive market, primarily after the introduction of reefer containers and with the development of Short Sea Shipping (SSS), in Europe and in the

Mediterranean area, that utilized semitrailers or trucks transported inside of RO-RO and RO-PAX ferries.

Until the arrival of the reefer container, the long haul maritime transport of perishable products was basing on reefer vessels (Figure 1), specifically built for this kind of transport and through shipping companies specialized in this industry, such as *Seatrade* and *NYK Cool*.

Figure 1: Example of Seatrade reefer vessel

Before a contribution by the European Union towards Short Sea Shipping in the Mediterranean and Northern Europe, maritime transport was only considered when strictly necessary; for example, for delivering across the English Channel or the Strait of Gibraltar.

The flow of products along the routes between North Africa and Europe has especially grown exponentially, mainly due to three reasons: the deregulation of the fruit and vegetable market, the increase of SSS services and the development of North African regions.

Spain is the main channel for the import of African products into Europe, contributing to the fact that the routes from the Moroccan Port of Tanger Med (Figure 2) through the Strait of Gibraltar are some of the busiest in the Mediterranean area.

Figure 2: Tanger Med Port, panoramic view

Although the Spanish national authority *Puerto de Estado* predicted the explosion of perishable products traffic with origin in North Africa and urged port authorities to consider and develop alternatives for managing and receiving this increased traffic, in most cases it was not sufficient.

The most striking case was the one regarding the *Puerto Bahia de Algeciras* (Algeciras Bay Port), located in the extreme south of Spain, where the Port Authority was forced to reduce the number of ships that could dock in the port due to an inability to manage and sort the amount of traffic of products coming from North Africa.

Bahia de Algeciras, defined in Spain as *Puerta de Europa*, is the main port in Spain for traffic of fruit and vegetables. Its extreme proximity to North Africa makes it a clear first choice for the transport of all the products that need to cross the *Estrecho* that leads into Europe.

In recent years, being the first choice has become a cause for concerns of harbour and all those associated with the *cold chain* between Africa and Europe.

The opening of the new ferry terminal in the Moroccan harbour in 2010 caused a continually increasing flow of ferries transporting reefer trucks and semitrailers.

Currently, the truck and trailer traffic between the two ports represents 40% of the total amount of exchanges (Figure 3).

On top of this, the traffic values continue to grow, being 11.81% higher in 2016 than in 2015. In 2016, 313,385 trucks passed in Bahia de Algeciras Port and 266,377 of them were RO-RO.

The increase of managerial and infrastructural capacities completed in Tanger Med did not find similar results in the Andalusian harbour.

In fact, it was a unsustainable situation for all the concerned subjects, i.e. the port authority, the carriers and the shipping lines, with trucks that are forced to pay for all the operations inside the port (roll-off, roll-on, PIF, customs, etc.) along 12 consecutive hours.

Figure 3: Strait of Gibraltar, satellite view with Algeciras Bay Port and Tanger Med Port

While waiting for the completion of all of the investments and infrastructure upgrades that were under development, the Bahia de Algeciras Port Authority acknowledged these critical issues.

All the loading and unloading operations for not-coupled semitrailer (the most common modality) moved from the Maritime Station to the less desirable options of quays in Isla Verde and Principe Felipe.

The main consequence of this decision, as carriers denounce, is that there is a deep reduction in the daily rotations (the number of times in one day that a ship finishes a roundtrip) offered to the not-coupled traffic, from 24 to only 4 rotations.
This 83% reduction has led many companies to research an economically and practically feasible alternative to the port of the *Estrecho*.

Some shipping companies that predicted the risks with traffic inside of the *Estrecho* have already opened, or are in the process of opening, new alternative routes for products coming from North Africa. The first one is the German company FRS that was already operating between Tanger Med and Algeciras and successfully opened the route Tanger Med - Motril.

All of these findings lend to the main point of interest of this thesis: from the carrier point of view, what is the most feasible and economically sustainable alternative to the route Tanger Med - Algeciras?

In the next few chapters, we will analyse the different alternatives to reach the main wholesale fruit markets in Spain and France: *Mercamadrid* in Madrid and *Saint Charles Int.* in Perpignan.

We chose Spain and France as destinations because these two countries together represent 45% of the total Moroccan exports.

As alternative ports to Algeciras, we took five Spanish ports and two French ports.

In Spain, we have:

- Motril;
- Malaga;
- Alicante;
- Valencia;
- Barcelona.

In France, we have:

- Sete;
- Marseille.

In order to compare the actual situation with the new possible alternatives, in the analysis we considered the infrastructural features of all the ports with estimated costs (ferry + road route) of each of the different routes, including those passing through the Bahia de Algeciras.

As for maritime cost, we consider the ticket that a shipping line would pay a carrier. The value derives by the ticket costs for routes that already exist, such as the Tanger Med-Sete (operated by GNV), Tanger Med-Barcelona (operated by Grimaldi Lines) and Tanger Med-Motril (operated by FRS).

For road costs, we calculated the sum of all the roadway tolls with all the kilometric costs for shipping from the different ports to Madrid and Perpignan.

Currently, environmental concerns are also very widely considered in the European and national political agendas. Because the intermodal transport, which includes a Short Sea Shipping route, is one of the most promising and feasible alternatives to simply road cargo transport, in this analysis we decided to consider also the analysis of the external costs that the community has to pay.

At the end of all of these considerations, we find the best solution, taking into account that it could involve more than one alternative, a combination of alternatives, not necessarily including the harbour with the best features.

In any case, I want to mention the magnitude of difficulty I encountered while searching data and developing the analysis due to the lack of collaboration by many haulers and shipping companies.

It is thanks to this experience that I now understand how deep the competition and lack of confidence are in the field of transports.

1. TEMPERATURE CONTROLLED TRANSPORT

Temperature controlled maritime transport is one of the main methods used in the *cold chain*.

Even though the specialization of intermodal transport services increased its reliability, many producers and carriers are still hesitant to use this mode of shipment. The possibility of cargo manipulation, even if in a closed container, the time-consuming processes for transhipment, the imperfect interconnectivity and the interoperability between the different subjects involved are all critical elements that have the potential to curb the intermodal growth.

The intermodal transport systems, in the recent years, received funds from the European Union, because they are able to contribute to achieving a sustainable European transport sector thanks to their comparatively low external costs.

As an example, the total external cost of an intermodal train per tonne-km, including the cost of accident, air pollution, greenhouse gases and noise, is only 28% of the external cost of a general freight unit.

Intermodal transport reduces transport cost because the most suitable transport mode covers each part of a trip, thereby increasing national competitiveness through increased economic productivity and efficiency.

During the last few years, the minimum distance for which intermodal transport solutions have been feasible has fallen to 400 km. In any case, the distance where costs break even varies both with the properties of the consignment and the transport services.

For analysing the controlled temperature maritime transport, we divide it into three main elements:

- Precooling;
- Refrigeration methods;
- Vessels and vehicles.

1.1 PRECOOLING

The first thing to consider is the difference between deep frozen products and frozen products.

With deep frozen products, the cooling procedure is rapid in order to avoid the formation of crystals and possible cracks.

With normal frozen products, the procedure is longer.

The choice of the procedure depends on the kind of product and its destination.

The chosen procedure also influences the kind of vehicle to use. Machines able to manage normal frozen products are not usually able to manage also deep frozen products.

The pre-cooling (or pre-warming if the product needs higher temperature) is the phase of chilling the product before storing it inside the reefer vehicle chosen for the transport.

It should occur before the transport and as soon as possible after the production or the harvest, in order to slow the deterioration of the products.

Precooling extends products life by reducing:

- Field heat;
- Rate of respiration (heat generated by the product);
- Rate of ripening;
- Loss of moisture;
- Production of ethylene;
- Spread of decay.

An example that demonstrates the importance of this phase is that fresh products with high respiration rates deteriorate as much in one hour at 26 °C, as in one week at 1 °C.

The four most common precooling methods are:

- Forced air cooling;
- Hydro-cooling;
- Vacuum cooling;
- Slush or package ice.

1.2 REFRIGERATION METHODS

Refrigeration methods maintain during transport the correct temperature for the specific type of product that reduces the metabolic processes normally leading to ripening.

All the systems control and avoid the heat load sources (internal, external and residual) that could accelerate the ripening of the products.

The total cooling capacity of the refrigeration systems is the sum of the three heat loads multiplied by a safety factor, measured in cubic capacity instead in tonnage value of heat.

Similar to the precooling systems, it is possible to work in the opposite way for heating.

During cold weather conditions, heating of transport vehicles is necessary to avoid chilling or freezing of fresh products.

With a properly cooled load, most of the heat that causes products warming is passing through the insulated walls and floor. This is particularly important for trailers with low insulation levels, for loads shipped under extreme hot or cold weather conditions, for products that are extremely perishable, and for trips that last for more than a day.

Four levels of temperature are commonly inside vehicles:

- Frozen: -15 °C;
- Cold chill: 0÷1 °C;
- Medium chill: 5 °C;
- Exotic chill: 10÷15 °C.

The methods split in two big groups:

- Controlled Atmosphere (CA) systems: the gases, liquids and products used to maintain the atmosphere are continuously recharged inside the vehicle during the transport;
- Modified Atmosphere (MA) systems: the concentration inside the vehicle is fixed before the departure and not adjustable during the transport.

The most common refrigeration systems are:

- Mechanical refrigeration;
- Ice cooling;
- Cryogenic cooling (dry ice);
- Wet ice;
- Gel refrigeration;

- Ventilation.

1.2.1 CONTROLLED ATMOSPHERE (CA)

Controlled Atmosphere systems (called also Inert Atmosphere systems) force the live products to go into a state similar to hibernation, by bringing down the temperature and removing oxygen using inert gas generators.

Atmospheric components such as O_2 and CO_2 create an environment that restricts the respiration process of fresh produce, helps to impede fungal growth, slows ethylene production, inhibits pathogen reproduction, and kills insects.

Nowadays, the control is meticulous and every deviation from normal air composition is checked: 21% of oxygen, 78% of nitrogen and 300 ppm of carbon dioxide.

The most commonly adjusted gas is nitrogen (N_2) and the resulting air mixture, pumped into the cargo holds, purges the existing mass of air.

The principal technologies employed for transportable CA systems include:

- Membrane type N_2 generators;
- Pressure Swing Adsorption (PSA) type generators;
- Stored gas (usually for air transport).

In Membrane Technology, compressed air enters in one end of a permeable membrane composed of many hollows fibres. The N_2 travels the length of the fibres and exits at the other end of the membrane. The O_2 in the air passes through the sidewall of the fibres and exits the other side of the membrane (Figure 4).

Prior to these processes, specific processes remove contaminants, moisture, etc.

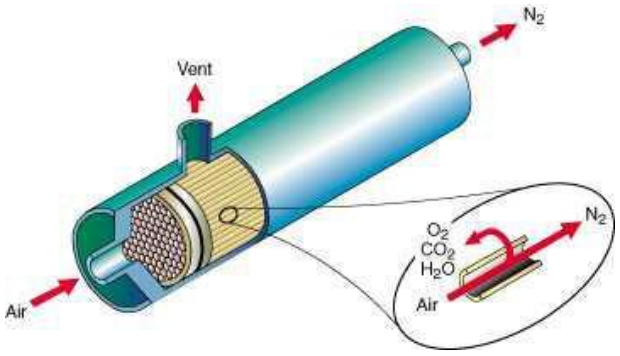

Figure 4: Membrane type N2 generator

In PSA Technology, compressed air enters one end of two absorber tubes filled with Carbon Molecular Sieve (CMS). While the absorption of smaller oxygen happens by means of the CMS, the larger nitrogen molecules pass through and are stored.

Upon saturation, the first absorber releases the oxygen, while the second absorber starts the process over again.
The absorption process lasts about one minute in one adsorption tower and immediately after the process, control passes over to the second tower after regenerating the first one (Figure 5).

With this system, Controlled Atmosphere requirements are very precise.

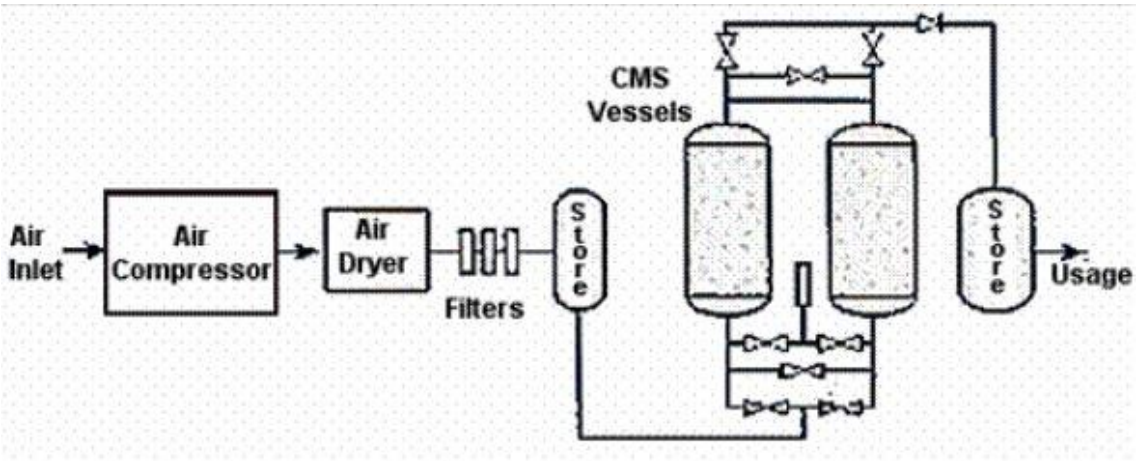

Figure 5: PSA (PRESSURE SWING ADSORPTION) type generators

One of the biggest problems of CA systems is the high danger of the holds where products are, due to the low oxygen content of the atmosphere.

It is mandatory to avoid entering a CA cargo hold, if the oxygen level is not at least 20% and if the fresh air ventilation is not working at maximum speed.

The main risk is asphyxia, a condition of severe deficiency of oxygen for the body that can lead to a hindrance of normal breathing, cause hypoxia and, in extreme cases, death.

ASPHYXIA SYMPTOMS	
21% oxygen	Breathing normal, all functions normal
17% oxygen	Candle is extinguished
12÷16% oxygen	Breathing and pulse rate accelerated. Ability to maintain attention and to think clearly diminished, but can be restored with effort. Muscular co-ordination for finer skilled movement is somewhat disturbed.
10÷14% oxygen	Consciousness continues, but judgement becomes faulty. Severe injuries (burns, bruises, broken bones may cause no pain. Muscular efforts lead to rapid fatigue, may permanently injure the heart, and induce fainting.
6÷10% oxygen	Nausea and vomiting may occur. Legs give away; person cannot walk, stand or even crawl. This is often the first and only warning and it comes too late. The person may realise he is dying, but he does not greatly care. It is painless.

Less than 6% oxygen	Loss of consciousness in 30÷45 seconds if resting, and sooner if active. Breathing in gasps, followed by convulsive movements, and then breathing stops.

Table 1: Asphyxia symptoms, Kohli P., Refrigerated Ships

Inside every cargo hold, there should be at least one temperature-recording device for continuously monitoring the state of the environment inside and around the products.

These devices give the possibility to carrier, shipper, and producer to be sure that the cargo is always at the right conditions.

The type of technology and device selected should be basing on a User Requirement Specification (URS) and the main features to consider should be accuracy, stability, reliability, affordability and ability.

Interpretation of data needs to account that the temperature recorders are influenced by the heat generation by the products themselves.

The recorders should never be in direct contact with the walls or roof of the hold because the temperature they record may be affecting heat transmitted through these surfaces.

The best-recommended placement is on top of the load, near a sidewall, one third of the way in front the rear doors, away from any direct discharge of refrigerated air, and between the packages in the area where the warmest temperature occurs.

The necessity of deep care in setting the correct composition of the atmosphere and temperature inside the cargo is perfectly reasonable considering that around 40% of the vegetables delivered around the world never reach the supermarket shelves due to damages incurred during transport.

There are many elements to keep in mind while setting the systems.

High percentage of CO_2 in the atmosphere may cause loss of flavours, off colours, and physiological disorders.

High temperatures may cause loss of vitamin C and sucrose may increase respiration rate and water loss causing loss in internal quality, shrivelling, and premature softening.

High level of N_2 in the environment may cause risk of suffocation.

Most products need transport and storage at high relative humidity (the percentage of water vapour in the air in relation to the saturation point of the air at a given temperature) because moisture-loss results in wilting and shrivelling, but at the same time, a high humidity level may cause presence of water that may damage fibreboard packages.

Many products need transport or storage at temperatures only 1÷3 °C above their freezing point. Thermostats, however, are usually set 1÷3 °C higher than the recommended temperature to avoid freezing.

Bruised, decaying, or overripe products can ruin an entire shipment due to an incomplete cleaning of the microbiological presence of the previous loads of food.

Although improved refrigeration technology has made somewhat less critical the time factor, perishable goods continue to be particularly sensitive with regard to on-time reliability.
For example, a delay in transit of 48 hours may cause a reduction of fresh fish prices by 20÷25%.

Reducing the losses in post-harvest fruit and vegetable operations is a worldwide goal.

1.3 VESSELS AND VEHICLES

Vessels and road vehicles have always been the main systems for the transport of perishable products. The first one has a very low unit cost of transport, while the latter aims to provide high flexibility to make possible to reach every possible place in the time allotted by the costumer.

Very often, these vessels and vehicles are specific for this purpose and not usable for other transports in order to be able to receive perishable products.

The possibility of modifying a pre-existing vehicle or vessel to make them able to transport perishable products depends on the law of each country.

In order to be a reefer, specialized equipment on board is necessary, such as:

- Cargo Cooling System: usually a bank of compressors used with cool refrigerant gas (Freon is most common). This cold Freon in turn cools the secondary refrigerant, which is usually brine. The brine is circulating to all cargo spaces and through cooling (evaporating coils) fitted under powerful fans. The subsequent air flow cools the cargo;
- Defrosting System: a powerful heating apparatus to remove the eventual ice;
- Control system;
- Monitoring equipment: for safe monitoring of equipment and cargo, manual or computerized;
- Effective ventilation control system: needed to maintain high level of humidity;

- Inert gases generators: needed to apply cooling and atmosphere control to the cargo.

During the transport, regardless of which system is used, the storage of the products can be:

- Loose;
- Unitized.

Loose shipments, which were more common in the past, nowadays disregarded in favour of unitized shipments, which means stocking the cargo piece-by-piece or in boxes, usually fibreboard boxes.

A minimum of 1896 kPa bursting test strength fibreboard is for boxes intended for export. This strength is to account for handling, transport conditions, and the high humidity that the boxes must endure.

In general, the packaging materials are basing on the needs of the product, packaging method, precooling method, strength, cost, and freight rates.

Unitized shipments mean that products are *unit loads*, which are usually pallets (Figure 6) or slip sheets, during transport.

Nowadays, this system is more common because it requires less work and product handling during the different phases. Regardless, specific procedures and equipment (mainly the forklift) for the loading and discharging are still in operation to save and protect the load.

Pallets are flat intermodal transport structures that support goods in a stable fashion while being moved during the loading and discharging operations.

They are usually in wood or plastic.

The wood version, the most common, must be strong enough to allow storage under load in three tier racks.

The two major types of pallets are:

- *Europallet* (800 x 1,200 mm);
- Standard pallet (1000 x 1,200 mm).

A 40-foot container can hold 23÷24 *Europallet* or 20÷21 standard pallets in one tier.

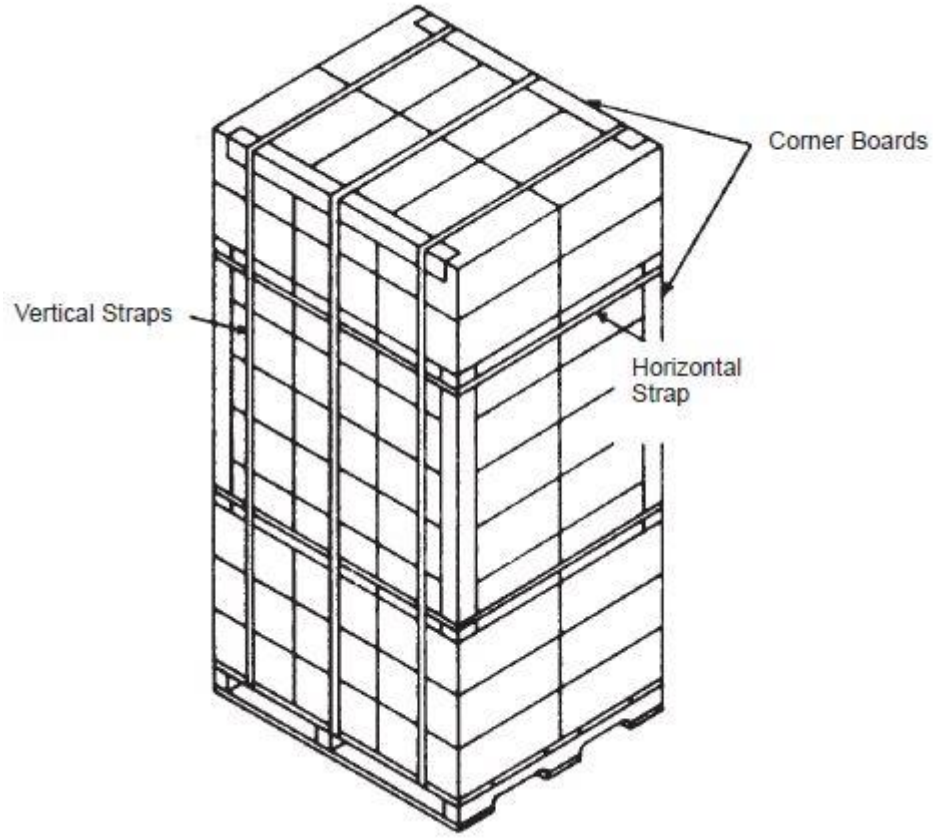

Figure 6: Pallet with strapping and corner boards

Slip-sheets are thin pallet-sized sheets used for intermodal transport.
They are usually made of plastic, heavy laminated craft paperboard, or corrugated fibreboard. When used in wet conditions, they should be wax impregnated.

Slip sheets used in transportation equipment should have holes for air circulation under the load.

Both with pallets and with slip-sheet, the unit load is usually stretch wrapped or shrink wrapped for stability.

In the case of perishable transport, the unit load has also an insulating cover that causes a stagnant air layer around the products and within the cover reducing air infiltration and conductive heat transfer.

1.3.1 VESSELS

The historical way to transport foodstuffs by sea is with reefer, or refrigerator, vessels.

These kinds of ships came into existence in the second half of 1800s with the improvement of production techniques when many countries started to produce big

quantities of food not for local consumption. Thus, the export of this to wherever required became convenient and necessary.

Conventional reefer vessels carry palletized cargo and individual cargo stowed loose in the cargo holds.

Cargo handling and stowing is easy with efficient gear and a minimum number of stanchions in the holds.

A number of vessels have side doors (Figure 7) and on board cranes equipped for fast, careful, and economical handling of the cargo on board the ships.
Loading and discharging via the ships' side doors, cranes, and elevators enables vessels to operate irrespective of the tidal variation. In bad weather conditions and with lacks in the port infrastructures, such as in some areas of Africa where there is a big production of exotic fruits, but a deep deficiency of technical transport instruments. The use of side doors also allows the ship to keep temperature losses out of open hatch covers at a minimum.

Figure 7: Seatrade reefer vessel with side doors open

Reefer vessels are for speed, not for comfort.

Their main aim is to reach its destination as soon as possible so that refrigerated cargo can reach the intended destination without any loss or decay.

They are one of the least comfortable vessels, but move easily to even slight and swell seas.

One of the biggest problems presented by reefer vessels is the environmental concern.

Many reefer vessels rely on Freon as the primary cooling agent, but if not well handled this agent could be harmful to the natural environment and represent a hazard to those working on-board.

Furthermore, these vessels also rely on brine as a second refrigerant that is very corrosive and highly dangerous for the sea environment if not correctly treated before released into the water after each operation.

In the last few decades, the introduction of an innovative way to transport perishable products has put the dominion of reefer vessels in danger: from the introduction of reefer container (Figure 8), a gradual but steady shift has occurred.

It is possible to observe a constant shift of the temperature controlled oceanic transport from "reefer vessels" to "reefer containers", that means to container vessels.

In 2000, the percentage of perishable products carried by reefer vessels was 60%, in 2016 it was 26%.

The main advantages and disadvantages that have decreed the success of container reefer in this challenge are:

Advantages:

- Lower cost;
- Container and cargo could be directly delivered as one unit to receiver's warehouse without any necessity of intermediate storage and handling in a port of discharge;
- Container allows an easier accessibility to the logistic network as whole;
- With containers the problem of the warehouses space inside ports is becoming less important;
- In case of breakdown or malfunction of the container', only a limited quantity of cargo (20 pallets) will be affected.

Disadvantages:

- Transit time needed to have containers shipped that could be considerably longer compared to the transit time needed when carrying the fruit on board of reefer vessels;
- One of the most frequent delay problems with containerized transport of fruits is the situation where a container misses its connection with other vessel at a certain transport point.

The main reason of success for reefer container is the second point of the advantages.

Figure 8: Reefer container

After been treated, reefer containers are sealing hermetically at the requested transport temperature and none can open the container until destination.

This implies that the *cold chain* remains constant until when the recipient does not open the container.

With reefer vessels, this is not possible because at least four handlings are necessary for products and the cold chain is broken at least three times.

Less load manipulations and *cold chain* not interrupted mean lower risks of damages, less temperature variations and a better result during loading and discharging operations.

In a context where reefer maritime transport is increasing with a rhythm of 4÷5%, all the main container shipping companies are getting ready their fleets for catching on percentages in refrigerated market.

Today the number of reefer containers is around 2.8 million of TEU and is increasing.

The 24% of these are by the Danish shipping company Maersk that controls most of the market.

The 74% of the offer in refrigerated cargo market is container traffic and only the 16% is traditional reefer fleet.

The operator in traditional reefer vessels Seatrade noticed a steady decrease in its market share that, in the last five years, corresponds to a 12% less.

Currently, reefer vessel fleet includes 624 units with an estimated capacity of 5.75 million of cubic meters.

The analysis point out that, since the beginning of the 21st century, scrapped vessels have not been replaced with new orders of same kind vessels.

Consequently, with the actual trend, statistics declare that until 2025 the fleet will be smaller by 41%, with 340 vessels and a total capacity of 3.39 million of cubic meters.

Another element we have to keep in mind is that from now to 2025 one third of the vessels now operating will be over 30 years old, which is the usual age to retire a ship from the service.

Conversely, the number of reefer containers was increasing of 6.5% between 2015 and 2016 reaching the value of 2.7 million TEU (the 7.6% of the total amount in world).

In the same period, in the global container vessel fleet, the reefer sockets reached 2 million units, with an increase of 7.5% compared the previous year.

Therefore, as already said before, considering a growth in values of refrigerated transport market, the main container shipping companies are going to get the main advantage in this situation.

The classic reefer vessel operators are moving in two different ways for surviving.

For example, the already mentioned *Seatrade*, the leader in the classic operation, with a market share of 14.7% and 57 reefer vessels, has recently started to order new container reefer vessels and to revamp its old vessels.

The revamping usually consists in the realization on the exposed upper deck of a series of cell guides, reefer sockets (typically 440 VAC), and inspection walkways that enable the vessel to carry also reefer containers.

In this way, both old vessels and new vessels will get the possibility to handle also reefer containers.

For *Seatrade*, the transformation in a container shipping company is going to begin next year with the receiving of its first 4 of 6 new container vessels.
With a capacity of 2250 TEU and around 670÷770, electric sockets these maritime units will be able to be completely loaded with 40 foot High Cube containers.

On the opposite, there are realities that still want to bet the traditional reefer transport.

The main example is *Star Reefer*, that just decided to order four new reefer conventional vessels, the first delivered in next year.

1.3.2 VEHICLES

The road transport of perishable products by trucks are in two ways:

- With reefer isothermic containers;
- With reefer isothermic trailers (Figure 9).

Both the ways, as explained before, are to maintain the chosen cargo temperature and not to reduce it.
The food temperature should be already at or below the desire carrying temperature at the time of loading.

Figure 9: Reefer trailer

There are three kinds of isothermic vehicles:

- Refrigerated;
- Fridge;
- Heater.

The insulating quality of vehicles is basing on the industry standard *U* Factor that is the coefficient of heat transferred.

This coefficient describes the rate of transferring of heat [W] through one square metre of a structure divided by the difference in temperature across the structure.

It is in ($W/m^2{}^\circ K$). This means that higher is the *U* Factor, worse is the thermal performance of the system. Low *U* Factor value usually means high level of insulation.

The thermal conductivity *K* Value is another insulating quality measurement system commonly used and indicates the ability of a material to conduct heat.
Lower is the *K* Value, better the material is for insulation.

U Factor is equal to the *K* Value divided for the thickness (*L*) of the layer.

$$U = \frac{K}{L}$$

The ability of an engine unit to keep a trailer to a wanted temperature is by a system developed by the Refrigerated Transportation Foundation (RTF).

Placards located on the outside front and inside rear of the unit are describing the rating. The trailer/container should have one of the following ratings:

- Deep Frozen (*DF*): less than 0 °F (-18 °C);
- Frozen (*F*): 0 to 32 °F (-18 to 0 °C);
- C35 Chilled: greater than 35 °F (2 °C);
- C65 Chilled: greater than 65 °F (18 °C).

All ratings are acceptable for perishable fruits, vegetables and horticultural commodities, excepting rating C65.

Differently from containers that are all intermodal, not all trailers can shift from a system of transport to another one.

When they are intermodal, their specific features are:

- For railway transport: upper coupler designed for piggyback loading/unloading or railroad hitches.
- For maritime transport: attachment to hitches for hold transport inside roll-on/roll-off barges and vessels.

There are three main kinds of refrigerated trailers and containers:

- 12 m (40 ft):
  - Max cargo weight 22,680 kg,
  - Internal measure 12x2.26x2.49 m,
  - Useable volume 62 m^3;
- 13.7 m (45 ft):
  - Max cargo weight 22,680 kg,
  - Internal measure 13.8x2.19x2.36 m,
  - Useable volume 66 m^3;
- 16.6 m (48 ft):
  - Max cargo weight 22,680 kg,
  - Internal measure 14.26x2.45x2.50 m,
  - Useable volume 80 m^3.

Before every loading and discharging operations, a series of operating inspections are necessary:

- Refrigeration unit and vehicle should have a RTF rating adequate for the load;
- Any necessary repairs should be completed;
- Trailer should be carried near the transport selected temperature;
- Refrigeration unit should be turned off before opening doors;
- Unit should look and smell clean, should be dry and in good repair before loading;
- Unit should be free of toxic materials that could be source of microbial contamination;

- Unit operators should track past shipments to verify if the unit is acceptable for food transport.

1.3.2.1 AIR CIRCULATION SYSTEM

Air circulation plays a critical role in maintaining produce temperature during transport of fruits and vegetables.

Conditioned air needs to circulate uniformly through, around, above and below the load in order to absorb internal and external heat loads.

For this scope, in order to allow a rapid heat removal and uniform air distribution, there are two types of air circulation systems:

- Top air delivery system;
- Bottom air delivery system.

Both of them are composed with fundamental components that enhance and improve control of load temperature during transport:

- Evaporator
- Air delivery ducts;
- Vertical channel or ribs;
- High airflow floors;
- Ribbed sidewalls or spacers;
- Return bulkhead.

The air delivery duct helps to distribute air from the outlet of the refrigeration unit to the rear and sides of the load. It is usually made of canvas or vinyl and is connecting to the blower discharger through an adapter.

To prevent damage, the duct needs to hangs no more than 0.185 m below the ceiling and the middle of the rear opening has to prevent caught in the pallets.

Prevention of blockage of the air ducts is by painting a line on the sidewalls below the level of the air duct indicating the maximum allowable loading height.

The space between the load and the floor of the trailer/container acts as a path for going or return air to the evaporator. If there is insufficient amount of space between the floor and the load, airflow will throttle and the fan will rotate without discharging any conditioned air to the load.

The most common types of floor are flat floors (without any channels), duct board floor, duct T-floor and T-beam floor.

Return air bulkhead is a false wall that provides a clean pathway for air to return to the evaporator. It serves to isolate the load from the front wall and to force air to go around and under the load without short-circuiting. The bulkhead can cover the full width and half the height of the front wall. Frame and solid/pressure bulkheads are commonly used.

Solid or pressure bulkhead generates a pressure difference across the outlet and inlet of the fan. This causes air to circulate through, around and underneath the load before returning to the refrigeration unit.

- TOP AIR DELIVERY SYSTEM (Figure 10)

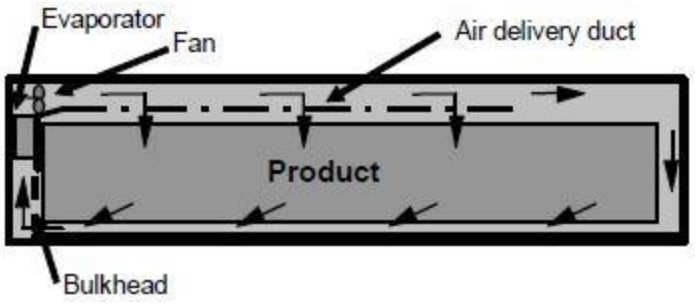

Figure 10: General aspect of a top air delivery system

It is the most widely used method of air circulation in refrigerated semitrailers.

This system delivers high velocity, low-pressure airflow longitudinally inside the trailer. Air travels above the load from the front to the rear of the trailer. Along the way, some of the air flows down between the sidewalls and the load. As the air reaches the rear end of the trailer, it flows downward between the rear door and the load. Air then moves underneath the load from the rear to the front along the floor, when it reaches the front wall, the air moves upward behind the load and returns to the evaporator.

- BOTTOM AIR DELIVERY SYSTEM (Figure 11)

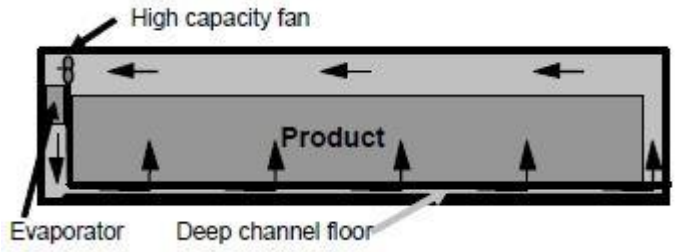

Figure 11: General aspect of a bottom air delivery system

Extensively used in intermodal containers, it has a limited use in refrigerated semitrailers.

Containers with this type of delivery system are generally equipped with horizontal T-beam floor, vertically ribbed rear doors and vertically ribbed sidewalls. Air movement in bottom air delivery system is mostly vertical. It requires area entirely covered by the load. The refrigeration system forces conditioned air underneath the T-beam floor of the container. The pressurized air flows from the front to rear of the container and forces upward through the load and the ribbed sidewalls.

When air reaches the ceiling of the container, it flows toward the front wall and returns to evaporator of the refrigeration unit.

Although this system provides an efficient method for circulating air, it has some disadvantages, which limit its use in refrigerated semitrailers.

Forklifts can easily damage ribbed sidewalls and deep T-beam floors during loading and unloading. Air circulation can easily got short-circuited when the trailer floor is not fully covered. In addition, the extra weight of accessories reduces the amount of produce that can be loaded in the trailer since highways have gross vehicle weight limits. Consequently, bottom-air delivery systems are in intermodal containers for long distance transport where cycles times are not frequent and weight restriction does not exist.

1.3.2.2 STORAGE INSIDE VEHICLES

The storage methods must allow a satisfactory volume of airflow with a reasonable pressure difference across the stacks, avoiding every possible short-circuiting that can cause inadequate provision of air circulation with the risk of ruining the load in some areas.

Storage of boxes inside trailer/container is along the three dimensions and the technical terminology is (Figure 12):

- ROW: chain of boxes over all trailer/container length;
- LAYER: boxes are disposed all over the floor for the length and width of the transport unit;
- STACK: boxes are disposed like a wall from one side to other of the container/trailer and from floor to ceiling.

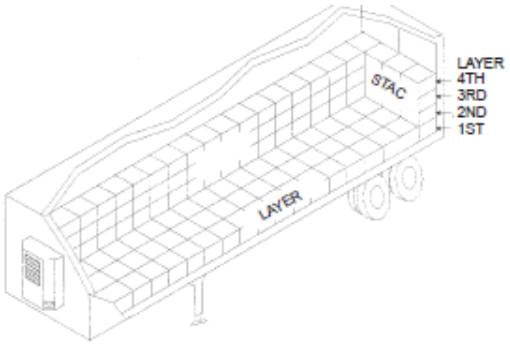

Figure 12: Arrangement of boxes inside trailer

Loading systems are firstly by the load's way of transport:

- Bulk Loading, by machine or hand, of unpackaged commodities;
- Hand loading of individual shipping containers, with or without pallets;
- Unit loading of palletized or slip-sheet loads of containers with pallet jacks or forklifts.

Trailers and container with two or three separate compartments are for carrying different kind of loads.

Compartments inside the transport unit uses stable or removable specific walls contaminant-proof. The conditions provided by the units with three compartments may include -18 °C, 0 °C, +10 °C or an ambient for products not requiring refrigeration.

The mixing of products inside the same compartment is not feasible.

When there is the possibility, the products in the same compartment should match according to their sensitivity to chilling, freezing, moisture lost, ethylene and odours.

The loading of fruits, vegetables or other food products with non-food cargoes that could provide any risk of contamination through transfer of odours or toxic chemical residues are also never feasible.

It is to load firstly the heaviest containers, evenly distributed across the floor of the trailer or container. In order to facilitate inspection of mixed loads at ports of entry, it is to let available near the door a representative sample of each commodity loaded, in this way will be possible to minimize the unloading of cargo for examination.

1.3.2.3 PALLET LOADING PATTERN

The loading pattern is a fundamental topic because it is concerning many different elements inside trailers and containers.

Some examples:

- The loading pattern affects air circulation, the amount of contacts between the load and the inner walls, the stability of the load, and the consequent removal of all heat loads on the trailer;
- The availability and direction of air channels is dependent on the loading pattern, which affect the airflow pattern around and across the load;
- The stability of a load is affected by how well pallets are interlocked with each other;
- The loading pattern influences the number of pallets in a given part of trailer.

The main loading patterns used by the industry are:

- Sidewall;
- Offset;
- Pinwheel;
- Centreline.

Sidewall loading (Figure 13) means loading the pallets straightway with their width facing the rear creating an empty space between the two rows of pallets. This longitudinal channel allows air to circulate freely between the rows of pallets. However, if a bracing system is not in the middle, the pallet may collapse and block this air channel.

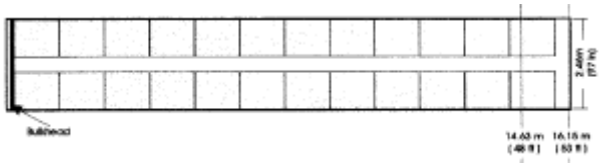

Figure 13: General aspect of a sidewall loading

In the *Offset loading* (Figure 14), all pallets are loaded *straight* with their width facing the rear doors. They are in pairs touching each other. The first pair is loaded against the one side of the trailer wall and the second pair is loaded against the opposite side of the wall. The rest of the load is arranged in this staggered or zig zag stile. This loading pattern increases the stability of the load and do not need any sideward bracing. This loading pattern also provides a better air circulation around the load by creating some alternating vertical channels around the load.

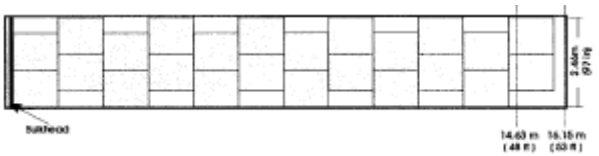

Figure 14: General aspect of an offset loading

In *Pinwheel loading* (Figure 15), pallets are loaded in a set of four. For the first pair of pallets, one is straight and the following is turned. In the next pair of pallets, the pallet behind the straight pallet (of the first pair) is turned and the other one is straight. Pinwheel loading provides more stability the offset loading. The chimney in the middle of each pinwheel provides an air channel surrounding the packages. However, this vertical circulation may not be uniform from the front to the rear of the trailer. The chimney provides a limited space for air circulation.

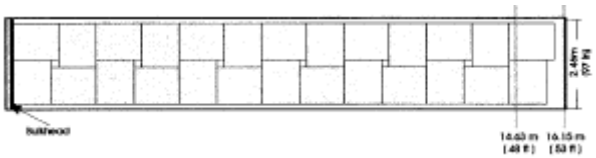

Figure 15: General aspect of a pinwheel loading

In *Centreline loading* (Figure 16), all pallets are loaded straight. The pairs of pallets are loaded closely together and placed in the middle of the trailer. Bracing system is required on both sides to prevent shifting. Wide air circulation channels in both sides load and across the space near the rear doors. This loading type eliminates all contacts between produce and sidewalls. The use of centreline loading protects highly perishable commodity such as strawberry, mushrooms and cut flowers during transportation.

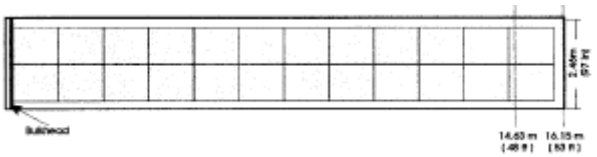

Figure 16: General aspect of a centreline loading

1.4 FERRIES AND SHORT SEA SHIPPING

Ferries are the fusion between the road transport and maritime transport for moving perishable products.

In the last years, thanks to the funding and support by the European Community this kind of transport has developed and concretized deeply in Europe in the form of Short Sea Shipping (SSS).

SSS currently provides more than 40% of internal freight transport within Europe and has been growing during the past decades.

Its success between carriers and EU is due to its possibility to offer effective transportation services with low relative cost and with fewer externalities compared to road transport, its main competitor.

SSS is a paramount importance for EU because it wishes to establish a complete and integrated system of intermodal transportation that will be able to guarantee not only free competition but also internal economic, environmental, and social cohesion.

Europe is a region proficient for this kind of intermodal transport thanks to these parameters:

- The European geography provides more than 67,000 km of coastline;
- Very few industrial centres are more than 400 km from the coast;
- There are approximately 25,000 km of navigable inland waterways.

With SSS, remarkable contribution to both logistic industry and environment is reachable.

The SSS is more efficient as for energy and fuel. Studies show that 1 t of cargo per gallon of fuel will travel around 800 km by sea and 100 km only by road.

Furthermore, SSS reduces congestion. The steady increase in road traffic has far outstripped any increase in infrastructure capacity, resulting in congestion and delays, increased energy consumption, safety problems and seldom causes them for others.

The ferry is the best choice kind of vessel for perishable products transport along short distances because it gives the advantage of reducing the time inside the harbour. The port operative time, so the time of loading and discharging, is greatly decreasing and it does not need any particular equipment for operations.

When vessel docks, the trailer can immediately get down and can takes the road for its final destination.

There are two kinds of ferries, influencing also the load of trailers and containers:

- RO-RO;
- RO-PAX.

RO-RO (Figure 18) are mainly for freight transport. The places to accommodate passenger/drivers is very few and, in fact, on this kind of ferries the most common way used for loading trailers and containers is alone, without tractors.

The freight space is usually more compared to a RO-PAX (Figure 19) ferry, where there are all the structures for accommodating in a comfortable way passengers and drivers, but the specific spaces for a complete truck (tractor + trailer), inside RO-RO ferries, are usually no more than 12.

On the other side, on RO-PAX ferries there is the possibility to load trailers and complete trucks. Indeed, this kind of ferry usually is realized mainly for touristic reasons, due to the common risk to find a vessel where the greater amount of space is designed for the transport of cars.

Longer the sea shipping part of the intermodal transport is, the more the RO-RO ferry is used and convenient.

Figure 17: Example of RO-PAX ferry, GNV La Suprema

Figure 18: Example of RO-RO ferry, Finnlines MS Finnsun

Studies carried out from *Escola Europea de Short Sea Shipping*, show that a SSS line is going to be a feasible success if some parameters are reachable.

Year traffic volume:

- 12,500 TEU;
- 15,000 trailers.

Quay features:

- 250 meters length;
- 8 meters draft.

Accessibility:

- Direct access to terminal;
- Direct access to rail network;

- Direct access to IT network.

Equipment:

- RO-RO double way ramp;
- Portainer crane;
- Ground handling equipment.

Administrative system without any custom or administrative problem or delay.

Maritime service:

- 2 weekly services for RO-RO;
- 1 weekly service for LO-LO.

It is highly recommended for a country or community that wants to organize a SSS network or system, to create a unique window for shipping companies that want to join the service.

By using this window, it should be possible for companies to check the different possible routes, the needed authorizations, and all the agreements between the regions for the import/export of products.

The planning of a SSS service needs to consider the arrival time in the destination harbour.

An example could be the SSS service between Barcelona and Civitavecchia, operated by Grimaldi Lines.

Trailers load in Barcelona around 10.15 pm and arrive in Civitavecchia the following day at 6 am, ready to reach the distribution centres.

In general, fruit and vegetables are the products more suitable for transport along the Mediterranean and Atlantic motorways of sea.

The two biggest problems, despite the numerous advantages, for the transport of these products are the strong dependency from seasons and the imbalance between import and export.

During the high season, fruit and vegetables fill up 40÷50% of loads along motorways of sea.

One of the main reasons why SSS service is not already the first choice for carriers and producers is because they are afraid about possible breaks of the *cold chain*.

Breaks could happen due to the intermodal passages and the maritime section, where the cargo could be alone.

For these reasons, shipping lines give the possibility to the truck driver of checking the cargo inside hold during the maritime crossing.

In case the trailer is shipping alone inside vessel, there is the possibility to let to vessel crew the responsibility of checking load conditions.

The perishable product traffic is the main client for SSS services in Spain, both along Atlantic and Mediterranean Sea.

In these two areas there are already 32 SSS connections with the possibility to transport fruit and vegetables.

The busiest route is the one with Morocco where, unfortunately, most of traffic uses the ferry only for crossing the *Estrecho* and continues the route for reaching the European markets along Spanish motorways.

Thanks to the deregulation of the fruit and vegetable market, the development of the North African regions and the opening of the new port hub of Tanger Med, many shipping lines have begun to bet, as well as on the already mentioned route of the *Estrecho*, also on longer routes.

CMA CGM announced the interest for opening soon a service, with a frequency of 3 times per week, between Tanger Med and Marseille. It is going to be very expensive for the shipping line because a service with this frequency, until when it will not reach a profitable level of use, can cost around 300,000 euro per week.
A service is profitable for a shipping line if the vessel hold is full for at least 80% of space.

Suardiaz recently increased to south the length of its motorway of sea Vigo - Saint Nazaire adding to it also the route Tanger Med - Vigo.

GNV announced the intention to strengthen its lines in the African country, like the route Tanger Med, Sete, buying new vessels with a greater cargo capacity.

Grimaldi declared its intention to regain the second weekly departure, closed two years ago. The service is ready to restart in March of 2018 with two weekly departures again.

In addition, the African shipping company *Africa Morocco Link* (AML) has intention to operate links between either Tanger and France or Tanger and north of Spain.

It also desires to strengthen the frequencies between the Moroccan ports, like Nador, and the Iberian Peninsula.

In any case, all the companies had shown their interest in developing the pure RO-RO traffic in the lines that operate in the *Estrecho*.

The RO-RO traffic is the most profitable ferry traffic for the shipping companies.

Today, considering all the trucks that from North Africa reach the ports of North Spain and France and that 30÷40% of them are unaccompanied trailers, only 5% of them are delivered with a pure RO-RO transport.

The shipping companies underline continuously the potential opportunities of a pure RO-RO transport where, with increasing the length of the route, also the earnings for the companies and for the carriers increase.

The main problem for this kind of intermodal service is the low service frequency.

With frequency less than three weekly departures to a certain harbour, carriers could find problems for modifying their logistic plans, since operational programs are difficult to modify again once elaborated or modified.

Other important problem, already noticed different times in the past, is the unreliability of shipping companies in creating and erasing vessels and routes for the SSS services to France and Italy.

In order to fight the unwillingness that producers and carriers still have to SSS service, and in order to have a real profitable service for shipping companies, are necessary real useful frequencies and forwarders, maybe also competitors, that use this service. In this way a real mass of movements and exchange are in the market to notice a real feasible and stable service that can be believable.

The services now available are on the actual market.

This is why, for example, GNV operates a service to Tanger Med, but without an option for the RO-RO specialized cargo and this is why Grimaldi, which has tried the cargo model, that is its favourite, now has to stand all the service costs.
CMA CGM decided to operate a pure RO-RO cargo service from Tanger Med, but only now that the market seems to be more stable and profitable.
In addition, *Suardiaz*, that until now has operated only in the transport of new cars, seeing the new market opportunities, would like to operate new routes to France and Vigo.

2. RULES AND LAWS

The transport of perishable products is regulated at many different levels in order to avoid any possible risk for consumers.
This is because the principal transported stuff are fruits, vegetables and medicines, that are products highly sensitive and, if spoiled, potentially dangerous for human health.

2.1 EU LEGISLATION FOR PERISHABLE PRODUCTS

The European legislative requirements are the most stringent and the most extensive because they cover each type of perishable product.

The basis for EU food safety public standards is laid down in the general food law or regulation (EC) 178/2002. The main objective of this regulation is to secure high level of food protection for public health and consumer interests with regard to food products.

The requirement of traceability ensures that products can be withdrawn from the market in the event of a problem.

This simplicity added with the always more stringent legislation are giving as result an increasing number of border rejections of products due to non-compliance with EU requirements.

It is sometimes argued that, due to these rejections, huge amount of fruits and vegetables are discarded and represent high economic losses and food waste.

The law also specifies that products entering/leaving the EU market must comply with the food safety requirements such as maximum limits on residual pesticide and absence of microbial pathogens. The products documentation has also to certify the compliance with hygiene and phytosanitary health requirements.

Year	Content	Legislation
2000	Phytosanitary certificate	Directive (EC) 200/29
2002	General Food Law	Regulation (EC)178/2002
2004	Hygiene requirements	Regulation (EC) 852/2004
2005	Microbial hazards	Regulation (EC) 2073/2005
2005	Pesticide residues	Regulation (EC) 396/2005
2006	Contaminants	Regulation (EC) 1881/2006
2008	Marketing standards	Regulation (EC) 1221/2008

Table 2: EU food legislation applicable to fruits and vegetables, Van Boxstael S., Fresh produce rejections at EU border inspection posts

Fruits and vegetables entering European borders are checked and controlled by EU Member States in BIP/PIF (Border Inspection Posts/*Puestos de Inspección Fronterizos*).

One of the main responsibilities of European Commission is to realize the list containing the foods with high safety risks.

It is revised every three to six months updating the hazards analysed.

The list is based upon several sources: notification from EU RASFF (Rapid Alert System for Food and Feed) alert system, reports from the European Commission's inspection service Food and Veterinary Office (FVO), scientific assessments from the European Food Safety Authority (ESFA) and exchange of information between EU Members States.

In developed countries a lot of losses seem to be wasted by consumers while in developing countries the losses are due to problems such as inadequate storage facilities, pests and managerial and technical limitations in harvesting techniques.

The European Commission has set up the *better training for safe food* programme, covering food and feed law, animal health and plant health rules. Via this programme, EU Members States and candidate countries involved in official controls are trained, but this training is also organised specifically for developing countries (particularly emerging economies and trade partners). The aim is to keep participants up-to-date with EU law and also to ensure more harmonised and efficient controls.
Efficient controls are an essential factor in maintaining high levels of consumer protection, animal and plant health. Additionally, in training participants from developing countries, the aim is to ease access for their products into the EU market and subsequently to keep the border rejection as low as possible.

2.1.1 BIP/PIF

The European Commission provided that all vegetables and animals from third countries entering the EU must be checked out by the Member States in specific and selected points designed with specific requirements and features indicated by the Commission itself.

These are the Border Inspection Posts (BIP) (Figure 19).

Inside BIPs the Member State can also carry out the national controls for the entering products, even if those are not vegetal or animal, the important is that, in order not to contaminate products, these checks are performed in specific isolated areas of the posts.

Today in all Europe there are around 300 BIPs.

Recently, inside all BIPs an area appointed specifically for controlling specific food and animal risks dangerous for human health was set out.
Now this area, called PDI, is in charge for analysing dried fruit where could be found the presence of Aflatoxin that is highly carcinogenic.

Figure 19: PIF Port de Barcelona

For every cargo the documents that are always checked are:

- Certificate of origin;
- Commercial invoice;
- Bill of landing;
- Packing list.

The kind of product can determine type and location of analysis that could be directly at terminal or more deeply at BIP.

In any case laboratories inside BIPs are very basic and cannot carry out many analyses (e.g. on metals or presence of mercury inside fishes).

When deeper analysis is necessary then it is usual to take three samples of product, and each of them has a different destination:

- 1 to laboratory;
- 1 to cargo owner;
- 1 to port authority.

This system has been planned to solve any kind of conflict that could arise when laboratory's answer after analysis is NO.

Commonly, at this point, cargo owner entrusts his/her sample to a different laboratory for a second analysis.

Should the result of the second analysis be a YES, the port authority uses its third and last sample for one more analysis.
A new laboratory is involved for third test, whose result is the last and final answer to the controversy.
For all these steps and operations are usually necessary three days.

2.1.1.1 TARIC CODE

It is a code designed for showing the various rules and controls applied to specific products when imported to EU.

This code includes the provisions of the Harmonised System and the combined nomenclature, but also additional provisions specific in European Community legislation, such as tariff suspensions, tariff quotas and tariff preferences, which exist for most of the EU trading partners (Figure 20).

In trade with third countries, the 10-digit TARIC code is fore custom and statistical declarations.

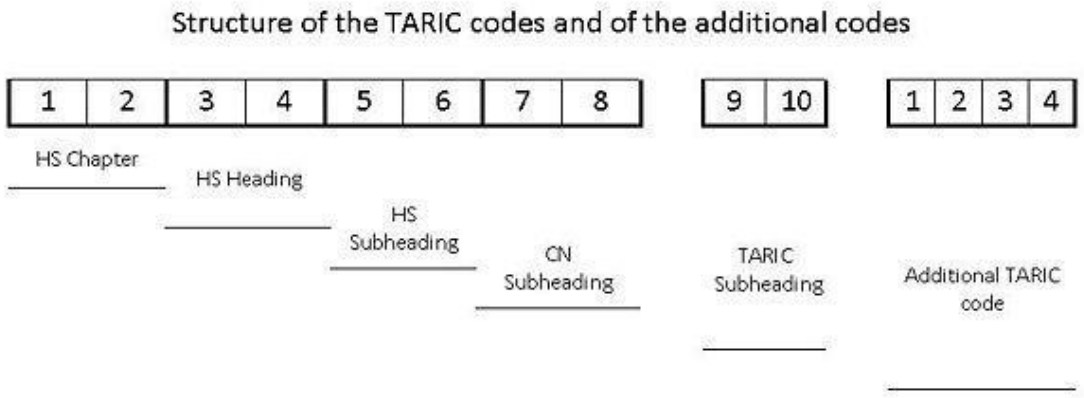

Figure 20: Structure of the TARIC codes and of the additional codes

2.1.1.2 PUESTO DE INSPECCIÓN FRONTERIZO (PIF)

Currently there are 42 PIF, 21 in ports and 21 in airports, and all of them are able to inspect Products with Animal Origin (POA) designated for human consumption.

Inside PIF the *Servicios de Inspeccion en Frontera* (SIF) are:

- *Sanidad Exterior*;
- *Sanidad Animal*;
- *Sanidad Vegetal*;
- *Servicio Oficial de Inspecion, Vigilancia y Regulacion del Comercio Exterior* (SOIVRE);
- *Aduana Maritima*;
- *Vigilancia Aduanera*.

Besides customs controls, inside PIF there are the first four para-customs controls.

These services are by specific bodies of the General Administration of State and consist in checking and inspecting all products for export and import. The aim is to verify if these products respect the necessary hygienic-sanitary conditions of commercial quality and of industrial security.

SERVICE	ORGANIZATIONAL DEPENDENCE	FUNCTIONAL DEPENDENCE
Sanidad Exterior	Ministry of Health	Government delegation in the autonomous community
Sanidad Animal	Ministry of Agriculture, Food and Environment	
Sanidad Vegetal		
SOIVRE	Ministry of Economy and Competitiveness	

Table 3: Para custom controls carried out inside PIF

2.1.1.3 SERVICIO OFICIAL DE INSPECCION, VIGILANCIA, Y REGULACION DEL COMERCIO EXTERIOR (SOIVRE)

SOIVRE is the main and official service of surveillance, certification, and technical assistance of foreign trade in Spain.

A national bureau working, since 2008, in deep collaboration with Spanish custom for controlling the importation and is responsible for:

- Inspection and conformity of Commercial Quality Food (agricultural, fish, olive oil, …);
- Import and industrial security controls (toys, protective equipment, electrical equipment, clothes, shoes, etc.).

The main service office is inside the State Secretariat of Foreign Trade, while along all the country there are 32 Technical Offices and over 140 Checkpoints.

Technical Offices correspond to main Spanish channel for import/export.

The principal objectives of this office are:

- To facilitate trade under fair conditions;
- To keep products of unsatisfactory quality off the market;
- To guide production to meet consumer demand;
- To guarantee high quality level of inspections with independency, integrity, and high efficiency level;
- To support Spanish export.

Regarding kind of inspections, SOIVRE follows all the European rules and standards about the European community agricultural market and vegetable sector.

Inside Spanish legislation there are three regulations that involve SOIVRE's tasks:

- R.D: 1456/2005 administrative regulation for Regional and Provincial Departments of Foreign Trade;
- O. PRE/3026/2003 and O.ITC/2869/2009 inspection and control rules for Regional and Provincial Departments of Foreign Trade.

SOIVRE performs different kind of inspections depending either from the origin or destination of the products.

If products are for/from European market countries, the main inspection regards the evaluation of the packaging *Auto-Control* system of the fruit and vegetables traders.

This control is working out directly in the packaging stations of traders or of companies.

If products are for or come from third countries, SOIVRE is responsible for all the extra inspections not required by EU legislation but required by the Spanish law.

All these inspections are carried out inside PIF points.

2.2 ACCORD TRANSPORT PERISHABLE (ATP)

The agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to use for such Carriage (ATP) was set up on 1st September 1970 and entered into force on 21st November 1976.

The objectives of ATP are to facilitate international transport of perishable foodstuffs and to ensure a high level of preservation of quality during the carriage.

The ATP is for the carriage of perishable foodstuffs performed on the territory of at least two Contracting States, not only by road, but also by rail and by sea (for crossings less than 150 km long).

In addition, several countries have also adopted the ATP as the basis for their national legislation.

The agreement treats the following data and details:

- It lays down standards for temperature controlled transport vehicles, including their refrigerating capacity, insulating capacity and efficiency of thermal appliances;
- It lists the foodstuffs to be carried in accordance with the ATP agreement and sets the appropriate temperatures, under which the various types of perishable foodstuffs should be carried;
- It specifies the tests to be carried out on such equipment conforming to the standards;
- It requires all Contracting Parties to recognize certificates issued in accordance with the agreement by the competent authorities of the other signatory countries.

The ATP is an Agreement between States and there is no overall enforcing authority. In practice, highway checks and non-compliance may result in legal action by national authorities against offenders, in accordance with their domestic legislation. ATP itself does not prescribe any penalties.

The insulation and refrigeration standards, with which specialist equipment must comply: 1) insulated only, 2) a combination of insulated with refrigeration, 3) insulated with heating or insulated with refrigeration plus heating.

All the new vehicles built in recent years are already Type Approved for the required standards. The Certification lasts for 6 years, after them it is possible to renew the certification for a period of 3 years.

ATP is an international Agreement, this means that all the Contracting Parties do not have any more a national certification, but they issue only the ATP one.

Whilst it is acceptable to carry the ATP Certificate on international journeys, it is permissible for the vehicle to display an ATP Plate showing the details of the certificate.
This plate is onto the bodywork of the vehicle and is recognizable by other Signatory Countries. The display of a Plate helps hauliers to avoid delays due to the misunderstanding or certificate loss.

The internal and external bodywork sides must not contain:

- Zinc and alloys with more than 10% lead;
- Tin alloy with more than 10% lead;

- Welds with tin + lead alloy with more than 10% lead.
  These alloys are tolerated if the external and internal sides are correctly impermeable from infiltration;
- Materials with compositions containing more than 3 centigrams of arsenic for 100 grams of material;
- Plastic products or done by other material, which may release tastes or smells that may modify organoleptic features and make harmful the foodstuffs;
- Metallic external thermic protections and paints.

2.3 URS, SOP, SLA

User Requirements Specification (URS) is the agreement between the shipper and client that clearly defines all the parameters, levels and instruments that should respect and use during the transport, like:

- The temperature and humidity parameters that must be maintained for each product or product type;
- Transportation mode and/or vehicles to be used;
- The required level of service;
- Acceptable levels of risk to product and performance;
- The types of packaging;
- The type of temperature and humidity monitoring devices to be employed and the acceptable level of accuracy of these devices;
- Specific service actions such as go/no-go decision making in the event of a temperature excursion event, or more complex analytical data gathering and reporting requirements.

The URS specifies that during the transport the shipper is totally in charge to respect all the specification reported in the document.

With the URS it is possible to fill in two more documents:

- Standard Operating Procedure (SOP): a set of instructions having the force of a directive, covering those features of operations that lend themselves to a definite or standardized procedure without loss of effectiveness. Standard operating policies and procedures can be effective catalysts to drive performance improvement and improve organizational results;
- Service Level Agreement (SLA): is a negotiated agreement between the consumer and provider that defined the common understanding about quality specifications, responsibilities, guarantees and communication

mechanism. It may also specify the target and minimum level performance, operation or other service attributes.

2.4 NEW ROAD TRANSPORT REGULATION

In winter 2017, EU developed the new mobility package of rules that introduces important news about road *cabotage*, minimum salary for foreign drivers, *Eurovignette*, rest of the driver in the cabin, and transported cargo weight.

In parallel the Spanish Government, with all the stakeholders of the road transport, is still discussing new ROTT, the regulation that directs the land transport in the Iberian Peninsula.

In EU package for road transport there is the proposal from the European Commission to reduce to five the maximum days for cabotage.

This proposal is reason for many discussions in Spain.

A research from the sector magazine *Cadena de Suministro* showed that in Spain 38% of carriers consider this proposal correct, but without limiting the number of possible operations during the five days. Another 31% considers this activity completely liberalized.

At institutional level, the Spanish Government required to increase days limit to seven, advantageous proposal for Spain being in Europe the second Country that transports mainly for cabotage.

About *Eurovignette*, many different factors scare different Spanish actors of the sector:

- The freedom that EU gives to member Countries for inserting or less the payment of their road network;
- The fact that Ministry of Economic Development does not choose a clean and precise position about this topic;
- The fact that, despite what Ministry of Economic Development tells, Ministry of Economy and Finance indicated as period the end of 2017;
- The proposal of autonomous communities like Basque Country and Catalonia to introduce unilaterally road tolls from 2018 and 2019 respectively.

With these premises, 84% of the interviewed by *Cadena de Suministro* considers sure that at the end the Government will introduce in Spain the Eurovignette.

Great disparity (84% yes, 16% no) between the interviewed about the possibility of introducing a minimum salary for not Spanish drivers, as neighbouring countries have already done.

Someone considers the correct system for contrasting the *social dumping* of companies from East Europe.

In Spain, it is difficult to find a value for minimum salary because there are more than fifty different collective agreements.

Again, from the research of *Cadena de Suministro*, the Spanish refrigerated road transport sector seems to be against the idea of increasing the beginning value, chosen in 2016, of cargo weight in the negotiation between carrier and forwarder. Currently this value is 44 tons.

The 83% of no is divided between these three reasons:

- At the end carrier will transport more cargo for the same price;
- There is a risk to compromise road transport safety;
- It is necessary to aim to fleet renovation.

From April 2017, thanks to action of *Asociacion Espanola de Empresarios de Transporte Bajo Temperatura Dirigida* (AEETBD), all road transports of perishable products in Spain are not included in weekends and national holidays traffic restrictions.

2.5 DRIVING TIME, BREAK AND REST PERIOD RULES FOR DRIVERS

Reefer lorry is considered like articulated lorry, usually with 4 axles.

Consequently, driver must respect the European law No 561/2006 about driving time, break and rest period.

The European legislation indicates as 4.5 the maximum value of consecutive driving hours, followed by a break of at least 45 minutes.

A driver can work a maximum of 9 hours/day.

The daily rest can be get in two ways:

- 11 uninterrupted hours;
- Two separate rests: 3 + 9 hours.

Only two times a week driver can work for 10 hours in one day. But in this case the seventh day must be mandatorily a resting day.

The maximum total amount of working hours for a driver in a week is 56 hours.

In two weeks, it is 90 hours.

Example about how to apply the regulation:

- For a journey shorter than 4.5 hours, the resting time is zero;
- For a journey of 10 hours (admissible only two times a week) the resting time is only 45 minutes;
- For a journey of 14.5 hours, the resting time is 9 hours and 45 minutes, spread out in 45 minutes of break + 9 hours of continuative resting time.

2.6 MAXIMUM SULPHUR CONTENT

Emissions from shipping transports, due to combustion of marine gas oil and marine diesel oil with high sulphur content, contribute to air pollution in the form of sulphur dioxide and particulate matter, which harm human health and environment and contribute to acid deposition.
This is why European Parliament and Council had set out Directive (EU) 2016/802, in order to lay down the maximum permitted sulphur content in maritime fuels.

All Member States must take all necessary measures for ensuring that marine fuels are not used in the areas of their territorial seas, exclusive economic zones, and pollution control zones if the sulphur content of those fuels by mass exceeds:

a) 3.5% as from 18th June 2014;
b) 0.5% as from 1st January 2020.

All Member States must take all necessary measures to ensure that ships at berth in Union ports do not use marine fuels with a sulphur content exceeding 0.1% by mass, allowing sufficient time for the crew to complete any necessary fuel changeover operation as soon as possible after arrival at berth and as possible before departure.

2.7 MOROCCO AND EUROPEAN UNION

Morocco is one of the seven extra European countries that has with European Community the *ADVANCED STATUS* partnership level.

It consists in a join reflection process aimed at strengthening the bilateral political, economic and trade relations, as well as cultural and human and at straightening political cooperation between Morocco and EU with a view to take a greater account of their respective strategic priorities.

For Morocco it means also the opportunity to become a member of the free EU internal market and to get appropriate European financial support.

The long process of Morocco for becoming a member of the European free trade market started in 1995 with the establishment of the Euro-Mediterranean partnership.

Than in 1996 followed the Association Agreement between EU and Morocco that came into force in 1st March 2000.

Inside this last there is also the agreement between EU and Morocco concerning reciprocal liberalization measures on agricultural products, fish and fishery products, which came into force on 1st October 2012. This aims for complete liberalization and creation of a *free movement of goods area*, with the exception of products considered by the two parties to be of a sensitive nature, which remain subject to special conditions.

The establishment of this agreement is the main cause why Tanger Med port was built, in order to be ready to the forecasted explosion of traffic and exchanges with Europe.

In addition to commercial exchanges, the agreement between EU and Morocco considers also:

- Political dimension (dialogue, Morocco-EU summits, common partnerships, etc.);
- Parliamentary cooperation (creation of a joint parliamentary committee Moroccan Parliament – European Parliament, obtaining for the Moroccan Parliament observer status in the Parliamentary Assembly of Council of Europe);
- Security cooperation;
- Strengthening dialogue and cooperation on human rights issues;
- Strong integration of the Moroccan economy with that of the EU on the standards that govern the European Economic Area;
- Reconciliation of Morocco's legislative framework with the European legislation knowledge;

- Connection with all the trans-European networks (transport, energy, ICT, water, agriculture, environment…);
- Human dimension.

Since 2003 Europe decided that all Eastern neighbours and southern Mediterranean countries that want to join Europe in its business, may do it only in proportion to their progresses in the field of respect of common values and the implementation of political, economic and institutional reforms.

In order to help Morocco for reaching all these targets necessary for sustaining exchange and dialogue with EU, the EU's financial assistance has given monetary support on sectors related to economic transition and strengthening of socio economic balance.

Usually, this monetary support and investments are proportional to trades between EU and the single country. This is why Morocco considers the received financing is not fair considering that two-thirds of its external trades are with Europe.

Morocco has also a special bilateral agreement with Spain about licences for working as driver in the two countries.

Currently 30,000 Moroccan and Spanish truck drivers can work between the two countries without problems.

Recently, this agreement had to face a polemic about the unequal utilization of these licences. Spain uses barely 5,000 of them for entering in Morocco, not helping in this way the Moroccan economy.

The idea that there is less traffic towards Morocco is not true, but simply there is a different way of working in the two countries.

Spanish operators prefer to send trailers alone in the maritime section of transport.

This gives them possibility to use directly local operators when ferries berth.

The same for the return trip in the opposite direction.

There are also exceptions of Spanish operators, like San José Lopez that request many of these unused licenses for operating in Moroccan ground, in order to work directly from Morocco where costs are lower.

This is an example of how the big differences between Moroccan and Spanish fleets are steady decreasing, thanks principally to high ambitions of Tanger and its port.

3. PERISHABLE PRODUCTS MARKET AND EXCHANGES

In last year in the world, around 174 million tons of perishable products were moved, equivalent either to 27,177 reefer vessels (capacity of 14,158 m2) or, alternatively, to 11.5 million TEU in reefer container.

Of these 174 million, around 108.5 were using refrigerated maritime systems and the 38% of them, so 66 million, were imported in Europe. In general, for this kind of market, it is forecasted from now to 2025 a steady growth rate of 4.5%.

Controlled temperature maritime transport in world is growing more than conventional maritime transport that in last year was grown only of 2,7%.

In the general growth of perishable transported products amount, the foodstuff that is showing greater growth percentage is the exotic fruit (kiwi, pineapple, avocado): beginning from 4.5 million tons in 2012, in last years experienced an annual growth rate of 9.1%.

Considering tons values, the greatest growth has been for the meats sector, that is passed from 22.8 million tons in 2002 to 93.3 million tons in 2015, with an annual growth rate of 4.8%.

This growth is helping to increase the number of firms that bet in this kind of transport, with the useful consequence for customers of seeing a constant reduction of prices.

Rates for conventional freight transport reached their minimum values in 2016, when minimum price for sending one 40' reefer container was around 700 dollars.

This price is just a few higher than for transporting a single normal container.
The real difference is about the price for buying a reefer container that is around 13,500 euro, six times higher than for buying a normal container.

3.1 SPANISH FREIGHT TRANSPORTS

A recent survey of *Cadena de Suministro* among the Spanish transport companies demonstrated that the refrigerated goods companies are the biggest in Spain.

Between 2015 and 2016 the growth in volume of controlled temperature goods was 3.6% in Spain and in 2017 the trend remained the same.

More specifically, in 2016 the fresh fruit export in Spain was grown of 20% to 2.1 billion of euro that correspond, in volume, to a grown of 14% to 2.6 million tons, distributed as follows among transport modes:

- 84.7% by road;
- 13.9% by sea;
- 0.9% by plane;
- 0.5% by train.

In recent years, among all transport modes, the maritime one has showed the greatest growth. Between 2008 and 2015 it was grown of 25%, with an annual rate that swings between 4 and 7%.

Trades that contributed principally to this growth are those with Africa and Europe.

In the ranking *Top socios comercio exterior Spain en trafico tot de frutas y verduras en 2016* France and Morocco are respectively:

- France is the first, with total exchanges of 3,412,583 tons, +1.9% compared to 2015, with only imports from Spain of 2,460,405 tons;
- Morocco is the ninth, with total exchanges of 389,228 tons, +19.9% compared to 2015, with only exports to Spain of 314,577 tons.

3.1.1 MARITIME TRANSPORT

Spanish ports in last year managed a fruit and vegetables traffic of 8.5 million tons: 42% of them with a final destination different from Spain.

Despite in last year a decrease of 3% was incurred in fruit and vegetables Spanish traffic, in period 2008-2016 the Spanish harbours system experienced a growth of 50% of fruit and vegetables volume moved. The quantity is passed from 5.6 million tons to the present 8.5 million.

80% of all this traffic, equivalent to 6.8 million tons, concentrated in only five ports:

- Bahia de Algeciras;
- Valencia;
- Las Palmas;
- Tenerife ;
- Barcelona.

In 2016 Bahia de Algeciras alone managed 3.8 million tons of fruit and vegetables that are 42% of all products of this kind transited in Spanish seaports.

Valencia, the second in the ranking, managed *only* 1.4 million tons, equivalent to 16.5%.

3.1.2 ROAD TRANSPORT

In 2016 the total revenue of the 50 main reefer Spanish road transport companies is 3 million euro.

This value is going to be confirmed, if not increased, in 2017 considering that, in the first half of the year, the growth was 9% compared with the same period in 2016.

Spanish reefer road transport companies have normally 10 to 50 tractors and trailers.

Employees in each company are on average 185 and the 85% of them are drivers.

Most of these companies deal mainly with fruit and vegetables transport in international and national field.

Main international destinations are France, Germany, United Kingdom and the Netherlands.

In addition to transport, they normally provide added value to products with extra services, as stocking and distribution to destination, thanks to their logistic divisions.

The model with own trucks fleet is the predominant: 49% of transport companies in Spain are owner of all their fleet, as well as 45% chose a mixed model that gives possibility to get a certain level of flexibility to face peaks in the reefer transport services demand, while only 6% of companies have a completely leasing fleet.

On average, the 83% of reefer truck fleet in Spain is owned by the transport company.

About dimensions of Spanish reefer truck fleets the situation is the following:

- Companies with 10 to100 unities:
    - 19% between 1 and 10 unities,
    - 32% between 10 and 50 unities,
    - 3% between 50 and 100 unities;
- Companies with 100 to 500 unities:
    - 29% between 100 and 300 unities,
    - 7% between 300 and 500 unities;
    - 10% more than 500 unities.

Similarly for reefer trailers fleet:

- Companies with 10 to 100 unities:
    - 20% between 1 and 10 unities,
    - 30% between 10 and 50 unities,
    - 6% between 50 and 100 unities;
- Companies with 100 to 500 unities:
    - 27% between 100 and 300 unities,
    - 7% between 300 and 500 unities,
    - 10% more than 500 unities.

About products managed, transport companies are divided as follows:

- 34% fruit and vegetables;
- 17% sea products;
- 15% pharmaceutical products;
- 14% meat;
- 20% other products.

About transport destinations:

- 36% national;
- 29% international (mainly cabotage).

Main international European transports are split as follows:

- 18% France;
- 17% Germany;
- 15% United Kingdom;
- 14% the Netherlands;
- 11% Italy;
- 10% European central countries;
- 4% Baltic countries;
- 2% North Africa;
- 1% Russia;
- 8% other countries.

The global offer in terms of logistic added values services are:

- 27% only road transports;
- 37% also stocking services;
- 19% also distribution to final destinations;
- 17% also other services.

52% of companies use intermodal transport services to complete and integrate their services vs. 48% providing road transport only.

The companies that provide intermodal service by using jointly road, maritime and railway systems are 56% of the total amount vs. 44% using only maritime and road systems.

The main reason why reefer transport companies decided to offer intermodal services is the following:

- 35% operating cost reduction;
- 20% significant saving in drivers working time;
- 15% environmental policies;
- 30% other reasons.

Finally, intermodal transport services used by Spanish reefer transport companies have multiple destinations:

- 41% in Mediterranean Sea;
- 25% between Strait of Gibraltar and North Africa;
- 22% along Atlantic coast;
- 12% in Cantabrian Sea.

4. PORTS AND MARKETS

As already mentioned in the introduction, in order to find alternative routes for perishable products with destination to the wholesale markets of *Mercamadrid* and *Saint Charles Int.* that cannot be anymore managed by Bahia de Algeciras port, we are going to analyse some ports along Spanish and French Mediterranean coast.

The criteria chosen for selecting ports are the presence of RO-RO/RO-PAX infrastructures and equipment, adequate facilities for HGVs (Heavy Good Vehicles) traffic and presence of links already operated between Europe and Morocco.

The chosen ports are five Spanish and two French.

SPAIN	FRANCE
Malaga	Sete
Motril	Marseille
Alicante	
Valencia	
Barcelona	

Table 4: Ports chosen for analysis

The first analysed seaports are those originating this analysis: Tanger Med and Bahia de Algeciras.

4.1 TANGER MED

It is the main port of Morocco and the biggest in Africa. Its first part came into service in July 2007.

Its construction is part of the economic policy orienting Morocco towards exports. It is based on eight clearly identified export sectors, with particular emphasis on the free trade agreement with the European Union implemented in 2012.

The port is implemented, coordinated and managed by TMSA (Tanger Med Special Agency), a private company with public prerogatives, operating under an agreement with the State and interacting with the different ministries involved.

Its particular position on the Straits of Gibraltar, at the crossing of two major maritime routes, and 15 km from the European Union enables it to serve the European free trade market.

It is also main container transhipment hub in the region and the leading hub for cereal transhipment, which facility was not existent in the north-west African region before.

In 2012 started to be operative "Tanger Med II", the expansion of the harbour that doubled the port capacity with purpose to meet the growing demand thanks two new container terminals with a total length of 2.800 meters and an additional nominal capacity of 5 million containers.

This extension of the port, with an investment of 200 million of euro by the European Investment Bank (EIB), is an example of infrastructure financed by the European Union for improving economy and status of extra- EU neighbourhood partners.

The port is designed with a traffic expectation of 8 million of containers, 7 million passengers, 700.000 trucks, 2 million vehicles, and 10 million MT of oil products.

Nowadays it is considered the busiest port on the Mediterranean.

In order to analyse the port, it is possible to divide the harbour in three specific areas:

TANGER MED I PORT
3 million containers of capacity
1.6 km of container docks at -16 and -18 meters
2.6 km of dikes
140 hectares of land, of which 80 hectares for container traffic, served by rail

Table 5: Tanger Med I Port features

TANGER MED PORT PASSENGERS
2.5 km of dikes
8 berths with draft of 9 and 12 meters
35 hectares of land reserved for passenger and TIR activities
Several supporting spaces representing a total of 30 hectares of median

Table 6: Tanger Med Port Passengers features

TANGER MED II PORT
5.2 million containers of capacity
2.8 km of container docks at -16 and -18 meters
4.8 km of dikes
160 hectares of land totally won over sea

Table 7: Tanger Med II Port features

4.2 BAHIA DE ALGECIRAS

Bahia de Algeciras (Figure 21) is the first Spanish port for amount of merchandise traffic moved and 25th in the world for number of containers.

In 2015 it managed 98.2 million tons of cargo products and more than 4.5 million containers.

Thanks to its proximity to Africa, it is considered the natural entrance for African products to Europe and the most important Spanish port for ferry traffic and fruit and vegetables traffic.

In 2016 it handled 3,756 thousand tons of fruit and vegetables, with an increase of 1.5% compare to 2015. In the same year, along the route with Tanger Med, that is the most important, 239,630 HGV were moved, with an increase of 10% compared to previous year.

Currently in Bahia de Algeciras there are eleven piers for docking RO RO and RO PAX ferries, and this shows the high bent of this port for this kind of traffic, that is the principal with North Africa ports.

It is possible to notice this aptitude also looking the high number and deep specialization of HGV parking areas.

They are divided in two maxi groups: Rotation Zone and Logistic Zone.

Rotation Zone is a public area for any heavy goods vehicle that is waiting to be loaded, embarked, etc., and does not have to take part to any service in the Algeciras Logistic Services Area.

This zone is composed of 409 spaces divided in:

- 398 Long Spaces;
- 11 Short Spaces.

Logistic Zone is an area used exclusively by operators with an AV (Added Value) Contract for semi-trailers and is arranged with only long spaces divided in four sub areas:

- Long import area with 246 spaces;
- Long export area with 279 spaces;
- Long wait area with 14 spaces;
- Long reefer area with 8 spaces.

Figure 21: Port of Algeciras Bay

The PIF area inside port is the only one in the Spanish port system ranked as Category 1, it means that it can manage any kind of cargo, either with animal or vegetal origin.

Opening time is 365 days per year and, in function of demand, for 24 continuous hours.

On average it operates 28,000 yearly inspections.

The operative area has a surface of 1,066 m^2 for 30 HGV unloading bays. There is one Scanner Unit and one HGV weight bridge.
The storage rooms are 9 divided in this way:

- 3 room temperature;
- 3 cold temperature;
- 3 freezer temperature.

For vehicles waiting to be inspected there are 60 HGV parking spaces.

4.3 MALAGA

The Port of Malaga (Figure 22) is the second most important after Barcelona in the Iberian cruise port system.

It manages freight traffics of cereals, cement, petroleum coke, dolomite and olive oil, and also cabotage traffics of general goods, vehicles and passengers ferried by regular lines with Ceuta and Melilla.

Figure 22: Port of Malaga

In 2016 the Port handled 14 thousand tons of fruit and vegetables products, with a growth of 57% compared to previous year.

These percentages show as the many investments of last decade are now giving the expected positive results.

Currently Port of Malaga has 3 RO RO/RO PAX piers:

- Canovas;
- Polivalente;
- Heredia.

The HGV parking area is not divided between import or export but simply for the length of layover:

- Short length (48h): 144 spaces;
- Long length (7 days): 41 spaces.

There are not spaces for reefer trailers.

The PIF area is metrically bigger than the Algeciras one, but it has less features and equipment:

- Operative area: 1305 m^2;
- HGV unloading bays: 7
- Room temperature rooms: 1;
- Cold temperature rooms: 1;
- Freezer temperature rooms: 1;
- HGV parking spaces: 19.

There are not Scanner units and HGV weight bridges.

4.4 MOTRIL

Despite it is one of youngest Spanish ports, next year is the 100th anniversary, the Port of Motril (considered as the port of Granada) (Figure 23) is one of the most active in recent years, with the opening of many new routes and a steady increase in passengers and vehicles traffic.

Port of Motril has already different lines that connect Spain with North of Africa.

The first daily connection for the port was established in 2011 from the Spanish company Naviera Armas and connects Motril with Melilla.

The same shipping company connects also the port of Granada with the Moroccan town of Alhucemas.

Furthermore, in Motril it is possible to find also the first route created as alternative to Bahia de Algeciras in the operations inside the Strait of Gibraltar.

In 2012 the German shipping company FRS opened the route Motril - Tanger Med. With more than 76,000 tons of goods and 3,852 trucks handled in first year of operations, the new line showed immediately to be an appreciate alternative to Algeciras.

In 2016 the port of Granada managed 37 thousand tons of fruit and vegetables, with a growth, compared to previous year, of +92% (in 2015: 19 thousand tons).

Figure 23: Port of Motril

From infrastructural point of view Port of Motril has 3 quays for ferries:

- Costa;
- Levante;
- Azucenas.

There are different HGV parking areas, whose have been impossible to find features information, and a PIF smaller than Algeciras and Malaga ones.

The PIF area has an operative surface of 422 m^2 and three HGV unloading bays.

Temperature rooms are four:

- 1 room temperature room;
- 2 cold temperature rooms;
- 1 freezer temperature room.

There are one HGV weight bridge and the HGV parking spaces are 6.

4.5 ALICANTE

Port of Alicante (Figure 24) is a harbour in Comunidad Valenciana with a predominant industrial vocation, especially in cement and its derivatives markets.

It manages important passenger traffics with Oran and Algeri in Algeria. In 2016 its fruit and vegetables trades reached the value of 145 thousand tons (+10% compared to value of 2015).

Thanks to its industrial vocation, Port of Alicante currently holds 9 RO RO/RO PAX quays (1 in muelle 9, 12, 13, 14,17, 21, 23, 25, and 2 in muelle 15).

It was difficult to find precise value about HGV parking areas in the harbour, but for sure there are two of them: one in the TMS zone, with 204 refeer spaces, and another one inside the ZAL (Zona Actividades Logísticas) with 360 short time spaces and no reefer areas.

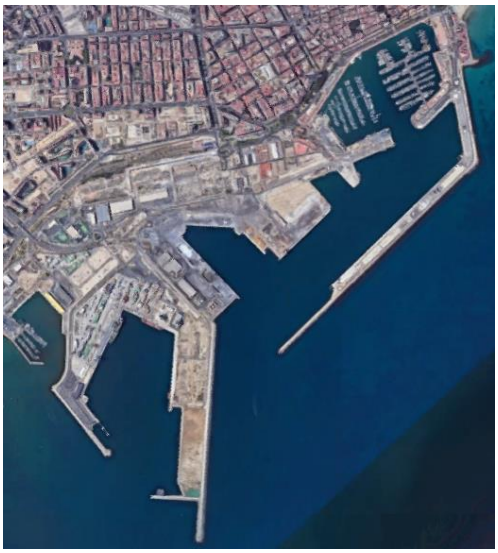

Figure 24: Port of Alicante

The PIF area is bigger than the Motril one and has 9 temperature stores:

- 5 room temperature stores;
- 3 cold temperature stores;
- 1 freezer temperature store.

There are not HGV unloading bays, weight bridges and scanner units.
The HGV parking spaces are 9.

4.6 VALENCIA

Port of Valencia is the second busiest Port of Spain and the second for number of TEU handled.

Thanks to its direct and busy railway line for Madrid, Valencia is considered the port of the Spanish capital.

In 2016, 6,232 vessels moored and 4,660,947 TEUs were handled (+1.77% compared to 2015).

Regarding fruit and vegetables traffic, Valencia, with 1405 thousand tons, is second only to Algeciras.

Currently, in Valencia the only operating ferry connection to North Africa is with the Algerian port of Mostaganem (with a traffic in the period 15 June - 15 July 2017 of 16,082 passengers and 1.031 vehicles).

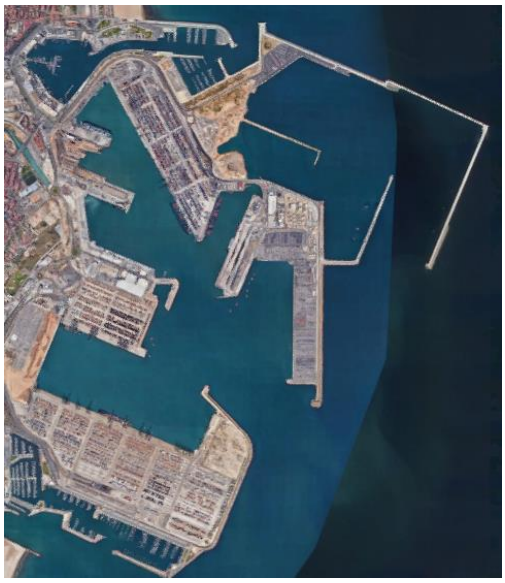

Figure 25: Port of Valencia

In Valencia there are 10 quays for ferries traffic:

- 2 in Valencia Termina Europa;
- 4 in Balearia Terminal;
- 4 in Transmediterranea Terminal.

It was not possible to find a precise number of HGV parking areas, but for sure there are two places with these spaces:

- Dique del este, with 350 spaces;
- Muelle Costa, with 150 spaces.

4.7 BARCELONA

Port of Barcelona (Figure 26) is the biggest harbour of Spain, the first for cruise traffic, the fourth for passengers transported and the third for number of TEUs handled.

From Port of Barcelona leave numerous ferry connections and two of them, operated by Grimaldi Lines and Grandi Navi Veloci, directed to Tanger Med.

Thanks to its inclination of being at the same time an important passenger, industrial and commercial seaport, inside harbour it is possible to find 14 ferry quays:

- 2 in Terminal Port Nou;

- 1 in Terminal Manipuladora de Mercancias;
- 6 in Termianl Ferry de Barcelona;
- 3 in Grimaldi Terminal Barcelona;
- 2 in Balearia Terminal.

Considering the high traffic level of trucks and trailers inside the Catalonian Port, the number of HGV parking spaces is not so high.

This is a specific and precise strategy adopted by the port authority. The aim is to push to an operative service level where carriers never have to wait. The waiting time for loading or disembarking from ferries or for taking part to the different services, inside the port or logistic area, have to be equal to zero.
The port authority wants to reach a level in which every truck needs simply to arrive in port area and immediately goes inside the vessel, or to the centre where there is its hired service.

Figure 26: Port of Barcelona

The spaces inside the port and its logistic area are divided:

- In three groups according to their length:
  - Places type A – higher than 15 meters;
  - Places type B – from 12 to 15 meters;
  - Places type C – less than 12 meters.
- In two groups according to parking time:
  - Rotate parking places;
  - Long term parking places.

The HGV parking areas are three: Moll de San Beltran, inside Termianl Ferry de Barcelona, TIR and Far del Llobregat, inside the ZAL (Zona de Actividades Logísticas).

	Moll de San Beltran		TIR		Far del Llobregat	
	Rotate places	Long term places	Rotate places	Long term places	Rotate places	Long term places
Type A	46	10	44	0	32	425
Type B	1	0	1	0	0	23
Type C	15	0	0	0	0	41

Table 8: Port de Barcelona HGV parking areas features

The PIF Area in Barcelona is the biggest between the ones analysed until now.

It has a surface of 5,723 m2 and 3,119 of them are for the 14 temperature stores:

- 7 room temperature stores;
- 5 cold temperature stores;
- 2 freezer temperature stores.

There are 31 HGV unloading bays and 8 different operative zones for the inspections.

4.8 SETE

Port of Sete (Figure 27) is the second most important harbour on French Mediterranean coast. In France it is the 16th for number of passenger and the 9th for gross weight of goods transported.

Its importance for now is due principally to the distance of only around 100 kilometres from Saint Charles International Market. This is the reason why the port raised interest into the Italian shipping company GNV that, in 2012, decided to open the successful route Sete - Tanger Med with intermediate stop in Barcelona.

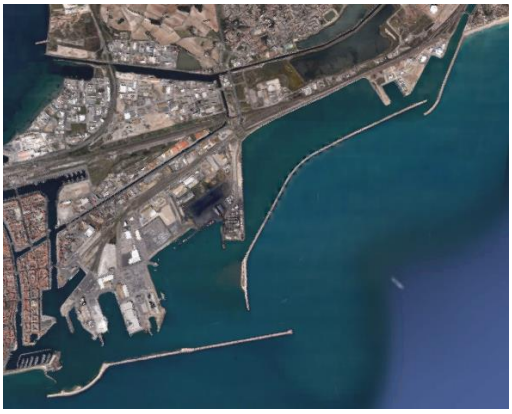

Figure 27: Port of Sete

Sete gets six RO RO/RO PAX quays divided in three terminals:

- Orsetti with 2 quays;
- Colbert with 2 quays;
- Voiture with 2 quasy.

4.9 MARSEILLE

Port of Marseille (Figure 28), correct name is Marseille Fos Port, as Barcelona in Spain, is the biggest multipurpose seaport of France, and the fifth in the Mediterranean area.

It is composed of two parts: the Old Port of Marseille, mainly with a touristic vocation, for cruises and ferries, and Fos-sur-Mer, more at north of Marseille, with commercial and industrial vocation.

Figure 28: Port of Marseille

The Old Port of Marseille has 20 ferry docks in 20 different quays:

BERTH 004	BERTH 012/013	BERTH 041/042	BERTH 053/054
BERTH 005	BERTH 026	BERTH 043	BERTH 057/058
BERTH 006	BERTH 028	BERTH 044/045	BERTH 109
BERTH 007/008	BERTH 030	BERTH 047/048	BERTH 118
BERTH 010/011	BERTH 040	BERTH 050/051	BERT 119

Table 9: Old Port of Marseille, quays with RO RO ferry docks

4.10 MERCAMADRID

Mercamadrid (Figure 29) is the main wholesale market, distribution centre, and food commercial and elaboration platform of Spain.

It was open in 1982 and it is managed by the semi-public company Mercamadrid SA.

Figure 29: Mercamadrid

The market covers an area of 2.21 million m^2 where around 800 companies operate divided in 6 different areas:

- Fish market;
- Fruit and vegetables market;
- Meat market;
- Commercial and administrative zone;
- Services and warehouses area;
- CTM (Transports centre).

Inside the market borders there is a daily traffic of 15,000 vehicles and 20,000 people.

Its influence area has a radius of 500 kilometres with a population of around 12 million possible consumers.

The internal fruit and vegetables market occupies a covered surface of 65,000 m^2 divided in six aisles. Each aisle can host 57 selling points, for a total number of 342 selling points.

The fruit and vegetables market has also a warehouse area of 8,880 m^2, where there are 120 storage rooms, for a total volume of 1,800 m^3.
These rooms are equipped with machineries for ripening products for future commercialization.

Mercamadrid handles around 10% of all fruits and vegetables arrives from Morocco.

4.11 SAINT CHARLES INTERNATIONAL MARKET

Saint Charles International Market is one of the most important wholesale market and logistics platform in Europe and the biggest in France.

France imports (from Europe and other countries) nearly 4.9 billion euros of fruit and vegetables, nearly 30% of which transit through Saint Charles.

This marketing, transport and logistics platform near Perpignan also handles nearly a quarter of France's 2.7 billion worth of exports.

Spain, with 1,139,962 tons imported in 2016, is still the foremost partner, accounting for 64% of the total volume.
Morocco, in second place, supplied 423,340 tons, nearly the 24% of the volume transiting through Saint Charles.
The total import in Saint Charles in 2016 is 1,766,111 tons.

Figure 30: Saint Charles International

In Saint Charles the main transport system used for receiving and sending cargoes is the truck.
The 100% of products from Spain and 90% from France arrive by truck.
Products from Morocco arrive 50% by boat and 50% by truck.
There is also a rail terminal used for managing 10% of products from France and 100% of products from and to Paris.

Despite the predominance of road and truck transports, in last years the maritime and rail ones have been booming. Their market share is increasing constantly.

Perpignan and its region offer different rail transport possibilities:

- Conventional;
- Piggyback;

- Combined rail – road.

The conventional rail transport service with container is carried out directly inside the Saint Charles rail terminal.
The terminal, built in 1985, was extended from 370 to 750 m in length so that it can take trains of the maximum length allowed in France.
The road/rail container traffic using the terminal was almost doubled as a result, increasing to 20,000 containers a year, with nearly 50 trains a week, reaching close to its break-even point is 30,000 containers a year.
The terminal is mainly publicly-funded.
The volume of fruit and vegetables shipped through this terminal is still small and the 75% of the containers loaded come from Asia.

The Piggyback service is operated by the Lorry Rail company at Le Boulou (between Perpignan and the Spanish border) where there is a rail terminal realised using the VIIA technology system. It consists of loading freight trailers onto special lowered platform wagons that can rotate.

These systems and terminals provide a competitive road - rail transport service for the wholesale market, but also for all companies based at Perpignan and the neighbouring regions of Barcelona, Toulouse and Montpellier.

The two main seaports operate with Saint Charles Int. are the Port of Port-Ventres and the Port of Sete.

Port-Ventres, the smallest one, is a Community Entrance Point (CEP) managed by the Perpignan Chamber of Commerce.
It respects all the international duties reported in the ISPS (International Ship and Port Facility Security) Code and has available two quays where can dock two ships with a length of 155 meters and a draught of 8 meters.
The two quays are close to the refrigerated warehouses and to the rail terminal linked with the national network and from where it is possible to reach, very rapidly, Saint Charles Int.
The warehouses can host 10,000 pallets and have a total surface of 18,000 m^2. Inside them there is also a refrigeration system that can treat 17,000 m^2.

Port-Ventres is still a port with very low traffic but increasing steadily every year.
Over 300,000 tons and 20,000 TEUs were imported through this port last year, particularly from West Africa and Morocco, and all of them had as destination the Perpignan market.

5. THE MODEL

The model we are going to use is a cost based model and it is divided in two main parts: road side and maritime side.
Both of them are then in turn divided in two subparts: direct costs and external costs.

The direct costs are all those costs that a carrier has to pay for carrying out the transport commissioned.

The external costs are all those costs that the community has to suffer and that are not included inside costs payed by the carrier.
In case of maritime and road transports, these external costs are principally due to various kinds of pollution.

The way in which we are going to use this model is for finding the cheapest alternative route from the Algeciras one. This is done for all those carriers and producers that decided to give up the Andalusian port for reaching, from Morocco, the fruit and vegetables market of Spain, here represented by Mercamadrid, and of France, here represented by Saint Charles Int.

5.1 MARITIME SIDE

The maritime side direct cost consists in the sum of costs that a carrier has to spend for loading a truck in a ferry along a specific route.

The prices are calculated considering the ones that shipping companies apply on the maritime routes already existing between the origin port and the country/countries taken under analysis.

These prices are calculated considering a *fixed part* and a *variable part*.

With *fixed part* are considered all those costs for port operations as docking, loading, and discharging. They are present in all routes and are responsible on average for 1/4 of the sailing prices.

With *variable part* is considered the product between the route length and a rate to pay for each nautical mile sailed.
This rate is the average value of the ratios between price of the ticket, less the *fixed part* of each route already existing, and the respective nautical miles.

The external cost for maritime transport analysed in this thesis is the one presented in the document *"Update of the Handbook on External Costs of Transport"*, published for the European Commission by the British publicly listed company *"Ricardo - AEA".*

The cost is the sum of three single costs:

- Air pollution costs;
- Climate change costs;
- Costs of up and down stream processes.

For the evaluation of external costs, it is necessary to identify precisely the kind of vessel under use. This consideration is important because it influences many important factors:

- Type and number of engines;
- Vessel speed;
- Type of fuel;
- Average consume rate;
- Emission factor;
- Engine load factor;
- Average hold load rate.

It is important to identify also:

- The route length;
- The maximum speed inside seaport;
- The distance between port mouth and quay.

The air pollution is due to the emission of nitrogen oxides (NO_x), non-methane volatile organic compound (NMVOC), particulate matter (PM), and sulphur oxide (SO_x).
Its cost is given by the sum, for the different navigation phases and for the different kinds of engines, of the products between the pollutants emission factor (g/kW h), the navigation time (h), the engine power (kW), and the engine load factor.

The climate change is caused mainly by the quantity of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) released during the transport.

The cost evaluation procedure is focused principally on the conversion of all the three pollutant emissions in Carbon dioxide equivalent values (CO_2eq).
This conversion is realized multiplying the single quantities of pollutant emitted for the relative Global Warming Potential factor.

These factors are:

- For CO_2: 1;
- For CH_4: 25;

- For N_2O: 298.

Once found the total amount of equivalent pollutant emitted, it is possible to calculate the Climate Change cost multiplying this value for 90, that is the external cost payed by community for each ton of CO_2eq released in the atmosphere.

The up and down stream processes cost is calculated multiplying the total distance travelled, also the one inside seaport, for the dead weight tonnage (DWT) and the specific "external cost for 1000 tkm (ton kilometre)", that is different for each kind of transport.
In the case of maritime transport this value is equal to 0,35 euro per 1000 tkm.

The sum of these three pollutant costs gives us the total external maritime cost.

5.2 ROAD SIDE

The direct costs in road transport are all the costs that haulier has to pay for using some services (for example: highways or insurance) plus the costs due to the consumption of equipment or instruments used for carrying the transport (for example: tyres or gasoline).

In this analysis all these costs are divided in two group:

- Highway costs;
- Costs indicated in the document *"Observatorio de costes del transporte de mercancia por carretera".*

Highways costs are derived from crossing the data of land route with price data provided by the different highway concessionary companies (some examples in Spain: Autopista del Sol, Autopistas Abertis, Ausur, etc).

"Observatorio de costes del transporte de mercancia por carretera" is a research developed every year by Spanish Ministry of Development where it is possible to find a detailed list of costs sustained by freight hauliers in Spain.

Costs are divided depending on kind of lorry, and for each kind there is a detailed profile where is possible to find:

- Average value of power, maximum payload weight, useful load weight, number of axles and tyres;
- Average value of annual kilometres run (total, load and empty), and of fuel consumption (lt/100 km);
- Average price of tractor and trailer;

- Useful life length;
- Average costs of driver, insurance, taxes, tyres, gasoline, maintenance (euro/km) and repairs (euro/km).

The external cost for road transport, as for the maritime one, is based on the document "*Update of the Handbook on External Costs of Transport*" by *Ricardo - AEA*.

In this case the total value is given by the sum of:

- Congestion costs;
- Accident costs;
- Air pollution costs;
- Noise costs;
- Climate change costs;
- Costs of up and down stream process;
- Marginal infrastructure cost (eurocent/vel km).

6. APPLICATION OF THE MODEL TO OUR CASE OF STUDY

With the application of the model to our case of study, we are going to find all the fundamental components useful for finding which one is, or which ones are, the best alternatives for transporting Moroccan products from Tanger Med to Mercamadrid and Saint Charles Int.

The best alternatives from the economic and environmental point of view.

Whit data we have, we are going to verify also if the maritime transport system is truly always a better alternative to the road one.

6.1 MARITIME SIDE

First of all, it is important to identify which is the ferry that better matches with our case of study.

Considering the types of ferries that already operate on the routes between Europe and North Africa and that the best way, from an economic and functional point of view, for transporting lorries and trailers is with an RO RO ferry, the vessel chosen for the analysis of this thesis is the *Euroferry Corfù* that operates for Grimaldi Lines.

EUROFERRY CORFU'	Shipping company: GRIMALDI LINES
Kind of ferry	RO RO
Built	1999
Size	188x29 m
Draught	6,3 m
Gross Tonnage	29.841 t
Death Weight Tonnage	8.383 t
Engines	4 Sulzer 8ZAL40S dieslar
Fuel kind	Distillate Marine Diesel Oil
Power	23050 Kw
Cruise speed	22 knots
Specific fuel consumption	203 g fuel/kW h
Engine load factor	0,87
Garage capacity	2.500 linear meters
Number tot vehicles (trucks + trailer)	264
Number trucks	12
Number trailers	252
Number reefer spaces	40
Average load factor	0,8

Table 10: Euroferry Corfù features

6.1.1 DIRECT COST

The maritime routes already existing between Tanger Med and the Spanish and French seaports are:

- Tanger Med – Motril, operated by FRS;
- Tanger Med – Barcelona, operated by Grimaldi Lines;
- Tanger Med – Sete, operated by GNV.

The prices applied on these routes by the shipping companies are:

	Normal price (euro)	Reefer price (euro)
Tanger Med – Motril	410	460
Tanger Med – Barcelona	850	900
Tanger Med – Sete	1.689	1739

Table 11: Ticket prices applied for routes already operating

How it is possible to see, the average increase for transporting a reefer cargo is 50 euro.

Technically there is also Tanger Med - Algeciras Bay, but it was not considered because along this route prices are highly influenced by the concurrency that is nowadays present.
On this line, that is long only 7.55 nautical miles, 5 different shipping companies operate (Balearia, Transmediterranea, Inter Shipping, AML, FRS), with a daily traffic of 39 runs.

Thanks to analysis developed by the Escola Europea de Short Sea Shipping, it was noticed that generally the costs for the services provided inside ports, the so called “fixed costs”, represent 1/4 of the price requested to customers.

Considering this result, it was found that the average value of the fixed costs for services inside port that is 115 euro.

This value has to be considered twice in the calculation of the final price because it is valid for the ports of departure and arrival.

For the evaluation of the *variable part*, firstly we have to calculate the rate per nautical mile sailed that customers have to pay.

This is equal to the average value of the ratio between the ticket price, less the *variable part*, and the respective route length.

		Ratio (euro/nautical mile)	Ratio tot (euro/nautical mile)
Tanger Med – Motril	Variable part: 345 euro	2.77	1.98
	Nautical miles: 124,73		
Tanger Med – Barcelona	Variable part: 675 euro	1.25	
	Nautical miles: 538,87		
Tanger Med – Sete	Variable part: 1304 euro	1.91	
	Nautical miles: 682,5		

Table 12: Euro/nautical mile ratio, total value and value for singular operating route

The value 1,98 euro is the average price that costumers have to pay to shipping company for each mile of navigation.

Using this average value and the fixed costs value, now it is possible to calculate the ticket price should be applied to each alternative maritime route where a service is not already provided.

Where there is a service already provided it is possible to use the price applied by the shipping company.

FIXED COSTS (euro)	115	
RATIO (euro/nautical mile)	1.98	
ROUTE	DISTANCE (nautical miles)	PRICE (euro)
Tanger Med – Malaga	86.39	400.75
Tanger Med – Alicante	325	872.37
Tanger Med – Motril	*124.73*	*460*
Tanger Med – Valencia	420,62	1,061.36
Tanger Med – Barcelona	*538.87*	*900*
Tanger Med – Sete	*682.50*	*1739*
Tanger Med – Marseille	751.44	1,644.08

Table 13: Ticket prices calculated for the routes not already operating

Some considerations about the prices applied by shipping companies on the routes to Motril, Barcelona and Sete.

As revealed by FRS and Grimaldi Lines, the prices applied, respectively, to services for Motril and Barcelona, are intentionally low for a specific marketing reason.

These routes are new and still without a solid market and a solid group of costumers, therefore the prices are so low.
In order to create an interest into costumers and to push them for trying these new services, the companies decided to maintain, in this first period, a low price even if they lose money.

This is, as they wrote, *"un esfuerzo comercial promocional de la línea"* (*"a commercial sacrifice for promoting the line"*).

For Sete the situation is different, the line was opened in 2012 and it was immediately a success for GNV.
Only in 2017 the traffic with North Africa, for the Italian shipping company, increased of 32.2%.
GNV can impose a high price along its routes without problems, because there is already a profitable and successful market on these routes.

A success that gave also a justification to GNV for investing 14.2 million euro to the renovation of the Masselin quay in the Port of Sete. The new quay can now accommodate ships with a length of up to 240 meters.

For the calculation of the total external cost for each alternative route, following the scheme reported in the *Ricardo – AEA* handbook, the first step is the evaluation of the Air Pollution costs.

6.1.2 AIR POLLUTION COSTS

The data necessary are:

- Emission factors specific for the kind of engines that move the ferry;
- Average pollutants cost in Mediterranean Sea in a certain period of time.

Emission factors		
NO_x	11.6	g/Kw h
NMVOC	0.2	g/Kw h
PM	0.3	g/Kw h
SO_x	70	Kg/tons fuel

Table 14: Emission factors for High-speed diesel - MDO/MGO, Trozzi C., Emission estimate methodology for maritime navigation

Pollutants costs in Mediterranean Sea in 2016 (euro for ton)	
NO_x	750
NMVOC	1,850
PM	18,500
SO_x	6,700

Table 15: Pollutants costs in Mediterranean Sea in 2016, Ricardo - AEA, Update of the Handbook on External Costs of Transport

With the emission factor it is possible to calculate the emissions of each pollutant long the different alternative routes. These are the product between: emission factor, navigation time (inside the ports and long the route), vessel engines power and engine load factor.

Multiplying these emissions with the respective pollutants costs in Mediterranean Sea, It is possible to find the cost of each pollutant on each alternative route.

The total air pollution cost for each route is the sum of all the singular pollutant costs.

Speed values for docking operations	
Port entrance speed	10 m/s
Port internal speed	3 m/s
Rotation speed	0.7 degrees/s

Table 16: Speed values for docking operations, Ricci S., Malavasi G., MARITIME TRANSPORT

6.1.2.1 TANGER MED – MALAGA

TANGER MED – MALAGA	
Nautical miles	86.39
Navigation time (h)	3.93

Table 17: Tanger Med - Malaga, nautical miles and navigation time

	TANGER MED PORT		MALAGA PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	1,200	120
Mouth – Quay (m)	400	133	1,600	533
Rotation for docking (degrees)	180	257	120	171
Total time for docking and leaving harbour (h)			0.4	

Table 18: Tanger Med Port and Malaga Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - MALAGA	TNG MED and MALAGA ports
NO_x	0.91	0.085
NMVOC	0.02	0.001
PM	0.02	0.002
SO_x	1.12	0.014

Table 19: Tanger Med - Malaga, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - MALAGA	TNG MED and MALAGA ports
NO_x	685.6	63.7
NMVOC	29.2	2.7
PM	437.4	40.7
SO_x	7,503.3	98.2

Table 20: Tanger Med - Malaga, air pollution costs

TOTAL AIR POLLUTION COST (euro)
8,860.8

FOR ONE REEFER TRAILER (euro)
42

Table 21: Tanger Med - Malaga, air pollution cost, total value and value for one reefer trailer

6.1.2.2 TANGER MED – MOTRIL

TANGER MED – MOTRIL	
Nautical miles	124.19
Time (h)	5,65

Table 22: Tanger Med - Motril, nautical miles and navigation time

	TANGER MED PORT		MOTRIL PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	431	43.1
Mouth – Quay (m)	400	133	1,250	417
Rotation for docking (degrees)	180	257	90	129
Total time for docking and leaving harbour (h)			0.3	

Table 23: Tanger Med Port and Motril Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - MOTRIL	TNG MED and MOTRIL ports
NO_x	1.31	0.069
NMVOC	0.02	0.001
PM	0.03	0.001
SO_x	1.61	0.012

Table 24: Tanger Med - Motril, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - MOTRIL	TNG MED and MOTRIL ports
NO_x	985.7	52.3
NMVOC	41.9	2.2
PM	628.8	33.4
SO_x	12,787.2	80.5

Table 25: Tanger Med - Motril, air pollution costs

TOTAL AIR POLLUTION COST (euro)
12,612.0
FOR ONE REEFER TRAILER (euro)
59.7

Table 26: Tanger Med - Motril, air pollution cost, total value and value for one reefer trailer

6.1.2.3 TANGER MED – ALICANTE

TANGER MED – ALICANTE	
Nautical miles	325
Time (h)	14.79

Table 27: Tanger Med - Alicante, nautical miles and navigation time

	TANGER MED PORT		ALICANTE PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	2,000	200
Mouth – Quay (m)	400	133	440	147
Rotation for docking (degrees)	180	257	90	129
Total time for docking and leaving harbour (h)			0.3	

Table 28: Tanger Med Port and Alicante Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - ALICANTE	TNG MED and ALICANTE ports
NO_x	3.44	0.062
NMVOC	0.06	0.001
PM	0.09	0.001
SO_x	4.21	0.010

Table 29: Tanger Med - Alicante, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - ALICANTE	TNG MED and ALICANTE ports
NO_x	2,580.5	46.8
NMVOC	109.7	2.0
PM	1,646.2	29.9
SO_x	28,239.8	72.1

Table 30: Tanger Med - Alicante, air pollution costs

TOTAL AIR POLLUTION COST (euro)
32,727.0
FOR ONE REEFER TRAILER (euro)
155

Table 31: Tanger Med - Alicante, air pollution cost, total value and value for one reefer trailer

6.1.2.4 TANGER MED – VALENCIA

TANGER MED – VALENCIA	
Nautical miles	420.62
Time (h)	19.14

Table 32: Tanger Med - Valencia, nautical miles and navigation time

	TANGER MED PORT		VALENCIA PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	3,000	300
Mouth – Quay (m)	400	133	2,500	833
Rotation for docking (degrees)	180	257	120	171
Total time for docking and leaving harbour (h)			0.3	

Table 33: Tanger Med Port and Valencia Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - VALENCIA	TNG MED and VALENCIA ports
NO_x	0.91	0.116
NMVOC	0.02	0.002
PM	0.02	0.003
SO_x	1.12	0.020

Table 34: Tanger Med - Valencia, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - VALENCIA	TNG MED and VALENCIA ports
NO_x	3,339.3	87.0
NMVOC	142.0	3.7
PM	2,130.2	55.5
SO_x	36,542.8	134.0

Table 35: Tanger Med - Valencia, air pollution costs

TOTAL AIR POLLUTION COST (euro)
42,434.6
FOR ONE REEFER TRAILER (euro)
200.9

Table 36: Tanger Med - Valencia, air pollution cost, total value and value for one reefer trailer

6.1.2.5 TANGER MED – BARCELONA

TANGER MED – BARCELONA	
Nautical miles	538.87
Time (h)	24.52

Table 37: Tanger Med - Barcelona, nautical miles and navigation time

	TANGER MED PORT		BARCELONA PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	1,500	150
Mouth – Quay (m)	400	133	1,500	500
Rotation for docking (degrees)	180	257	90	129
Total time for docking and leaving harbour (h)			0.4	

Table 38: Tanger Med Port and Barcelona Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - BARCELONA	TNG MED and BARCELONA ports
NO_x	5.70	0.082
NMVOC	0.10	0.001
PM	0.15	0.002
SO_x	6.99	0.014

Table 39: Tanger Med - Barcelona, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - BARCELONA	TNG MED and BARCELONA ports
NO_x	4,278.0	61.5
NMVOC	181.9	2.6
PM	2,729.1	39.2
SO_x	46,816.1	94.7

Table 40: Tanger Med - Barcelona, air pollution costs

TOTAL AIR POLLUTION COST (euro)
54,203.3
FOR ONE REEFER TRAILER (euro)
256.6

Table 41: Tanger Med - Barcelona, air pollution cost, total value and value for one reefer trailer

6.1.2.6 TANGER MED – SETE

TANGER MED – SETE	
Nautical miles	682.5
Time (h)	31.06

Table 42: Tanger Med - Sete, nautical miles and navigation time

	TANGER MED PORT		SETE PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	1,100	110
Mouth – Quay (m)	400	133	1,200	400
Rotation for docking (degrees)	180	257	95	136
Total time for docking and leaving harbour (h)			0.3	

Table 43: Tanger Med Port and Sete Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - SETE	TNG MED and SETE ports
NO_x	7.22	0.073
NMVOC	0.12	0.001
PM	0.19	0.002
SO_x	8.85	0.012

Table 44: Tanger Med - Sete, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - SETE	TNG MED and SETE ports
NO_x	5,418.3	55.1
NMVOC	230.4	2.3
PM	3,456.5	35.1
SO_x	59,294.1	84.8

Table 45: Tanger Med - Sete, air pollution costs

TOTAL AIR POLLUTION COST (euro)
68,576.7
FOR ONE REEFER TRAILER (euro)
324.7

Table 46: Tanger Med - Sete, air pollution cost, total value and value for one reefer trailer

6.1.2.7 TANGER MED – MARSEILLE

TANGER MED – MARSEILLE	
Nautical miles	715.44
Time (h)	32.56

Table 47: Tanger Med - Marseille, nautical miles and navigation time

	TANGER MED PORT		MARSEILLE PORT	
	DISTANCE	TIME	DISTANCE	TIME
Port entrance (m)	1,000	100	1,500	150
Mouth – Quay (m)	400	133	1,800	600
Rotation for docking (degrees)	180	257	100	143
Total time for docking and leaving harbour (h)			0.4	

Table 48: Tanger Med Port and Marseille Port, distances and times for docking and leaving operations

EMISSIONS (tons)		
	TNG MED - MARSEILLE	TNG MED and MARSEILLE ports
NO_x	7.57	0.089
NMVOC	0.13	0.001
PM	0.20	0.002
SO_x	9.28	0.015

Table 49: Tanger Med - Marseille, emissions during navigation and inside ports

COSTS (euro)		
	TNG MED - MARSEILLE	TNG MED and MARSEILLE ports
NO_x	5,679.8	67.0
NMVOC	241.6	2.9
PM	3,623.3	42.8
SO_x	62,155.6	103.3

Table 50: Tanger Med - Marseille, air pollution costs

TOTAL AIR POLLUTION COST (euro)
71,916.2
FOR ONE REEFER TRAILER (euro)
340.5

Table 51: Tanger Med - Marseille, air pollution cost, total value and value for one reefer trailer

6.1.3 CLIMATE CHANGE COSTS

For the evaluation of the climate change costs, we need to know four new kind of data:

- Fuel density;
- Emission factor for: CO_2, CH_4 and N_2O;
- Global warming potential value for: CO_2, CH_4 and N_2O;
- CO_2eq pollution cost.

DISTILLATE MARINE DIESEL OIL DENSITY (kg/l)
0.94

Table 52: Distillate marine diesel oil density, Chevron, Everything You Need to Know About Marine Fuels

Emission factors		
CO_2	2.99	Kg per l
CH_4	0.27	Kg per l
N_2O	0.08	Kg per l

Table 53: Emission factors for High-speed diesel - MDO/MGO, Trozzi C., Emission estimate methodology for maritime navigation

Global warming potential (CO_2eq)	
CO_2	1
CH_4	25
N_2O	298

Table 54: Global warming potential values, Greenhouse Gas Protocol, Global Warming Potential Values

CO_2eq EQUIVALENT POLLUTION COST (euro/ton CO_2eq)
90

Table 55: CO_2eq equivalent pollution cost, Ricardo - AEA, Update of the Handbook on External Costs of Transport

The diesel oil density, multiplied with the mass of fuel consumed during the navigation, can give the litres of fuel consumed.

These litres, combined with the specific emission factor, are useful for finding the kilograms released by each pollutant.

Multiplying these kilograms for the equivalent global worming potential values, and summing all the results together, can give the total kilograms of CO_2eq.

The total climate change costs are equal to the product between the total kilograms and the CO2eq equivalent pollution cost.

6.1.3.1 TANGER MED – MALAGA

FUEL CONSUMED
17.6 tons
16,565 litres

Table 56: Tanger Med - Malaga, fuel consumed

EMISSIONS (kg)		
	TNG MED - MALAGA	TNG MED and MALAGA ports
CO_2	49,529.8	205.92
CH_4	4.5	0.019
N_2O	1.3	0.011

Table 57: Tanger Med - Malaga, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - MALAGA	TNG MED and MALAGA ports
CO_2	49,529.8	205.92
CH_4	111.8	0.46
N_2O	394.9	1.64
TOT	50,036.5	208.02

Table 58: Tanger Med - Malaga, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - MALAGA	TNG MED and MALAGA ports
4,503.3	18.72

Table 59: Tanger Med - Malaga, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
4,522.01
FOR ONE REEFER TRAILER (euro)
21.41

Table 60: Tanger Med - Malaga, climate change cost, total value and value for one reefer trailer

6.1.3.2 TANGER MED – MOTRIL

FUEL CONSUMED
24.3 tons
22,873 litres

Table 61: Tanger Med - Motril, fuel consumed

EMISSIONS (kg)		
	TNG MED - MOTRIL	TNG MED and MOTRIL ports
CO_2	68,388.8	168.90
CH_4	6.2	0.015
N_2O	1.8	0.004

Table 62: Tanger Med - Motril, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - MOTRIL	TNG MED and MOTRIL ports
CO_2	68,388.8	168.90
CH_4	154.4	0.38
N_2O	545.3	1.35
TOT	69,088.5	170.63

Table 63: Tanger Med - Motril, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - MOTRIL	TNG MED and MOTRIL ports
6,218.0	15.36

Table 64: Tanger Med - Motril, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
6,233.32
FOR ONE REEFER TRAILER (euro)
29.51

Table 65: Tanger Med - Motril, climate change cost, total value and value for one reefer trailer

6.1.3.3 TANGER MED – ALICANTE

FUEL CONSUMED
61.4 tons
57,721 litres

Table 66: Tanger Med - Alicante, fuel consumed

EMISSIONS (kg)		
	TNG MED - ALICANTE	TNG MED and ALICANTE ports
CO_2	172,585.4	151.19
CH_4	15.6	0.013
N_2O	4.6	0.004

Table 67: Tanger Med - Alicante, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - ALICANTE	TNG MED and ALICANTE ports
CO_2	172,585.4	151.19
CH_4	389.6	0.34
N_2O	1,376.1	1.21
TOT	174,351.0	152.74

Table 68: Tanger Med - Alicante, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - ALICANTE	TNG MED and ALICANTE ports
15,691.6	13,75

Table 69: Tanger Med - Alicante, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
15,705.34
FOR ONE REEFER TRAILER (euro)
74.36

Table 70: Tanger Med - Alicante, climate change cost, total value and value for one reefer trailer

6.1.3.4 TANGER MED – VALENCIA

FUEL CONSUMED
79.1 tons
74,359 litres

Table 71: Tanger Med - Valencia, fuel consumed

EMISSIONS (kg)		
	TNG MED - VALENCIA	TNG MED and VALENCIA ports
CO_2	222,333.2	151.19
CH_4	20.1	0.013
N_2O	5.9	0.004

Table 72: Tanger Med - Valencia, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - VALENCIA	TNG MED and VALENCIA ports
CO_2	222,333.2	150.73
CH_4	501.9	0.34
N_2O	1,772.7	1.20
TOT	224,607.8	152.27

Table 73: Tanger Med - Valencia, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - VALENCIA	TNG MED and VALENCIA ports
20,214.7	13.70

Table 74: Tanger Med - Valencia, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
20,228.41
FOR ONE REEFER TRAILER (euro)
95.78

Table 75: Tanger Med - Valencia, climate change cost, total value and value for one reefer trailer

6.1.3.5 TANGER MED – BARCELONA

FUEL CONSUMED
101.4 tons
95,305 litres

Table 76: Tanger Med - Barcelona, fuel consumed

EMISSIONS (kg)		
	TNG MED - BARCELONA	TNG MED and BARCELONA ports
CO_2	284,961.4	198.68
CH_4	25.7	0.017
N_2O	7.6	0.005

Table 77: Tanger Med - Barcelona, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - BARCELONA	TNG MED and BARCELONA ports
CO_2	284,961.4	198.68
CH_4	643.3	0.45
N_2O	2,272.1	1.58
TOT	287,876.7	200.72

Table 78: Tanger Med - Barcelona, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - BARCELONA	TNG MED and BARCELONA ports
25,908.9	18.06

Table 79:Tanger Med - Barcelona, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
25,926.97
FOR ONE REEFER TRAILER (euro)
122.76

Table 80: Tanger Med - Barcelona, climate change cost, total value and value for one reefer trailer

6.1.3.6 TANGER MED – SETE

FUEL CONSUMED
127.8 tons
120,160 litres

Table 81: Tanger Med - Sete, fuel consumed

EMISSIONS (kg)		
	TNG MED - SETE	TNG MED and SETE ports
CO_2	359,278.1	177.88
CH_4	32.4	0.016
N_2O	9.6	0.004

Table 82: Tanger Med - Sete, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - SETE	TNG MED and SETE ports
CO_2	359,278.1	177.88
CH_4	811.1	0.40
N_2O	2,864.6	1.42
TOT	362,953.7	179.7

Table 83: Tanger Med - Sete, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - SETE	TNG MED and SETE ports
32,665.8	16.17

Table 84: Tanger Med - Sete, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
32,682.01
FOR ONE REEFER TRAILER (euro)
154.74

Table 85: Tanger Med - Sete, climate change cost, total value and value for one reefer trailer

6.1.3.7 TANGER MED – MARSEILLE

FUEL CONSUMED
134.2 tons
126,182 litres

Table 86: Tanger Med - Marseille, fuel consumed

EMISSIONS (kg)		
	TNG MED - MARSEILLE	TNG MED and MARSEILLE ports
CO_2	377,284.0	21.58
CH_4	34.1	0.019
N_2O	10.1	0.005

Table 87: Tanger Med - Marseille, kg of pollutants emitted

EQUIVALENT CO_2 VALUES (kg)		
	TNG MED - MARSEILLE	TNG MED and MARSEILLE ports
CO_2	377,284.0	216.58
CH_4	851.7	0.49
N_2O	3,008.2	1.73
TOT	381,143.9	218.79

Table 88: Tanger Med - Marseille, equivalent CO_2 values

CLIMATE CHANGE COST (euro)	
TNG MED - MARSEILLE	TNG MED and MARSEILLE ports
34,303.0	19.69

Table 89: Tanger Med - Marseille, climate change cost

TOTAL CLIMATE CHANGE COST (euro)
34,322.65
FOR ONE REEFER TRAILER (euro)
162.51

Table 90: Tanger Med - Marseille, climate change cost, total value and value for one reefer trailer

6.1.4 COSTS OF UP AND DOWN STREAM PROCESSES

The last value we have to find for external costs is the one regarding the so called "up and down stream processes".

In order to calculate this kind of costs, on *Ricardo - AEA* handbook it is possible to find the specific rate for maritime transport that society has to pay (suffer) every 1000 tkm.

UP AND DOWN STREAM PROCESSES COST RATE (euro per 1000 tkm)
0.35

Table 91: Up and down stream processes cost rate, Ricardo - AEA, Update of the Handbook on External Costs of Transport

First of all, it is necessary to find the Tonne-Kilometre (tkm) value.
It is equal to the product between the total length traversed during navigation (inside and outside harbours) and the vessel Dead Weight Tonnage (DWT).

Multiplying tkm for the cost rate, it is possible to find the cost of up and down stream processes.

6.1.4.1 TANGER MED – MALAGA

TOTAL LENGTH TRAVERSED (km)
160.49
TONNE-KILOMETRE (tkm)
1,345,410

Table 92: Tanger Med - Malaga, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
470.89
FOR ONE REEFER TRAILER (euro)
2.23

6.1.4.2 TANGER MED – MOTRIL

TOTAL LENGTH TRAVERSED (km)
230.44
TONNE-KILOMETRE (tkm)
1,931,807

Table 93: Tanger Med - Motril, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
676.13
FOR ONE REEFER TRAILER (euro)
3.20

6.1.4.3 TANGER MED – ALICANTE

TOTAL LENGTH TRAVERSED (km)
602.44
TONNE-KILOMETRE (tkm)
5,050,283

Table 94: Tanger Med - Alicante, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
1,767.60
FOR ONE REEFER TRAILER (euro)
8.37

Table 95: Tanger Med - Alicante, cost of up and down stream processes, total value and value for one reefer trailer

6.1.4.4 TANGER MED – VALENCIA

TOTAL LENGTH TRAVERSED (km)
779.49
TONNE-KILOMETRE (tkm)
6,534,487

Table 96: Tanger Med - Valencia, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
2,287.07
FOR ONE REEFER TRAILER (euro)
10.83

Table 97: Tanger Med - Valencia, cost of up and down stream processes, total value and value for one reefer trailer

6.1.4.5 TANGER MED – BARCELONA

TOTAL LENGTH TRAVERSED (km)
998.44
TONNE-KILOMETRE (tkm)
8,369,951

Table 98: Tanger Med - Barcelona, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
2,929.48
FOR ONE REEFER TRAILER (euro)
13.87

Table 99: Tanger Med - Barcelona, cost of up and down stream processes, total value and value for one reefer trailer

6.1.4.6 TANGER MED – SETE

TOTAL LENGTH TRAVERSED (km)
1264.45
TONNE-KILOMETRE (tkm)
10,599,989

Table 100: Tanger Med - Sete, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
3,709.96
FOR ONE REEFER TRAILER (euro)
17.57

Table 101: Tanger Med - Sete, cost of up and down stream processes, total value and value for one reefer trailer

6.1.4.7 TANGER MED – MARSEILLE

TOTAL LENGTH TRAVERSED (km)
1,325.46
TONNE-KILOMETRE (tkm)
11,111,330

Table 102: Tanger Med - Marseille, total length traversed and tonne - kilometre

COST OF UP AND DOWN STREAM PROCESSES (euro)
3,888.97
FOR ONE REEFER TRAILER (euro)
18.41

Table 103: Tanger Med - Marseille, cost of up and down stream processes, total value and value for one reefer trailer

6.1.5 TOTAL MARITIME COSTS

Here it is possible to read a summary of all maritime costs for all the alternative routes.

TANGER MED - MALAGA		
Direct cost		
TICKET (euro)	400.75	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	8,860.8	42
CLIMATE CHANGE COST (euro)	4,522.01	21.41
COST OF UP AND DOWN STREAM PROCESSES	470.89	2.23
TOTAL EXTERNAL COSTS	13,853.7	65.64

Table 104: Tanger Med - Malaga, summary of all maritime costs

TANGER MED - MOTRIL		
Direct cost		
TICKET (euro)	460	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	12,612.0	59.70
CLIMATE CHANGE COST (euro)	6,233.32	29.51
COST OF UP AND DOWN STREAM PROCESSES	676.13	3.20
TOTAL EXTERNAL COSTS	19,521.45	92.41

Table 105: Tanger Med - Motril, summary of all maritime costs

TANGER MED - ALICANTE		
Direct cost		
TICKET (euro)	872.37	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	32,727.0	155
CLIMATE CHANGE COST (euro)	15,705.34	74.36
COST OF UP AND DOWN STREAM PROCESSES	1,767.60	8.37
TOTAL EXTERNAL COSTS	50,199.94	237.73

Table 106: Tanger Med - Alicante, summary of all maritime costs

TANGER MED - VALENCIA		
Direct cost		
TICKET (euro)	1,061.36	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	42,434.6	200.9
CLIMATE CHANGE COST (euro)	20,228.41	95.78
COST OF UP AND DOWN STREAM PROCESSES	2,287.07	10.83
TOTAL EXTERNAL COSTS	64,950.08	307.51

Table 107: Tanger Med - Valencia, summary of all maritime costs

TANGER MED - BARCELONA		
Direct cost		
TICKET (euro)	900	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	54,203.3	256.61
CLIMATE CHANGE COST (euro)	25.926,97	122.63
COST OF UP AND DOWN STREAM PROCESSES	2,929.48	13.87
TOTAL EXTERNAL COSTS	83,059.75	393.11

Table 108: Tanger Med - Barcelona, summary of all maritime costs

TANGER MED - SETE		
Direct cost		
TICKET (euro)	1,739	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	68,576.72	324.71
CLIMATE CHANGE COST (euro)	32,682.01	154.74
COST OF UP AND DOWN STREAM PROCESSES	3,709.96	17.57
TOTAL EXTERNAL COSTS	104,968.69	497.02

Table 109: Tanger Med - Sete, summary of all maritime costs

TANGER MED - MARSEILLE		
Direct cost		
TICKET (euro)	1,644.08	
External costs		
	TOTAL	*FOR ONE REEFER TARILER*
AIR POLLUTION COST (euro)	71,916.2	340.52
CLIMATE CHANGE COST (euro)	34,322.65	162.51
COST OF UP AND DOWN STREAM PROCESSES	3,888.97	18.41
TOTAL EXTERNAL COSTS	110,127.83	521.44

Table 110: Tanger Med - Marseille, summary of all maritime costs

6.2 ROAD SIDE

The highway costs are one of that expenses haulier has to pay for using a service, in this case for using infrastructure.

In Spain there are two kinds of highways, the ones managed directly by the State, and the ones managed by a concessionary company.

Usually the ones under state control are without toll, the ones under private control are with toll.

No-tolled highways are named "A-" plus one or two numbers, tolled highways add a "P" before the dash, and must be clearly identified as such in road signs.

For checking prices of tolled highways, it is possible to consult directly the website of the different concessionary companies where, by law, all tools have to be reported.

Some companies could apply different prices, "normal" and "special", for normal days and for holidays days or for day time hours and night time hours.

Some of the different routes may not require the payment of any tool thanks to the fact that they do not cross any tolled highways.

An important and influential element that must be considered is the kind of lorry under analysis.
It is important because tolls change depending on kind of vehicle, and because in *"Observatorio de costes del transporte de mercancia por carretera"* and in the Handbook by *Ricardo - AEA* the direct, indirect and external costs are divided for type of truck and number of axles.

In this thesis, the kind of lorry used for the costs analysis is the *"vehiculo frigorifico articulado" (reefer lorry),* with the following features:

- Average power: 309 kW;
- Maximum allowed weight: 40.000 kg;
- Maximum payload: 24.000 kg;
- Number of tyres: 12;
- Number of axes: 4.

Times necessary for travelling the different routes are already increased with the mandatory rest and break times for drivers.

6.2.1 DIRECT COSTS

During the research of the fastest routes for reaching Mercamadrid and Saint Charles Int., it was noticed that the tolled highways used are always under the control of the same three companies:

- In Spain
  - Autopistas Abertis (www.autopistas.com);
  - Autopista del Sol (www.autopistadelsol.com);
- In France
  - VINCI autoroute (www.vinci-autoroutes.com).

For transporting perishable products along highways there is not an increase price due to reefer trailer.

Some of the highways included in the fastest routes are beltways and city accesses roads that now are qualified as real freeways.
They are named with the first letter of the city plus a number. For example, "B-" and "M-" means that these are roads for entering in Barcelona and Madrid respectively.

In following lists, it is possible to find also Regional-managed highways, that means under the direct control of Autonomous Communities. They can be with or without tolls.

6.2.1.1 MALAGA

MALAGA – MERCAMADRID			
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
527	515	6.6	7.35

HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A7	-	-	-	-
A92	-	-	-	-
A44	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			0	0

Table 111: Malaga - Mercamadrid, highway costs

MALAGA – SAINT CHARLES INT.			
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
1,182	1,163	14.75	27.25

HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A7	-	-	-	-
A92	-	-	-	-
A44	-	-	-	-
A4	-	-	-	-
A43	-	-	-	-
A3	-	-	-	-
A7	-	-	-	-
AP7	Sagunto	Barcelona Sur	62.2	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			100.05	0

Table 112: Malaga - Saint Charles Int., highway costs

6.2.1.2 MOTRIL

MOTRIL – MERCAMADRID			
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
477	466	5.96	6.71

HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A7	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			0	0

Table 113: Motril - Mercamadrid, highway costs

MOTRIL – SAINT CHARLES INT.			
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
1,099	1,081	13.75	26.25

HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A7	-	-	-	-
A31	-	-	-	-
A7	-	-	-	-
AP7	Sagunto	Barcelona Sur	62.2	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			100.05	0

Table 114: Motril - Saint Charles Int., highway costs

6.2.1.3 ALICANTE

ALICANTE – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY		EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
418	410		5.25	6
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A31	-	-	-	-
A3	-	-	-	-
M50	-	-	-	-
TOT			0	0

Table 115: Alicante - Mercamadrid, highway costs

ALICANTE – SAINT CHARLES INT.				
KILOMETRES TOT	KILOMETRES HIGHWAY		EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
707	696		8.80	9.55
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A77	-	-	-	-
A7	-	-	-	-
AP7	Sagunto	Barcelona Sur	62.2	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			100.05	0

Table 116: Alicante - Saint Charles Int., highway costs

6.2.1.4 VALENCIA

VALENCIA – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY		EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
355	342		4.43	4.43
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A3	-	-	-	-
M50	-	-	-	-
TOT			0	0

Table 117: Valencia - Mercamadrid, highway costs

VALENCIA – SAINT CHARLES INT.				
KILOMETRES TOT	KILOMETRES HIGHWAY		EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
1,099	1,081		13.75	26.25
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)

AP7	Sagunto	Barcelona Sur	62.2	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			100.05	0

Table 118: Valencia - Saint Charles Int., highway costs

6.2.1.5 BARCELONA

BARCELONA – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
630	619	7.9	8.65	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
B20	-	-	-	-
B23	-	-	-	-
AP2	Barcelona Sur	Martorell Acceso	5.35	-
AP2	Med. Barcelona	Alfajarin	65.45	-
A2	-	-	-	-
M50	-	-	-	-
M45	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			70.8	0

Table 119: Barcelona - Mercamadrid, highway costs

BARCELONA – SAINT CHARLES INT.				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
184	178	2.3	2.3	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
B10	-	-	-	-
C58	-	-	-	-
C33	Mollet	Mollet	3.27	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			41.12	0

Table 120: Barcelona - Saint Charles Int., highway costs

6.2.1.6 SETE

SETE – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
927	900	11.6	23.35	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A9	Sete	Spanish Border	42.7	-
AP7	La Frontera	Cassà	16.45	-
C17	-	-	-	-
A2	-	-	-	-
AP2	Soses	Alfajarin	27.6	-
A2	-	-	-	-
M50	-	-	-	-
M45	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			86.75	0

Table 121: Sete - Mercamadrid, highway costs

SETE – SAINT CHARLES INT.				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
148	132	1.85	1.85	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A9	Sete	Perpignan Sud	34.2	-
TOT			34.2	0

Table 122: Sete - Saint Charles Int., highway costs

6.2.1.7 MARSEILLE

MARSEILLE – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
1,101	1,078	13.76	26.26	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A55	-	-	-	-
A7	Lancon	-	-	-
A54	-	S. M. de Crau	13	-
A9	Montpellier 1	Montpellier 1	5.6	-
A9	Montpellier S.	Spanish Border	49.1	-
AP7	La Frontera	Cassà	16.45	-
C17	-	-	-	-
A2	-	-	-	-
AP2	Soses	Alfajarin	27.6	-

A2	-	-	-	-
M50	-	-	-	-
M45	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			111.75	0

Table 123: Marseille - Mercamadrid, highway costs

MARSEILLE – SAINT CHARLES INT.			
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)
322	310	4	4

HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
A55	-	-	-	-
A7	Lancon	-	-	-
A54	-	S. M. de Crau	13	-
A9	Montpellier 1	Montpellier 1	5.6	-
A9	Montpellier S.	Perpignan Sud	14	-
TOT			34.2	0

Table 124: Marseille - Saint Charles Int., highway costs

All the other costs that hauliers have to go through for providing their services are reported in the ministerial document *"Observatorio de costes del transporte de mercancia por carretera"*, that is upgraded yearly.

For a *"vehiculo frigorifico articulado" (reefer lorry)*, they are:

PRICES FOR A REEFER LORRY		
Average sale price for tractor unit (without VAT)	99,797.54	euro
Average sale price for reefer trailer (without VAT)	69,392.93	euro
Average consumption	39	Lt/100 km
Reefer system average consumption	4	Lt/hour
Insurance annual costs	8,460.66	euro
Fiscal annual costs	1,036.17	euro
Average annual cost of driver (including social security and others)	31,575.00	euro
Annual benefits and compensations	15,624.00	euro
Maintenance costs (without VAT)	0.0222	euro/km
Repair costs (without VAT)	0.426	euro/km

Table 125: Direct operative costs for a reefer lorry, Ministero de Fomento, Observatorio de coste del transporte de mercancias por carretera

In the same document it is possible to find also the average gasoline price at petrol station.

Average gasoline price	1.052	euro/lt

Table 126: Average gasoline price, Ministero de Fomento, Observatorio de coste del transporte de mercancias por carretera

Following the list provided by *Ministerio de Fomento*, the consumptions and costs that hauliers have to sustain for each road route are:

	MALAGA	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	203	455
Reefer system consumption (lt)	29	109
Cost of gasoline consumed (euro)	244	593
Maintenance costs (without VAT) (euro)	12	26
Repair costs (without VAT) (euro)	225	504
TOT (euro)	713	1,687

Table 127: Malaga - Mercamadrid and Malaga - Saint Charles Int., direct operative costs for a reefer lorry

	MOTRIL	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	184	423
Reefer system consumption (lt)	27	105
Cost of gasoline consumed (euro)	221	556
Maintenance costs (without VAT) (euro)	11	24
Repair costs (without VAT) (euro)	203	468
TOT (euro)	646	1,576

Table 128: Motril - Mercamadrid and Motril - Saint Charles Int., direct operative costs for a reefer lorry

	ALICANTE	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	161	272
Reefer system consumption (lt)	24	38
Cost of gasoline consumed (euro)	195	327
Maintenance costs (without VAT) (euro)	9	16
Repair costs (without VAT) (euro)	178	301
TOT (euro)	567	954

Table 129: Alicnate - Mercamadrid and Alicante - Saint Charles Int., direct operative costs for a reefer lorry

	VALENCIA	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	137	204
Reefer system consumption (lt)	18	29
Cost of gasoline consumed (euro)	162	246
Maintenance costs (without VAT) (euro)	8	12
Repair costs (without VAT) (euro)	151	226
TOT (euro)	476	717

Table 130: Valencia - Mercamadrid and Valencia - Saint Charles Int., direct operative costs for a reefer lorry

	BARCELONA	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	243	71
Reefer system consumption (lt)	35	9
Cost of gasoline consumed (euro)	292	84
Maintenance costs (without VAT) (euro)	14	4
Repair costs (without VAT) (euro)	268	78
TOT (euro)	851	247

Table 131: Barcelona - Mercamadrid and Barcelona - Saint Charles Int., direct operative costs for a reefer lorry

	SETE	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	357	57
Reefer system consumption (lt)	93	7
Cost of gasoline consumed (euro)	474	68
Maintenance costs (without VAT) (euro)	21	3
Repair costs (without VAT) (euro)	395	63
TOT (euro)	1,339	198

Table 132: Sete - Mercamadrid and Sete - Saint Charles Int., direct operative costs for a reefer lorry

	MARSEILLE	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	424	124
Reefer system consumption (lt)	105	16
Cost of gasoline consumed (euro)	556	147
Maintenance costs (without VAT) (euro)	24	7
Repair costs (without VAT) (euro)	469	137
TOT (euro)	1,579	432

Table 133: Marseille - Mercamadrid and Marseille - Saint Charles Int., direct operative costs for a reefer lorry

6.2.2 EXTERNAL COSTS

As written in the model description, the components of the road external costs are six:

- Congestion costs;
- Accident costs;
- Air pollution costs;
- Noise costs;
- Climate change costs;
- Costs of up and down stream process.

For the different routes, the total amount of external costs is the sum of the six components.

Following the indications and values reported in the Handbook by *Ricardo - AEA*, the evaluation of each component is the product between the routes length and a specific rate of pollution.

These rates, different for each kind of cost, depend from the type of road crossed and from type of truck used.

The values taken for this analysis are:

CONGESTION COSTS		
Rural motorway	38.8	Eurocent/veh km
Metropolitan motorway	77.6	Eurocent/veh km

Table 134: Road congestion costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

ACCIDENT COSTS		
HGV motorway	1.8	Eurocent/veh km
HGV no urban motorway	77.6	Eurocent/veh km

Table 135: Road accident costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

AIR POLLUTION COSTS		
Motorway	2.3	Eurocent/veh km
Suburban	6.2	Eurocent/veh km

Table 136: Road air pollution costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

NOISE COSTS		
Rural DAY	1.1	Euro for 1000 veh km
Rural NIGHT	77.6	Euro for 1000 veh km
Suburban DAY	8.6	Euro for 1000 veh km
Suburban NIGHT	15.7	Euro for 1000 veh km

Table 137: Road noise costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

CLIMATE CHANGE COSTS		
Motorway	3.7	Eurocent/veh km
Suburban	3.9	Eurocent/veh km

Table 138: Road climate change costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

COSTS OF UP AND DOWN STREAM PROCESS		
Motorway	2.4	Eurocent/veh km
Suburban	3.5	Eurocent/veh km

Table 139: Road costs of up and down stream proces, Ricardo - AEA, Update of the Handbook on External Costs of Transport

MARGINAL INFRASTRUCTURE COSTS		
Motorway	2.8	Eurocent/veh km
Suburban	36.7	Eurocent/veh km

Table 140: Road marginal infrastructure costs, Ricardo - AEA, Update of the Handbook on External Costs of Transport

The total external costs for each route are:

	MALAGA	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	271	626
OTHER KIND OF ROAD (euro)	15	25
TOTAL (euro)	287	651

Table 141: Malaga - Mercamadrid and Malaga - Saint Charles Int., total external costs

	MOTRIL	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	245	581
OTHER KIND OF ROAD (euro)	14	23
TOTAL (euro)	259	604

Table 142: Motril - Mercamadrid and Motril - Saint Charles Int., total external costs

	ALICANTE	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	215	369
OTHER KIND OF ROAD (euro)	10	14
TOTAL (euro)	226	383

Table 143: Alicante - Mercamadrid and Alicante - Saint Charles Int., total external costs

	VALENCIA	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	179	275
OTHER KIND OF ROAD (euro)	17	12
TOTAL (euro)	196	286

Table 144: Valencia - Mercamadrid and Valencia - Saint Charles Int., total external costs

	BARCELONA	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	327	93
OTHER KIND OF ROAD (euro)	14	8
TOTAL (euro)	342	100

Table 145: Barcelona - Mercamadrid and Barcelona - Saint Charles Int., total external costs

	SETE	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	481	69
OTHER KIND OF ROAD (euro)	35	21
TOTAL (euro)	515	89

Table 146: Sete - Mercamadrid and Sete - Saint Charles Int., total external costs

	MARSEILLE	
	MERCAMADRID	SAINT CHARLES INT.
MOTORWAY (euro)	579	162
OTHER KIND OF ROAD (euro)	30	15
TOTAL (euro)	609	178

Table 147: Marseille - Mercamadrid and Marseille - Saint Charles Int., total external costs

6.2.3 TOTAL ROAD COSTS

In this paragraph, it is possible to read a summary of all road costs for reaching Mercamadrid and Saint Charles Int., from the seven alternative ports.

	MALAGA	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	0	100.05
Other costs (euro)	713	1,687
TOTAL DIRECT COSTS (euro)	713	1,787.05
TOTAL EXTERNAL COSTS (euro)	287	651

Table 148: Malaga - Mercamadrid and Malaga - Saint Charles Int., total road costs

	MOTRIL	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	0	100.05
Other costs (euro)	646	1,576
TOTAL DIRECT COSTS (euro)	646	1,676.05
TOTAL EXTERNAL COSTS (euro)	259	604

Table 149: Motril - Mercamadrid and Motril - Saint Charles Int., total road costs

	ALICANTE	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	0	100.05
Other costs (euro)	567	954
TOTAL DIRECT COSTS (euro)	567	1,054.05
TOTAL EXTERNAL COSTS (euro)	226	383

Table 150: Alicante - Mercamadrid and Alicante - Saint Charles Int., total road costs

	VALENCIA	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	0	100.05
Other costs (euro)	476	717
TOTAL DIRECT COSTS (euro)	476	817.05
TOTAL EXTERNAL COSTS (euro)	196	286

Table 151: Valencia - Mercamadrid and Valencia - Saint Charles Int., total road costs

	BARCELONA	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	70.8	41.12
Other costs (euro)	851	247
TOTAL DIRECT COSTS (euro)	921.8	288.12
TOTAL EXTERNAL COSTS (euro)	342	100

Table 152: Barcelona - Mercamadrid and Barcelona - Saint Charles Int., total road costs

	SETE	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	86.75	34.2
Other costs (euro)	1,339	198
TOTAL DIRECT COSTS (euro)	1,425.75	232.2
TOTAL EXTERNAL COSTS (euro)	515	89

Table 153: Sete - Mercamadrid and Sete - Saint Charles Int., total road costs

	MARSEILLE	
	MERCAMADRID	SAINT CHARLES INT.
Motorway (euro)	111.75	34.2
Other costs (euro)	1,579	432
TOTAL DIRECT COSTS (euro)	1,690.75	466.2
TOTAL EXTERNAL COSTS (euro)	609	178

Table 154: Marseille - Mercamadrid and Marseille - Saint Charles Int., total road costs

6.3 TOTAL COSTS

For a direct evaluation of the best alternative routes for reaching the two wholesale markets, here all the costs are reported and summed up.

The costs reported here are referred for the transport of one reefer trailer.

DIRECT COSTS (euro)					
		MARITIME		ROAD	TOT
Tanger Med	Malaga	400.75	Mercamadrid	713	1,113.75
			S. Charles Int.	1,787.05	2,187.80
	Motril	460	Mercamadrid	646	1,106.00
			S. Charles Int.	1,676.05	2,136.05
	Alicante	872.37	Mercamadrid	567	1,439.37
			S. Charles Int.	1,054.05	1,926.42
	Valencia	1,061.36	Mercamadrid	476	1,537.36
			S. Charles Int.	817.05	1,878.41
	Barcelona	900	Mercamadrid	921.8	1,821.80
			S. Charles Int.	288.12	1,188.12
	Sete	1,739	Mercamadrid	1,425.75	3,164.75
			S. Charles Int.	232.2	1,971.20
	Marseille	1,644.08	Mercamadrid	1,690.75	3,334.83
			S. Charles Int.	466.2	2,110.28

Table 155: Comparison between all the direct costs

EXTERNAL COSTS (euro)					
		MARITIME		ROAD	TOT
Tanger Med	Malaga	65.64	Mercamadrid	287	352.64
			S. Charles Int.	651	716.64
	Motril	92.41	Mercamadrid	259	351.41
			S. Charles Int.	604	696.41
	Alicante	237.73	Mercamadrid	226	463.73
			S. Charles Int.	383	710.73
	Valencia	307.51	Mercamadrid	196	503.51
			S. Charles Int.	286	593.51
	Barcelona	393.11	Mercamadrid	342	735.11
			S. Charles Int.	100	493.11
	Sete	497.02	Mercamadrid	515	1,012.02
			S. Charles Int.	89	586.02
	Marseille	521.44	Mercamadrid	609	1,130.44
			S. Charles Int.	178	699.44

Table 156: Comparison between all the external costs

7. ANALYSIS OF RESULTS OBTAINED

From the results obtained and from an economical point of view, it is possible see that the best choice for reaching Mercamadrid is the route Tanger Med - Motril - Mercamadrid, with a total price of 1.106,00 (= 460+646) euro. While the best choice for reaching Saint Charles Int. is the route passing through Barcelona, with a total price of 1,188.12 (900+288,12) euro.

Analysing more in deep the two total values, it is possible to see that both are results highly influenced by the ticket price costs.

In both the cases, they are routes already existing and operating and, as already considered in paragraph 6.1.1, in both the cases the prices are directly decided by the Shipping Companies and deliberately low.

Considering the model used for the maritime routes not already in function, the ticket prices for Motril and Barcelona should be:

FIXED COSTS (euro)	115	
RATIO (euro/nautical mile)	1.98	
ROUTE	DISTANCE (nautical miles)	PRICE (euro)
Tanger Med – Motril	*124.73*	*476.53*
Tanger Med – Barcelona	*538.87*	*1,295.09*

Table 157: Ticket prices values for the maritime routes already operating using the euro/nautical mile ratio system

And, consequently, the total values of direct costs should become:

DIRECT COSTS (euro)					
		MARITIME		ROAD	TOT
Tanger Med	Motril	476.53	Mercamadrid	646	1,122.53
	Barcelona	1,295.09	S. Charles Int.	288.12	1,583.21

Table 158: Direct costs values for the already operating maritime routes considering the ticket prices found

Comparing these new values with the values obtained for the other seaports, it is possible to notice that some results change:

DIRECT COSTS (euro)					
		MARITIME		ROAD	TOT
Tanger Med	Malaga	400.75	Mercamadrid	713	1,113.75
			S. Charles Int.	1,787.05	2,187.80
	Motril	476.53	Mercamadrid	646	1.122,53
			S. Charles Int.	1,676.05	2,136.05
	Alicante	872.37	Mercamadrid	567	1,439.37
			S. Charles Int.	1,054.05	1,926.42

	Valencia	1,061.36	Mercamadrid	476	1,537.36
			S. Charles Int.	817,05	1,878.41
	Barcelona	1,295.09	Mercamadrid	921,8	1,821.80
			S. Charles Int.	288,12	1,583.21
	Sete	1,739	Mercamadrid	1.425,75	3,164.75
			S. Charles Int.	232,2	1,971.20
	Marseille	1,644.08	Mercamadrid	1.690,75	3,334.83
			S. Charles Int.	466,2	2,110.28

Table 159: Comparison between all the direct costs considering the new direct costs values for the already operating maritime routes

For the route with destination Saint Charles Int., the best choice is still the one passing through Barcelona, but now with a higher total price of 1,583.21 (288.12+1,295.09) euro.
For the route with destination Mercamadrid, the new best route is Tanger Med - Malaga - Mercamadird, with a total price of 1,113.75 (400.75+713) euro.

From the environmental and social point of view, the route that releases less pollutants and social costs for reaching Saint Charles Int. is the same chosen for its direct costs: Tanger Med - Barcelona - Saint Charles Int., with a total value of 493.11 (100+393.11) euro.

For reaching Mercamadrid the best choice is the route that passes through Motril, with a total external costs value of 351.41 (259+92.41) euro.

The results obtained are principally due to the model used, that highly considers the distance travelled and the measures linked to it, like: tons and litres of fuel consumed, hours travelled, kilowatt for hour, etc.

			DISTANCE (km)		MARITIME EXT. COSTS (euro)	ROAD EXT. COSTS (euro)	TOT (euro)
Tanger Med	Malaga	Mercamadrid	159.99+527	686.99	65.64	287	352.64
		S. Charles Int.	159.99+1,182	1,341.99	65.64	651	716.64
	Motril	Mercamadrid	230.99+477	707.99	92.41	259	351.41
		S. Charles Int.	230.99+1.099	1,329.99	92.41	604	696.41
	Alicante	Mercamadrid	601.9+418	1,019.90	237.73	226	463.73
		S. Charles Int.	601.9+707	1,308.90	237.73	383	710.73
	Valencia	Mercamadrid	778.98+355	1,143.98	307.51	196	503.51
		S. Charles Int.	778.98+1,099	1,877.98	307.51	286	593.51

	Barcelona	Mercamadrid	997.98+630	1,627.98	393.11	342	735.11
		S. Charles Int.	997.98+184	1,181.98	393.11	100	493.11
	Sete	Mercamadrid	1,263.99+927	2,190.99	497.02	515	1,012.02
		S. Charles Int.	1,263.99+148	1,411.99	497.02	89	586.02
	Marseille	Mercamadrid	1,391.66+1,101	2,492.66	521.44	609	1,130.44
		S. Charles Int.	1,391.66+322	1,713.66	521.44	178	699.44

Table 160: Comparison between all the external costs

As it is possible to see, the option Barcelona, for delivering products to Saint Charles Int., is really the shortest for the number of kilometres travelled and the cheapest for the external costs value.

The situationt is different for Mercamadrid because, from a kilometric point of view, the shortest path is the one passing through Malaga (686.994 km), but the cheapest option is the Tanger Med - Motril - Mercamadrid (707.99 km).

Malaga, compared to Motril, has smaller values for the maritime distance and external cost, 159.99 km and 65.64 euro, but it has higher values for the road distance and the related external costs value, 527 km and 287 euro.
Motril is the opposite. Maritime distance and external costs are higher, 230.99 km and 92.41, road distance and pollution costs are smaller, 477 km and 259 euro.

This is an example of how, in an intermodal transport, increasing the maritime section and reducing the road one, it is possible to reduce the transports environmental impact.

7.1 COMPARISON OF THE BEST CHOICES WITH THE ALGECIRAS ALTERNATIVE

The purpose of this paragraph is to analyse if the routes found as the best, from an economic and environmental point of view, are really more attractive compared to the actual route passing through Algeciras.

For the maritime section of the path that passes through Algeciras, it is used the price applied by the shipping companies. As already mentioned, this price is not 100% reliable, because it is deeply influenced by the competition that nowadays exists and that makes this route as one of the busiest in the world.

TANGER MED – ALGECIRAS			
Nautical miles	Navigation time (h)	Normal price (euro)	Reefer price (euro)
7.55	0.34	410	460

Table 161: Tanger Med - Algeciras, features

FUEL CONSUMED
1.5 tons
1,367.55 litres

Table 162: Tanger Med - Algeciras, fuel consumed

	TANGER MED PORT		ALGECIRAS PORT	
	DISTANCE (m)	TIME (sec)	DISTANCE (m)	TIME (sec)
Port entrance (m)	1,000	100	520	52
Mouth – Quay (m)	400	133	1,500	500
Rotation for docking (degrees)	180	257	160	229
Total time for docking and leaving harbour (h)			0.4	

Table 163: Tanger Med Port and Algeciras Port, distances and times for docking and leaving operations

TOTAL LENGTH TRAVERSED (km)
17.96

Table 164: Tanger Med - Algeciras, total length traversed

	TNG MED - ALGECIRAS		TNG MED and ALGECIRAS ports	
	EMISSIONS (tons)	COSTS (euro)	EMISSIONS (tons)	COSTS (euro)
NO_x	0.079	59.3	0.082	61.6
NMVOC	0.001	2.5	0.001	2.6
PM	0.002	37.8	0.002	39.3
SO_x	0.10	649.1	0.071	474.5

Table 165: Tanger Med - Algeciras, emissions during navigation and inside ports

	TNG MED - ALGECIRAS		TNG MED and ALGECIRAS ports	
	EMISSIONS (kg)	CO_2eq (kg)	EMISSIONS (kg)	CO_2eq (kg)
CO_2	3,890.1	3,890.1	199.00	199.00
CH_4	0.4	8.8	0.017	0.45
N_2O	0.1	31.0	0.005	1.59

Table 166: Tanger Med - Algeciras, kg of pollutants emitted and equivalent CO2 values

TONNE-KILOMETRE (tkm)
150,545

Table 167: Tanger Med - Algeciras, tonne – kilometre

TOTAL MARITIME EXTRNAL COSTS (euro)		
	TOT VALUE	FOR TRAILER
AIR POLLUTION COST	1,326.9	6.3
CLIMATE CHANGE COST	371.79	1.76
COST OF UP AND DOWN STREAM PROCESSES	52.69	0.25

Table 168: Tanger Med - Algeciras, total maritime external costs

ALGECIRAS – MERCAMADRID				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
657	644	8.2	8.95	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
AP7	Manilva	Malaga	17.05	23.15
A7	-	-	-	-
A45	-	-	-	-
A92	-	-	-	-
A44	-	-	-	-
A4	-	-	-	-
M40	-	-	-	-
TOT			17.05	23.15

Table 169: Algeciras - Mercamadrid, highway costs

ALGECIRAS – SAINT CHARLES INT.				
KILOMETRES TOT	KILOMETRES HIGHWAY	EXPECTED TOT TIME (h)	EXPECTED TIME WITH RESTS (h)	
1,311	1,291	16.4	28.9	
HIGHWAY	From	To	Normal tolls (euro)	Special tolls (euro)
AP7	Manilva	Malaga	17.05	23.15
A45	-	-	-	-
A92	-	-	-	-
A44	-	-	-	-
A4	-	-	-	-
A43	-	-	-	-
A3	-	-	-	-
A7	-	-	-	-
AP7	Sagunto	Barcelona Sur	62.2	-
AP7	Parets	Frontera	28.75	-
A9	Le Perthus	Perpignar Sud	9.1	-
TOT			117.1	123.2

Table 170: Algeciras - Saint Charles Int., highway costs

	ALGECIRAS	
	MERCAMADRID	SAINT CHARLES INT.
Consumption (lt)	253	505
Reefer system consumption (lt)	36	116
Cost of gasoline consumed (euro)	304	653
Maintenance costs (without VAT) (euro)	15	29
Repair costs (without VAT) (euro)	280	558
TOT (euro)	887	1,861

Table 171: Algeciras - Mercamadrid and Algeciras - Saint Charles Int., direct operative costs for a reefer lorry

ROAD EXTERNAL COSTS (euro)		
	ALGECIRAS -MERCAMADRID	ALGECIRAS - SAINT CHARLES INT.
MOTORWAY	341	581
OTHER KIND OF ROAD	17	23
TOTAL	358	604

Table 172: Algeciras - Mercamadrid and Algeciras - Saint Charles Int., road external costs

DIRECT COSTS (euro)				
MARITIME	ROAD			
Tanger Med – Algeciras	Algeciras - Mercamadrid		Algeciras – Saint Charles Int.	
460	Normal	Special	Normal	Special
	904.05	910.15	1,978.1	1,984.2
TOTAL				
Tanger Med – Algeciras – Mercamadrid			Tanger Med – Algeciras- Saint Charles Int.	
Normal	Special		Normal	Special
1,364.05	1,370.15		2,438.10	2,905.2

Table 173, Tanger Med - Algeciras - Mercamadrid and Tanger Med - Algeciras - Saint Charles Int., total direct costs

EXTERNAL COSTS (euro)		
MARITIME	ROAD	
Tanger Med – Algeciras	Algeciras - Mercamadrid	Algeciras – Saint Charles Int.
8.28	716	1,208
TOTAL		
Tanger Med – Algeciras – Mercamadrid		Tanger Med – Algeciras- Saint Charles Int.
724.28		1,216.28

Table 174: Tanger Med - Algeciras - Mercamadrid and Tanger Med - Algeciras - Saint Charles Int., total external costs

COMPARISON DIRECT COSTS (euro)			
Mercamadrid		Saint Charles Int.	
Tanger Med - Algeciras	Tanger Med - Malaga	Tanger Med – Algeciras	Tanger Med - Barcelona

Normal	Special	Normal	Normal	Special	Normal
1,364.05	1,370.15	1,113.75	2,438.10	2,905.20	1,583.21

Table 175: Comparison between Algeciras and the two best alternatives for direct costs

COMPARISON EXTERNAL COSTS (euro)			
Mercamadrid		Saint Charles Int.	
Tanger Med - Algeciras	Tanger Med - Motril	Tanger Med – Algeciras	Tanger Med - Barcelona
724.28	351.41	1,216.28	493.11

Table 176: Comparison between Algeciras and the two best alternatives for external costs

As it is possible to see in all the cases, the alternative options chosen are always better than the previous situations.

7.2 MARITIME TRANSPORT AS ALTERNATIVE TO ROAD TRANSPORT

As last analysis of results, it is possible to verify if the maritime transport is always a better alternative to road one, from economic and environmental point of view.

In next lines and tables, the road routes and maritime routes for reaching the seven alternative ports analysed are compared for understanding which mean of transport is the best.

The routes compared are:

	MARITIME	ROAD
Malaga	Tanger Med- Malaga	Tanger Med – Algeciras – Malaga
Motril	Tanger Med – Motril	Tanger Med – Algeciras – Motril
Alicante	Tanger Med – Alicante	Tanger Med – Algeciras – Alicante
Valencia	Tanger Med – Valencia	Tanger Med – Algeciras – Valencia
Barcelona	Tanger Med – Barcelona	Tanger Med – Algeciras – Barcelona
Sete	Tanger Med – Sete	Tanger Med – Algeciras – Sete
Marseille	Tanger Med – Marseille	Tanger Med – Algeciras – Marseille

Table 177: Routes chosen for checking if maritime transport is a valid alternative to road transport

	MALAGA			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	86.9	3.93	152.98	2.59
DIRECT COSTS (euro)	400.75		Normal	Special
			664.05	670.15
EXTERNAL COSTS (euro)	65.64		88.28	

Table 178: Malaga, comparison between maritime route and road route

	MOTRIL			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	230.44	5.95	246.98	3.74
DIRECT COSTS (euro)	460		Normal	Special
			790	796
EXTERNAL COSTS (euro)	92.41		147.28	

Table 179: Motril, comparison between maritime route and road route

	ALICANTE			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	602.44	14.79	619.98	9.49
DIRECT COSTS (euro)	872.37		Normal	Special
			1,295.65	1,301.65
EXTERNAL COSTS (euro)	237.73		337.28	

Table 180: Alicante, comparison between maritime route and road route

	VALENCIA			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	779.49	19.14	783.98	22.09
DIRECT COSTS (euro)	1.061,36		Normal	Special
			1,605	1,607
EXTERNAL COSTS (euro)	307.51		433.28	

Table 181: Valencia, comparison between maritime route and road route

	BARCELONA			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	998.44	24.52	1,140.98	27.24
DIRECT COSTS (euro)	900		Normal	Special
			2,157	2,163
EXTERNAL COSTS (euro)	393.11		627.28	

Table 182: Barcelona, comparison between maritime route and road route

	SETE			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	1,264.45	31.06	1,444.98	31.14
DIRECT COSTS (euro)	1.739		Normal	Special
			2,723	2,729
EXTERNAL COSTS (euro)	497.02		815.28	

Table 183: Sete, comparison between maritime route and road route

	MARSEILLE			
	MARITIME		ROAD	
	Length (km)	Time (h)	Length (km)	Time (h)
	1,325.46	32.56	1,648.98	44.64
DIRECT COSTS (euro)	1.644,08		Normal	Special
			3,128	3,134
EXTERNAL COSTS (euro)	521.44		921.28	

Table 184: Marseille, comparison between maritime route and road route

With results obtained, it is possible to see that maritime transport is always more convenient than road transport, either in direct costs than in external costs.

The maritime direct costs are always less expensive of around the 25 - 35%.

The external ones of around the 35 - 42%.

8. CONCLUSIONS AND FINAL CONSIDERATIONS

The steady increase of perishable products transport has created many problems in the port system of South Europe.

Morocco, from being the Spanish main partner in fruits and vegetables market, has become now the main trouble.

The development of the fruit and vegetable market, the development of North African economy, the increase of SSS services thanks to EU and, principally, the opening of the new Tanger Med Port, caused an explosion of perishable products traffic from the "Black Continent" that the Port of Algeciras Bay, in Andalucía, could not manage.

Bahia de Algeciras, with its vicinity to Morocco, only 24 kilometres, is considered the natural door for African products to Europe and is the most important Spanish port for ferry traffic and fruit and vegetables traffic.

In 2016 it handled 3,756 thousand tons of fruit and vegetables, and from Tanger Med it received 313,385 HGV. Of these trucks, 266,377 were transported with a RO RO ferry.

Trucks and trailers loaded in ferries is the most common way of transport used for products coming from Morocco, and it is the modality most damaged by the solution taken by the Andalusian Port Authority.

It was decided to change the location of all the operations for handling not-coupled semitrailers, the most used modality.
From the Maritime Station they have been moved to two less desirable quays: Isla Verde and Principe Felipe.

This decision implied a reduction of 83% of daily rotations offered for this kind of traffic, from 24 to 8, and obliged many companies to undertake a research for an economically and practically feasible alternative to the port of the Estrecho de Gibraltar.

The bigger amounts of products with origins from Morocco have as intermediate destinations the two wholesale markets of Mercamadrid (Madrid, Spain) and Saint Charles International (Perpignan, France).

Considering these information, the study conducted in this thesis, that wants to help producers and carriers in the research undertaken, found, as best alternatives for carrying one trailer, the routes:

- Malaga for Mercamadrid;

- Barcelona for Saint Charles Int.

These two different destinations are, at the same time, the best between the other alternatives analysed and the best compared to the present path passing through Algeciras.

The other alternative ports analysed are: Motril, Alicante, Valencia, Sete and Marseille.

In Motril, Barcelona, and Sete there are already routes operating with Tanger Med. This consideration is important because influences the final results obtained.

During the research it was found that initially the best alternative for products with destination the Spanish market, so Mercamadrid, is the route with Motril.

But the analysis was developed considering the ticket price applied by the Shipping Company FRS for its service in this port: 460 euro.

This price, as for tickets with destination Barcelona (900 euro), is extremely low, well below market price. The same Shipping Companies, FRS and Grimaldi Lines, admitted that these prices are low for a specific marketing strategy. The purpose is to promote the new maritime routes for Africa.

The same does not happen for the route to Sete (ticket price: 1,739 euro). This route is already fully operative, and with a solid customers block, so it does not need a strategy that includes a price promotion.

Applying the model used for calculating the tickets value for the other routes, more expensive prices were found for the port of Catalunya (Barcelona) and the port of Granada (Motril).

With these prices, the total final costs for the two maritime services are:

- Tanger Med - Motril, 1,122.53 euro
- Tanger Med - Barcelona, 1,583.21 euro.

These costs are the combination of the maritime costs (ticket price for the ferry + prices for harbour services) and road costs (highway tolls + consumptions + services costs).

Comparing these final values with the ones found for the other ports, it was noticed that:

- For Saint Charles Int., the route passing through Barcelona still remains the best one;
- For Mercamadrid, the route passing through Malaga, with a total price of 1,113.75 euro, becomes the best.

Being nowadays, the environmental protection a topic really cherished in the agenda of many countries, the analysis considers also the environmental side with an evaluation of the externalities produced by all the routes.

For the maritime side, the externalities evaluated are the sum of the following costs:

- Air pollution costs;
- Climate change costs;
- Costs of up and down stream processes.

For the road side, the externalities are the sum of the same costs, plus:

- Congestion costs;
- Accident costs;
- Noise costs.

The results obtained show that for Saint Charles Int. the best choice is again Barcelona. Also for the externalities produced, Barcelona has the cheapest price compared to the other selected ports, 493.11 euro.

Different is the situation for Mercamadrid. For reaching the wholesale market of the Spanish capital, the route with the cheapest externalities is the one passing through Motril, with a total cost of 351.41 euro.

With a total external costs value of 352.64 euro, Malaga is the second in the ranking. The route passing through Malaga has a maritime section with a length of 159.99 km and a road section length of 527 km.
While the one passing through Motril has the two sections with a length of, respectively, 230.99 and 477 km.

These results show that the increase of the maritime section length, at the expense of the road one, is a positive element for the community because implies a reduction of externality costs.

The comparison of the road routes and the maritime routes shows that the utilization of the maritime ones is always a convenient choice both for carriers and the society.

The transport costs are always cheaper of the 25 - 35%, and there is a saving of pollution and externalities of around the 35 - 42%.

In fact, the routes found are not only the best alternatives between the harbours selected, but are also better alternatives compared to the Algeciras one used until now.
The fact that they include always a longer maritime section implies a general saving in direct costs and external costs.

The routes chosen for Mercamadrid, so Malaga and Motril, show an average saving of 18% in direct costs and an average saving of 52% in external costs.

The route chosen for Saint Charles Int., that is only the one passing through Barcelona, shows an average saving in direct and external costs of, respectively, 40% and 59,5%.

With these results it is demonstrated why the European Union decided to finance the SSS with a value of 2 billion of euro in the last decade, and why it has already chosen to renovate its support in the maritime transport for the next three years.

With the new program “Motorway of the seas detailed implementation plan”, the Europe proves its interest in a transport system that "guarantees not only free competition but also economic, environmental, and social cohesion" between the countries of the Union. Whit this program, Europe proves its interest in a transport system that finally found its dimension in the transport market also for short and medium routes.

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