

Article

Analysis of Intermodal Transport Potentials for Vegetables Export from Southeast Spain

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Received: 8 September 2020; Accepted: 13 October 2020; Published: 15 October 2020



Abstract: This work studies the viability of intermodal transport of horticultural products from southeast Spain to the rest of Europe. This sector has an exportation turnover of 4100 million € and accounts for 69% of total Spanish exports and 35% of the consumption of vegetables in the European Union. The transportation services for the sector are carried out entirely by refrigerated trucks. Due to increased cost, transit limitations, and the strategic dependence on only one transport mode, it is necessary to seek out alternative logistics formulas. In this sense, intermodal transport could be a good option as it can reduce cost and the environmental impact of transport. This paper analyzes the problems involved in using intermodality by conducting a survey among exporters with the additional goal of looking for viable routes using road + short sea shipping. The impact of the transport modal shift on exports is also analyzed using a gravity model. The results show that the route from southeast Spain to the United Kingdom is the most viable. What is more, this strategy can increase exports to this country by reducing transport costs. In general, intermodality can help improve the competitiveness of the Spanish horticultural export sector.

Keywords: logistics; truck; short sea shipping; export gravity model

1. Introduction

Transport represents an important part of the European Union economy and is a strategic sector: it employs almost 10 million people and accounts for approximately 5% of GDP [1]. Despite its importance, the structure of the sector is often called into question, especially in recent years as the European Commission has a clear commitment to the implementation of “clean mobility”. These EU policies on land traffic reflect the context of structural change and challenges that the road transport sector currently faces. The Commission has recently undertaken several initiatives to promote the development of the European Transport Area—a policy that it has been pursued for decades. More specifically, the first standards in history on CO₂ emissions applicable to heavy vehicles have been introduced, promoting a low-emission mobility system [2]. In 2025, the average CO₂ emissions of new trucks will have to be 15% lower than in 2019. For 2030, a reduction target of at least 30% compared to 2019 has been established. In addition, in the case of freight, there has also been a proposal to achieve a modal transfer of 50% of road transport to rail and maritime transport.

Several researchers have investigated the relationship between transport costs and international trade [3–9]. There is evidence that transport costs have a negative impact on trade, although depending on the industry and commodities analyzed [5,7]. However, there are no specific studies for highly perishable goods, such as fruits or vegetables. In the case of Spain [7], it is seen that some high value-added sectors are more sensitive to transport cost changes.

This work's sector of analysis is Spanish horticulture, with special mention of Almería (southeast Spain) as the main province in production and exportation. Other important neighboring provinces are Murcia and Granada. More specifically, the present study analyzes the transport of vegetables (perishable) from southeast Spain to the European Union and the feasibility of a modal shift using short sea shipping (SSS). The European Union is Spain's fundamental market, representing 96% of the total exported (Figure 1): Germany is the main destination with 27% of the total, followed by France (16%) and the United Kingdom (14%). Currently, 76% of production is destined for exports [10]. Regarding the sales channel, it should be noted that the large-scale European distributors (Aldi, Edeka, Tesco, Carrefour, Lidl, etc.) absorb 70% of purchases from Spanish producers [11]. Altogether, 35% of all vegetables purchased by European consumers come from southeast Spain [12]. This area represents 69% of the total Spanish export of vegetables [13].

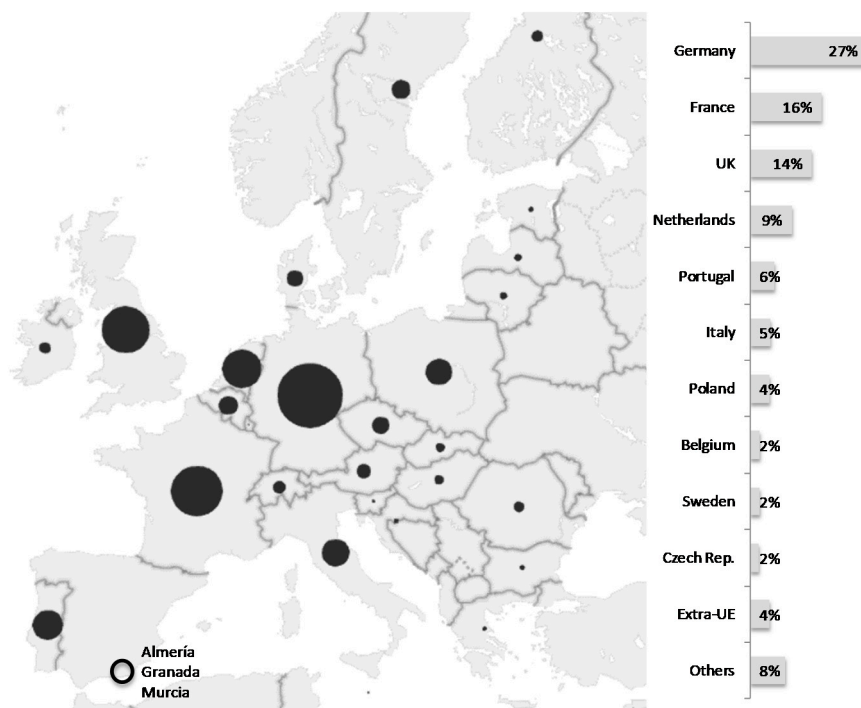


Figure 1. Destination of Almería + Murcia + Granada vegetable exports (Tons) in 2019. Source: Own elaboration based on [13].

Road transport is currently the most common means of international transport, due to the need to fulfil the conservation requirements of perishables (up to 98%). The combination of flexibility, speed, transparency, simplicity, and the absence of problems crossing borders makes road transport, especially for short distances, a modality with which it is difficult to compete [14]. As for its drawbacks, there is an upward trend in its cost, apart from the short-term declines in recent years due to cheaper fuel, although this expense represents 23% of the total cost of transport by truck [15], and it is only surpassed by the labor costs included in the different phases of the process (Figure 2). It is worth noting that in an international transaction, transport cost can account for 13–27% of the sale price [16]. This highlights the need to seek out alternatives and/or complements to modify the transport pattern within the perishables supply chain.

In the Spanish case, fruit and vegetable exports are transported using refrigerated trucks, thus this sector is highly dependent of road transport. However, there are a number of potential risks that threaten this means of transport, such as future eco-taxes and the trend towards increasing costs [17]. This context makes it necessary to find logistics alternatives, and the use of intermodality (ships and trucks) could be the easiest option to implement.

The intermodal option for the southeast of Spain for fruit and vegetables has been studied in various works [18,19], all of them based on the premise of creating ad hoc lines that could make a modal shift more feasible. The main problem identified was the atomization of the supply (small companies), which made it difficult to group and coordinate loads. The novelty of this work is that it focuses on developing routes that are already operational today, so that the speed of implementation would be faster once the decision has been made. In addition, this work seeks to contribute to the literature by answering the following research questions: (i) what are the obstacles, according to exporters, that hinder the use of intermodality for highly perishable products?; (ii) What economic and environmental effects can the implementation of intermodality have on these types of products?; (iii) Can intermodality, through transport cost reduction, increase exports?

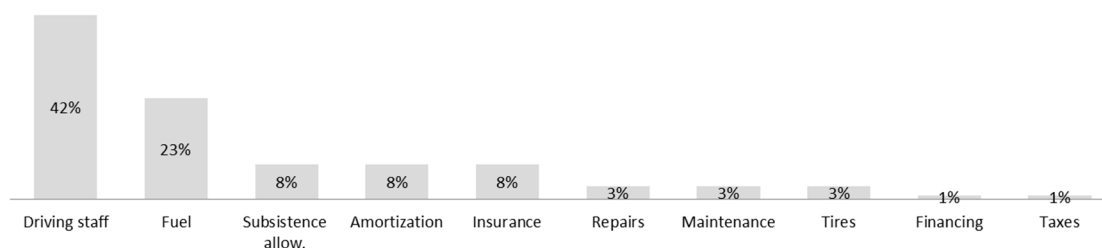


Figure 2. Cost detail of an articulated refrigerated truck, 2017. Source: Own elaboration based on Spanish Ministry of Public Works and Transport data [15].

2. Intermodality and SSS

Intermodality is understood as the movement of goods in the same load-carrying unit, using two or more modes of transportation without handling the goods when changing the mode of transportation, and where most of the route is by rail or inland waterway [20]. It is presented as the logistics system with greatest efficiency and respect for the environment and it is conducted in a series of stages [21]: (i) pick up in the area of origin and transport by road to the intermodal terminal; (ii) transfer of the goods to the following means of transport used (rail, sea, air); (iii) transport of the cargo between the intermodal terminals of origin and destination; (iv) transfer of the products to a truck; and, (v) distribution by road from the terminal to the final destination of the goods.

The main objective of intermodality is to take advantage of the strengths of different means of transport in an integrated chain, thereby optimizing economic performance. However, for intermodality to be considered as an alternative to long-distance road transport, the general costs have to be equal or less, and the additional costs incurred by pre- and post-transport, as well as the transfers at the intermodal terminals, must be compensated [22].

There are different intermodality options, such as rail + road, rail + sea, or sea + road. However, given the lack of development of the railway lines that surround Almeria and the advantages of SSS, the intermodal option that prioritizes maritime transport and road is the most feasible alternative from the southeast of Spain.

Furthermore, there are not only economic benefits but also ecological benefits, since by combining different means and using the most appropriate one for each part of the trip, environmental impact is reduced [20]. For this reason, the European Union has included intermodality as a priority strategy in the different White Papers on Transport, initiatives for addressing congestion on the main road transport routes, decreasing CO₂ emissions, and reducing accidents [23,24]. In any case, it should be noted that the issues with road transport can be solved using other strategies. For example, collaborative freight transport [25], or the collaboration among road transport carriers and ports [26] in order to reduce terminal congestion and flatten workload peaks [27]. In fact, optimization of port operations is a common strategy used to improve transport sustainability within intermodality [28].

In Spain, following the line established by the EU, intermodality forms part of the action guidelines of the Strategic Plan for Infrastructure and Transport 2020, both for passenger and freight transport [29].

In relation to the latter, among its objectives are: (i) the improvement of the intermodal capacity of ports and their rail access; (ii) the consolidation of the intermodal network of logistics platforms and freight centers in cooperation with the rest of the public administrations, operators, and the private sector; (iii) the creation of multimodal freight corridors that complement the traditional corridors; and, (iv) the development of motorways of the sea.

Today, there are a multitude of regular shipping lines that connect EU Member States to each other and to other riparian countries, in a type of navigation known as short sea shipping (SSS). This is understood as the movement of goods and passengers by sea between ports located in the territory of the European Union or between those ports and ports located in non-European countries with a coastline in the seas that surround Europe, according to community regulations and Spanish legislation. For the past two decades, the European Union has led the promotion of maritime corridors as an alternative to road transport. The need to establish a level playing field between transport modes, as well as to reduce congestion and other environmental damages caused by road transport, has been identified as the main motivation [30].

This transport system is part of the maritime–terrestrial chains and its competitiveness depends on covering all levels of quality and price imposed by the demand for transport [31]. Furthermore, to be effective and efficient, there must be reasonable alternative chains of rail and/or road transport. Consequently, the concept of SSS in Europe is also based on competition between maritime–terrestrial and exclusively terrestrial chains [32].

The SSS concept is linked to the so-called Motorways of the Sea (MoS)—routes between certain maritime areas in which it is possible to establish logistics chains, with simplified customs and administrative procedures, and also to introduce common traffic management systems. In other words, the MoS come from the idea of creating a permanent “route” at sea, establishing routes with a defined schedule and ports of origin and destination, which will not be changed in the short term. They provide a door-to-door transport option that integrates SSS with road transport and the use of trucks for the pick-up and delivery links [33].

The potential of rail and sea transport has barely been exploited in the case of fruits and vegetables due to the reluctance of exporters to use anything other than trucks, especially in European destinations such as Germany or England, due to the flexibility of this option when offering a “door-to-door” service. Besides operator preference, there are other reasons that explain this situation, for example, the lack of an infrastructure that links maritime transport with surface modes and eliminates the restrictions derived from the breakdown of transit chains [34]. In this sense, intermodal transport solutions can cause the transit time to be excessive or the product to be damaged in transshipments. However, these obstacles can be managed, therefore intermodal transport does have a high growth potential.

However, at the European level, there are rail and sea connections that allow the transport of all types of goods across the continent, and technological improvements are being achieved which, in turn, lead to the improvement of logistics for perishable goods. Regarding SSS, the minimum requirements that facilitate the successful transit of these products are [15]:

- Groupage loads to reduce the cost per transit, together with ensuring minimum loads to guarantee regular traffic.
- The organization of the origin operators is required to complete loads.
- Client participation is not essential since there are various cargo storage options in ports.

The main obstacle hindering the use of this system is the delay and randomness of delivery times, a circumstance that is also repeated in rail transport.

In summary, intermodality presents future possibilities due to the saturation of road transport. It streamlines the transport logistics chain whilst reducing energy consumption, promotes the proper use of infrastructure, and reduces environmental impact by taking advantage of the capacity of maritime transport and the greater flexibility of road transport. Furthermore, public policies and private initiatives are aimed at promoting alternatives to using trucks.

3. Methodology

Intermodality is an efficient and sustainable solution to road transport as long as the general costs are equal to or less than the latter, and times and conditions are guaranteed to ensure the final quality of the perishables. In this work, the intermodal option prioritizing maritime transport is the alternative under examination.

Of the different ships used to perform the basic operations of SSS, the Ro-Ro type (roll-on-roll-off, in which the ship transports the load on wheels, using a ramp for loading and unloading) is the most suitable for short sea distances, as in the case of this work. Despite a higher cost compared to vertical loading systems (Lo-Lo ships), they allow for the use of the refrigerated truck of origin, provide regular and more frequent services, and reach higher speeds at sea [35]. Ro-Ro transport represents 14% of total SSS in the EU28; 6% of total maritime transport and 1.3% of goods transported in the EU [36].

Most of the intermodal route feasibility studies contemplate the study of minimum load thresholds, the predisposition of the end user, the optimal determination of destinations, and the comparison of key decision variables (time and cost) with respect to the base mode of transport, in this case trucks [19,20,37]. For this reason, four analyses are carried out (Figure 3):

- Study of the propensity to set up: aimed at verifying whether there is a real interest in the modal shift of transport with southeastern Spain's agri-food companies. It is determined from a survey of 19 fruit and vegetable marketing companies with a combined market volume of 327,000 tons. The survey was designed as a Google form, to be answered online via a web link sent by email. For this reason, it was necessary to contact the Association of Organizations of Fruit and Vegetable Producers of Andalusia (APROA). This association provided the contact information (e-mails) of the commercial manager of each company. In short, besides the control questions (commercial volume, extent of transport controls, average transported distance, willingness to collaborate), the questionnaire focused on ascertaining the reasons for not using maritime transport and for the most important factors when selecting a transport system for perishables.
- Calculation of feasible goods transit: defining the volume to be transported along the Atlantic and Mediterranean area. This calculation is made using ICEX export data (year 2019), accepting that the most populated areas are those with the highest purchasing capacity, and therefore with greater importation, and assuming a percentage of the exports from Granada (20%) and Murcia (10%) as part of the Almeria hub. These percentages were reached by consensus after an interview with commercial managers from Granada and Murcia.
- Identification of optimal unloading endpoints: By searching for operators and conducting an analysis of existing routes, although for other kind of goods. This strategy accelerates the implementation of intermodality against the creation of ad hoc maritime routes. For example, facilitating the groupage of loads, which was carried out using the transport chain simulator CoModalWeb 2.0. This tool was designed by the Ministry of Public Works and Transport in collaboration with the Spanish Short Sea Promotion Center, the University of Cantabria, the European Short Sea Network, and the Port Authorities of the main Spanish ports. Among all options shown by the simulator, the shortest transit time route was chosen as it is the most important selection criterion for perishable products (see Table 1). A preliminary analysis of this work can be seen in [38].
- Analysis of costs, transit time, and CO₂ emissions for road and intermodality transport: calculating costs, transit times, and environmental impact in the current situation (land route by refrigerated truck) and the potential (intermodal land-sea use). The simulator CoModalWeb 2.0 was also used for this task.
- Gravity model applied to the Atlantic and Mediterranean export areas: the gravity model tries to explain commercial fluxes between different areas based on characteristics of produce origin and its destination (income, population, distance, etc.). In the last section of this paper, a gravity model is used to determine the impact of transport costs on the volume of exports for the United Kingdom,

Mediterranean, and Atlantic area. In the context of the agri-food sector, different studies have applied this methodology, e.g., [39] assess the determinants of Italian F&V exports; [40] apply a similar analysis in the case of Turkey's citrus exports; [41] focus on tariffs for non-EU Mediterranean countries. These works estimate gravity equations using distance as a proxy of transport costs. In our case, we start with the generalization of the function proposed by [42] with the explicit inclusion of transport costs. We also estimate a demand model based on a log-linear form of a gravity equation. Similar applications can be found in [7,43,44], and [41].

Table 1. Factors to consider when choosing a transport system, according to respondents.

	Average	Stand. Dev.
Shipping is done in the shortest delivery time possible	4.3	0.7
Costs are the lowest	3.9	0.9
The quality of the products shipped depends on production standards and the regulations of the destination country	3.1	1.1
A transport system and service requested by the client is used	2.6	0.7
The most environmentally friendly transport system is used	2.2	0.8

Note: Rating from 1 to 5 where 5 is the most important and 1 the least. Source: Own elaboration.

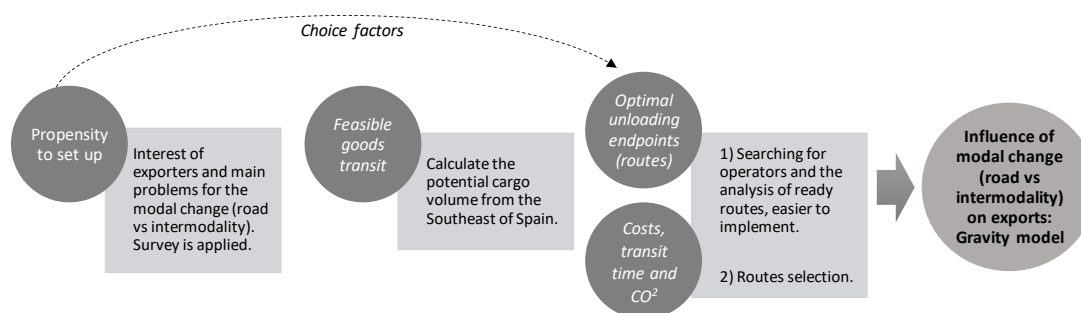


Figure 3. Summary of the methodology. Source: Own elaboration

4. Results and Discussion

4.1. Propensity to Set Up

The analysis of the surveys shows that the average goods transport time is 45 ± 11 h; the Spanish companies assume and manage an average of $32 \pm 9\%$ of the traffic, and the rest of the freight is managed by the client.

Although maritime transport had been used at some point by 27% of the respondents, its average use was established at less than 2%. In this regard, the commercialization companies who had never used maritime transport stated that the main reason was that there was no guarantee the product would arrive on time. The other two most important reasons were lack of knowledge of the system and the belief that the conservation of quality is not guaranteed (Figure 4).

On the other hand, the most important factor when choosing a transport system is that the shipment is made in the shortest possible time, followed by the lowest costs (Table 1). In addition to those evaluated, the interviewees described three other factors: the frequency of the means of transport, which has repercussions on time, the availability in real time of the means of transport, and that there are no real alternatives to the truck.

Finally, 100% of the respondents expressed their willingness to temporarily partner with other companies to carry out joint shipments using new transport options.

Surveys show that although the modal shift can be led by the commercialization companies, it must be done in conjunction with their main clients—the large European distributors—since they

are the ones who actually manage most of the shipments. In addition, according to the bibliography, maritime transport is practically not used at all due to issues of time.

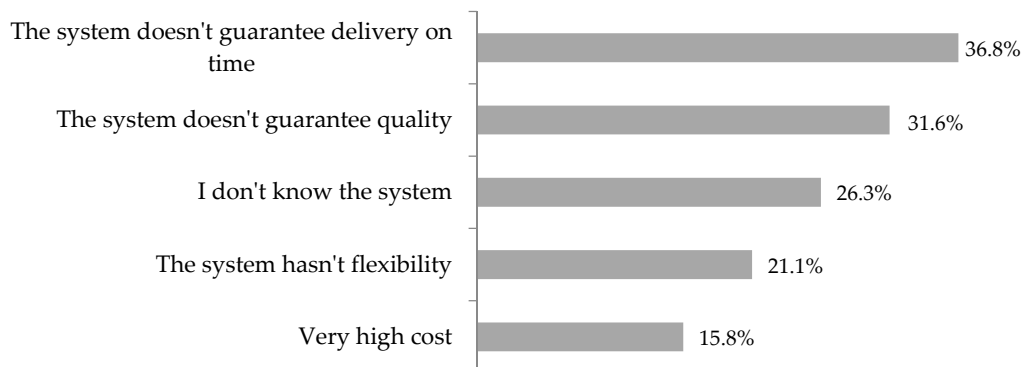


Figure 4. Reasons why maritime transport is not used according to respondents. Source: Own elaboration.

Regarding the criteria for choosing a transport system, guaranteeing times and costs are the most important factors. However, there is a contradiction in the sector, since whilst European policies and consumer trends increasingly prioritize environmental sustainability, this is the criterion least valued by the surveyed commercialization companies.

As a whole, the surveys show a predisposition towards new forms of transport provided that shipping times and costs are guaranteed, and training is available.

4.2. Calculation of Feasible Goods Transit

To know the feasibility of the proposal, it is necessary to calculate the current fruit and vegetable demand from Almeria on the Atlantic and Mediterranean basins. On the one hand, the priority countries are those that have been the largest importers of products from Almeria for years, more specifically, Germany, France, the United Kingdom, the Netherlands, and Italy. On the other hand, there is a secondary area of complementary countries that, although they import a smaller share, can benefit from intermodal lines due to their proximity and good connections with the priority area: Belgium, Switzerland, Austria, and Ireland (Figure 5). Given the need to add a second ship upon arrival in the United Kingdom and due to the low volumes required, Ireland was not considered as within the British area of influence for calculation purposes.

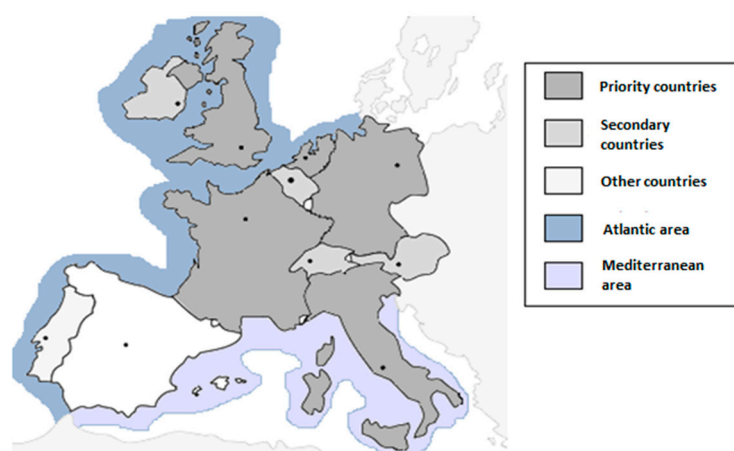


Figure 5. Location of the Almeria fruit and vegetable demand in western Europe. Source: Own elaboration.

Based on the population density of these countries, the final demand is estimated (or the consumption or necessary supply), assuming that the most populated areas are those with the highest purchasing capacity. For example, in France, the Atlantic slope is prioritized due to the existence of high demand in the Paris hub. The same is true in Germany due to the Hamburg Hub. [19].

A distinction is made between the Mediterranean and Atlantic areas and the United Kingdom is considered to have sufficient demand to use a direct line and avoid using a second ship from the first port, thereby saving on time. In addition, the possibility is contemplated that 20% of Granada's exports and 10% of Murcia's are marketed. Taking into consideration the areas to be supplied as well as the approximate volumes and production, the estimate of the possible transit is obtained (Table 2).

Table 2. Traffic estimation according to destination. 2019. Tons.

	Atlantic Area		Mediterranean Area
Estimated transit (Tons)	100% United Kingdom	60% France + 75% Germany + 100% (Belgium + Netherlands)	40% France + 25% Germany + 100% (Italy + Switzerland + Austria)
Almeria (100%)	341,998	1284,432	632,269
Granada (20%)	4162	21,125	7041
Murcia (10%)	34,705	63,934	31,250
Total	380,865	1369,491	670,560

Source: Own elaboration using [13] data.

The three main zones that have been selected have the capacity to distribute 78.7% of current exports from Almeria, 8.1% from Murcia, and 15% from Granada.

4.3. Determination of Optimal Unloading Endpoints

It is understood that the optimal unloading endpoint in each of the three selected areas (according to Figure 5) must be in a strategic position with short connections to the different demand areas. With this criterion, the search for operators is limited to the south and center of England for the United Kingdom, the north of France, Belgium or the Netherlands on the Atlantic coast, and northeast Italy in the Mediterranean basin.

As for Spain, among the different ports that operate with Ro-Ro ships, the most important are Santander, Bilbao, and Vigo on the Atlantic coast, and Barcelona and Valencia on the Mediterranean.

Analyzing the possible routes from these ports to the established optimal unloading areas, seeking the shortest transit time (taking into account the highest frequencies), the best prices between shipping companies and the shortest land distances, three unloading ports are selected:

- To the United Kingdom, Portsmouth (England) via Bilbao.
- On the Atlantic coast, Le Havre (France) via Santander.
- On the Mediterranean coast, Savona (Italy) via Valencia.

4.4. Analysis of Costs, Transit Time, and CO₂ Emissions

Five routes are identified for the Atlantic Ocean (of which one is direct to the United Kingdom) and another five for the Mediterranean Sea (Table 3). Figure 6 shows an example of the proposed routes.

Table 3. Routes selected for analysis from the Atlantic and Mediterranean coasts.

	Intermodal				Road		
Atlantic Ocean	UK	Almeria	Bilbao	Portsmouth	London	Almeria	London
	GERMANY	Almeria	Santander	Le Havre	Berlin	Almeria	Berlin
	FRANCE	Almeria	Santander	Le Havre	Paris	Almeria	Paris
	NETHERLANDS	Almeria	Santander	Le Havre	Amsterdam	Almeria	Amsterdam
	BELGIUM	Almeria	Santander	Le Havre	Brussels	Almeria	Brussels
Mediterranean Sea	GERMANY	Almeria	Valencia	Savona	Munich	Almeria	Munich
	FRANCE	Almeria	Valencia	Savona	Marseilles	Almeria	Marseilles
	ITALY	Almeria	Valencia	Savona	Rome	Almeria	Rome
	AUSTRIA	Almeria	Valencia	Savona	Vienna	Almeria	Vienna
	SWITZERLAND	Almeria	Valencia	Savona	Bern	Almeria	Bern

Source: Own elaboration.

**Figure 6.** Example of selected routes for comparison. Source: Own elaboration.

For each route, the simulator CoModalWeb 2.0 bases its predictions on 18 net tons of refrigerated cargo in semi-trailers by land and sea with Ro-Ro ships. In addition, it is considered that only one driver is in the vehicle and the time of each journey includes both the daily rest and the obligatory breaks in daily driving. The transit times and costs of the maritime transport are provided by the shipping companies.

The parameters to be defined for the simulator are: (i) the costs in €/km, calculated based on the nominal cost in the year 2018 for a double-axle refrigerated vehicle, according to the Ministry of Development, and (ii) the average speed for the land sections in km/h, obtained from the European Union Road Safety Policy (Online: http://ec.europa.eu/transport/road_safety/going_abroad/index_es.htm), prioritizing transport on divided highways rather than expressways, to avoid tolls, and applying a 5% reduction to the maximum road speed for this type of vehicle, assuming losses along the way (due to the use of secondary roads, highway ramps, inclines, among others). Finally, all the current routes for the selected origin and destination are shown, in our case prioritizing transport time—the most important choice factor for perishable products.

The results obtained were analyzed differentiating between the Atlantic and the Mediterranean coasts (Table 4).

Table 4. Comparison between intermodal route (road + ship) versus the current one (road) for each destination country.

Atlantic Ocean					
Country	Cost	Time	Cost	CO ₂ Emission	
BELGIUM	+10.2%	+26.4%	12.9 h	+12.7%	−29.3%
NETHERLANDS	+9.3%	+1.9%	1.2 h	+11.3%	−27.1%
FRANCE	+18.5%	+31.6%	14.1 h	+20.6%	−28.6%
GERMANY	+18.2%	+21.6%	14.7 h	+18.7%	−15.1%
UK	−26.0%	+6.9%	3.5 h	−8.4%	−48.4%
Mediterranean Sea					
Country	Cost	Time	Cost	CO ₂ Emission	
AUSTRIA	−17.0%	+16.5%	10.8 h	−9.9%	−39.8%
SWITZERLAND	−9.1%	+30.1%	13.4 h	+3.3%	−41.8%
FRANCE	+14.0%	+103.3%	28.3 h	+29.6%	−30.8%
GERMANY	−18.2%	+19.1%	9.7 h	−8.5%	−44.4%
ITALY	−22.8%	+20.9%	10.1 h	−13.0%	−49.1%

Source: Own elaboration.

Regarding the Atlantic zone, the studied intermodal routes to western Europe are 9–18% more expensive than using only road transport and transit time increases by an average of 10 h. However, the direct intermodal route to the United Kingdom is 26% cheaper and the transit time increases by only 3.5 h compared to trucks, but with almost half the pollution. For the rest of the Atlantic lines, the intermodal option reduces CO₂ emissions by around 25%. Overall, the sea–land route to the United Kingdom is the only feasible option since it is less expensive and the increase in transit hours is not significant (Figure 7).

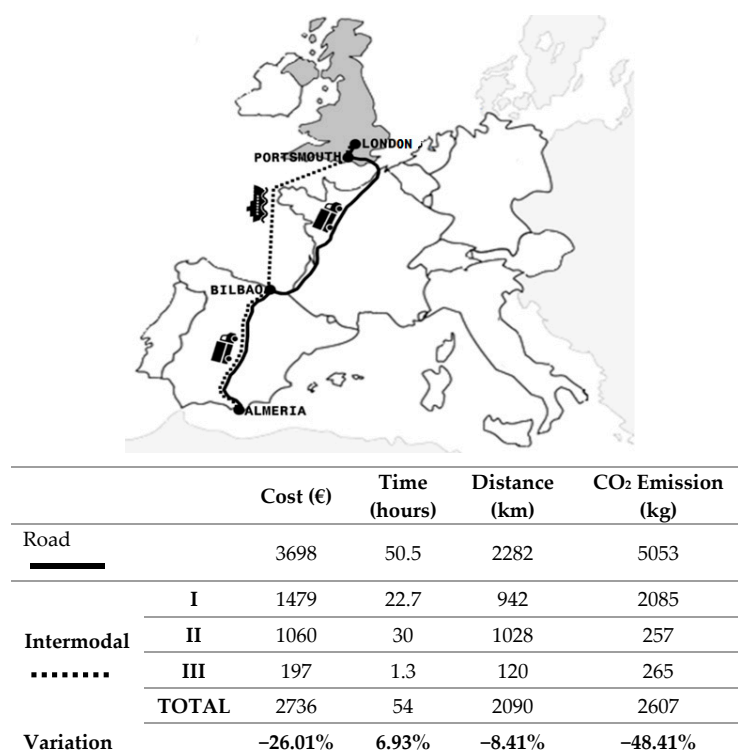


Figure 7. Most feasible route: UK via Atlantic Ocean. Source: Own elaboration.

In relation to the Mediterranean basin, the studied intermodal route to the south of France is not profitable, neither in terms of cost nor time. However, the rest of the routes are between 10–22% cheaper, although with an average time increase of 11 h. In this case, CO₂ emissions are reduced by 40–50% with the intermodal option (without considering France). Of the routes studied along this coast, the intermodal route to Italy is the best for cost difference and CO₂ reduction, but it increases transit time by 10 h.

In all situations, it should be noted that the cost difference would be reduced by introducing tolls and external costs (derived from accidents, congestion, etc.), which would increase truck transit time by around 5–10%, depending on the route. Furthermore, the addition of a second driver would reduce the time it would take to cover the land sections, while the management of the return of the full truck back to Almeria would reduce transport costs and is a more sustainable option than an empty return.

Within the Spanish Guidelines for the drafting of specifications regarding the environmental actions taken by Fruit and Vegetable Producer Organizations—the legal association in which the majority of Spanish commercialization companies are grouped according to regional regulations—a section (Action 7.26. Year 2017. Online: https://www.mapama.gob.es/es/agricultura/temas/regulacion-de-los-mercados/directricesmedioambientales2017_tcm30-380318.pdf) is included, stipulating that aid can be received for the total difference in costs between rail or sea transport generated in the year in question and the average cost of road transport generated in the previous two years.

4.5. Gravity Model Applied to the United Kingdom, the Atlantic and Mediterranean Export Areas

The analysis incorporates annual data for the period 1995 to 2019 (25 years) from Spain to the United Kingdom, Atlantic and Mediterranean export areas [13]. We use the Spanish Ministry of Public Works and Transport databases [16] for data on transport costs. In a time period t , the variables used are:

- Exports Y_{it} : denotes the Spanish vegetable exports (The products included are pepper, tomato, cucumber, zucchini, eggplant, lettuce, green bean, melon, and watermelon) to area i (in tons) in the year t . In our case, the United Kingdom, the Atlantic and Mediterranean export areas [13].
- Prices p_i : the vegetable import price to area i . Calculated by dividing export value by tons [13].
- Relative income ($M_{it} = m_{jt}/m_{it}$) between the importing and exporting area: where m_{it} is the real Spanish gross domestic product (GDP) and m_{jt} is the average GDP for importer area [45] according to the percentages included in Table 2 for each area.
- Transport costs (T_{it}): costs in euros of an articulated refrigerated truck to area i multiplying a unit cost in euros per kilometer [15] by the mean distance in kilometers to area i . In addition, we calculated the center of gravity of the Atlantic and Mediterranean area to determine the halfway point of unloading.

All variables were transformed into logarithms (ln) and then the variations (Δ) of one period were calculated. The specification process has considered the stationarity of the data to avoid problems of spurious regressions for the use of non-stationary variables. However, an exception arises when the variables are integrated to order one, and the combinations of the variables are stationary, that is, they are cointegrated. Given the relationship of co-integration, an error correction mechanism (ECM) can be formulated to model the short and long-term dynamics of the data, according to the following model calculated in 2 stages [46]:

$$\Delta \ln Y_{it} = \alpha + \partial_{1i} \Delta \ln p_{it} + \partial_{2i} \Delta \ln M_{it} + \partial_{3i} \Delta \ln T_{it} + \varnothing_i ECM_{it-1} + \varepsilon_{it},$$

where the equilibrium model is calculated incorporating the long-term residual ECM_{it-1} estimated in a previous stage:

$$ECM_{it-1} = \ln Y_{it-1} - \beta_{1i} \ln p_{it-1} - \beta_{2i} \ln M_{it-1} - \beta_{3i} \ln T_{it-1}.$$

The estimates can be seen in Table 5:

Table 5. Estimates of the gravity equations. Dependent variable = $\Delta \ln Y_{it}$.

	UK	Medit. Area	Atlantic Area
Constant	0.071	0.062	0.281 *
$\Delta \ln p_{it}$	-0.120	-0.149	-0.461 *
$\Delta \ln M_{it}$	0.391 *	-0.098	0.034
$\Delta \ln T_{it}$	-0.211 *	-0.139 *	-0.101
ECM_{it-1}	-0.649 ***	-0.601 ***	-0.591 **
R ²	0.623	0.593	0.580
R ² adjusted	0.491	0.436	0.431
F	4.220 ***	3.571 **	3.629 **
Resid ADF ^a	-3.612 **	-3.925 **	-4.003 ***
Q-Stat (1)	0.394	0.703	0.873
Akaike	-2.991	-3.261	-3.102

^a ADF = augmented Dickey–Fuller test (using tendency, independent term and two lags). *p*-values in parentheses: *, **, *** indicates significance at 10%, 5%, and 1%, respectively. Source: Own elaboration.

In Table 5, the significance of ECM in almost all the equations can be observed, demonstrating that co-integration exists in the relationships. The behavior differs depending on whether it is short or long-term, producing a very high fit in the long term for all areas (over 60 percent on average). This was to be expected in the case of perishable produce, in which the urgency of sales leads operators to act quickly in the short term, thereby making long-term agreements with customers quite rare [29]. The data also reflect the fact that transport costs are a major variable in exports of Spanish vegetables to Europe, as they prove influential in almost all markets ($p < 10$ percent). The sign obtained is the correct one, since an increase in transport costs implies a reduction in exports. This demonstrates that intermodality strategies that imply a cost reduction could improve exports to these areas. Moreover, these findings are in line with previous works that highlight the importance of optimizing all the operations involved in transport to increase business [47], more so in the case of perishables [32,48]. If the current intermodal channels were used, the only destination that would display savings in costs would be the United Kingdom, departing from the Port of Bilbao. For example, knowing that there is a 26% cost savings to London (Figure 7), exports could increase by more than 18,000 tons (5% more). It is important to highlight the relevance of the price on the Atlantic coast, since there is strong competition that comes from other origins (for example, Morocco). Consequently, price is a key variable to maintain exports.

In general, it is not clear that the use of intermodal routes, already in operation, reduce the cost compared to the current situation. This makes it impossible to take advantage, in a general sense, of the improvements in exports resulting from the reduction of transport costs [32]. These results differ from previous studies on this kind of products: these works describe ad hoc intermodal routes [18,19] where there is cost reduction, regardless of destination, if the loads are completed. There is agreement regarding transit time, which is greater in all cases: it counteracts cost savings, and therefore has a negative influence on operators' decisions. In line with other studies, the reduction in CO₂ emissions is corroborated [17,34], provided that maritime routes are maximized. In addition, managing cargo groupage at origin is clearly a key aspect, as is the collaboration between exporting companies and clients [12], which could increase the shipping supply and frequency, thereby reducing transit times [16] and accelerating the modal change.

5. Conclusions

Intermodality constitutes a solution to the saturation of road transport. It streamlines the transport logistics chain, reduces energy consumption, encourages the proper use of infrastructure, and reduces environmental impact. This system takes advantage of the ample load capacity of maritime transport

and the flexibility of the road. It is also perfectly aligned with public policies and private initiatives that promote alternatives to using trucks. Given the lack of development of railway connections, the intermodal option, prioritizing maritime transport, is the most feasible alternative in the Spanish southeast to expand its logistics alternatives.

More specifically, it is observed that there is a predisposition among horticultural commercialization companies to adopt the modal shift as long as the times and costs of the current road transport are guaranteed. However, although intermodal lines are significantly more sustainable (between 15–50%), they generally do not equal land traffic in terms of time or cost.

In general, the modal shift takes place not only to subsidize these cost differences, but also to support and incentivize companies who today are opting for more sustainable logistics. In the long term, higher volumes will mean better shipping prices, more regular frequencies, and even the availability of ships with higher speeds, which in turn will reduce transit times.

The intermodal route from Almeria to the United Kingdom through the ports of Bilbao and Portsmouth is the only feasible option at the moment as it cuts costs by 26%, with acceptable time differences. From an environmental point of view, the modal shift of 100% of the estimated traffic to the United Kingdom would emit 43 million tons less CO₂ into the atmosphere than the current option. On the other hand, these results are relevant in that it is foreseeable that land traffic to the United Kingdom will drastically slow down as a consequence of the establishment of border controls following Brexit. Using SSS within an intermodal framework could alleviate this situation.

Gravitation models show how increased transport costs can negatively influence exports and how the correct cost reduction policies through intermodality could have a positive effect. These policies should promote innovation in the shipping sector and invest in the improvement of infrastructures, equipment and implement additional forms of transport, e.g., railway. In this regard, the high capacity of SSS actually proves to be a disadvantage because it is necessary to organize cargo optimally, which requires a great deal of organization by exporting regions to ensure regular shipments [29]. However, as an advantage, a large volume of cargo can reduce unit costs. In general terms, using sea shipping as part of an intermodal system might help to maintain costs and, therefore, improve the competitiveness of fruit and vegetables exporters in southeast Spain. This aspect is especially important in a sector where international competition, from outside Europe (for example, Morocco), follows a competitive strategy based on low prices [49], which includes sea shipping to ports in Northern Europe [16].

The incorporation of the railway into the intermodal framework would be a viable option if a unified “Mediterranean Corridor” project was achieved and connected to the European railway network. However, this scenario will be difficult to accomplish before 2030. Despite these observations, many of the operational problems related to the modal switch to sea transport are identical to those of rail, for example, the obligatory consolidation of cargo to ensure optimal shipment frequency.

In terms of limitations, this study is based on existing routes, featuring loads that can be filled with other cargo in order to avoid groupage problems at origin. This practice impedes the creation of ad hoc routes that are more direct and specialized. For this reason, it could prove useful to investigate the possible coordination protocols of exporters, for example, the use of new technologies (Big Data or the Internet of Things) within the supply chain. Furthermore, it would be interesting to analyze the viability of using consolidation, redistribution, and repackaging centers, seeking an optimal location closer to the customer to improve service and implement inverse logistics strategies.

Author Contributions: Conceptualization and methodology, L.A. and J.C.P.-M.; formal analysis and investigation, M.S.-A. and R.S.-F. All authors contributed substantially to the work reported. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by Spanish MCINN and FEDER aid [project ECO2017–82347-P], FEDER-UAL aid [UAL2020-SEJ-D2026] and UAL-TRANSFIERE 2018 (FoodNET).

Conflicts of Interest: The authors declare no conflict of interest.

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