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ECONOMIC EVALUATION OF THE SPANISH PORT SYSTEM USING THE PROMETHEE MULTICRITERIA DECISION METHOD

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RESUMEN:

Tras las modificaciones legislativas producidas durante los años noventa, el Sistema Portuario Español ha atravesado una serie de cambios que, coincidentes con un periodo de expansión económica y crecimiento generalizado de los tráficos marítimos, han afectado a su organización y funcionamiento. Las transformaciones producidas configuran un nuevo modelo de explotación para las Autoridades Portuarias, que pasan a gestionarse con arreglo a criterios y procedimientos empresariales, alejándose de su dependencia del Estado. Como consecuencia, los puertos españoles de interés general, desarrollan su actividad en un mercado fuertemente competitivo, donde la financiación con recursos propios y la suficiencia financiera, se imponen como objetivos de gestión prioritarios.

Estas circunstancias son abordadas en nuestro trabajo, desde el enfoque de los modelos de decisión con objetivos múltiples, con el propósito de estudiar la evolución de la actuación de las Autoridades Portuarias, mediante ciertos ratios con significado económico, que nos permitirán determinar el modo en que ha variado su ordenación relativa en el conjunto nacional.

Palabras clave: Economía portuaria, decisión multicriterio, método Promethee.

ABSTRACT

Due to legislation changes during the Nineties, the Spanish Port System has gone through a series of changes that, simultaneous with a period of economic expansion and generalized marine traffic growth, have affected the Port System's composition and organization. The gradual transformations produced, give shape to a new model of operation for Port Authorities, which now start to be managed under business criteria and procedures of functional autonomy and competition.

Our work considers these circumstances from the approach offered by multiple objective decision models, using certain ratios with economic meaning which will allow determining how their relative ranking within the national set has varied.

The great variety of available business ratios gives the problem a discrete multicriteria dimension. Thus we have chosen the Promethee method for our analysis, given its results simplicity and easy understanding for the decision agent, the economic interpretation of its parameters, and the stability of its results.

Keywords: Spanish Port System, Multicriteria Analysis, Promethee Method.
JEL Classification: C61, H54, I92.

1. INTRODUCTION: GOALS

This paper analyzes, from an economic and financial perspective, changes in the ranking of the twenty-seven Port Authorities in the Spanish Port System in response to last decade's legal changes. Due to those legal changes general purpose Spanish ports began to play a more important role as economic agents with autonomous decision power in a market that is increasingly less regulated.

This new strategy introduces some complexity in the decision making process of these management units, as several objectives are now to be satisfied, namely delivery of quality public service, competitive prices, self-financing that allows a suitable offering). These objectives are usually in conflict. Therefore the problem of optimizing a decision based on multiple criteria forces Port Authorities to find a balance or compromise among objectives that are generally contra posed.

Given that this dilemma is actually shared by most economic problems, the fruitful research development on Multicriterion Decision Theory in different decision contexts is not surprising[1]. Some of the most recent applications of multicriterion techniques are found in the management of agrarian and environmental resources[2], in the industrial sector[3], in territorial planning and spatial modelling[4], or in financial and business decision making[5].

Still, Multicriterion Decision Theory is not frequently applied to Transportation Economics. Methods using hierarchical structuring and evaluation of alternatives, such as Cost Benefit Analysis, are more common in that domain. Accordingly the results described in this

[1] C. Romero (1993) describes the appearance of the paradigm multicriterion in the decision problems as a "true scientific revolution", with its germ in the works of Kuhn and Tucker, Koopmans, Charnes, Cooper and Ferguson from the 1950's and its reaching theory consistency in 1970's-1980's by the hand of authors like Zeleny.
[2] See for example Davis L. S. and Liu, G. (1991); Romero, C., (1993); Cabello González, J. M. and Cano Capurro, A. (2000); or Jiménez Bolívar, J. F., Berbel Vecino J. and Torrico Herruzo, M. (2001).
[3] Sala Ríos, M. (2000) is worth mentioning here.
[4] See for example Alarcón S. (1994); Barreno Cano, J. and Bosque Sendra, J. (1995); or Barba-Romero Casillas, S. and Pérez Navarro, J. (1997).
[5] Some work in this line is Mareschal, B. and Mertens, D. (1993); Ballestero E., Cohen, D. (1998); Padilla, N., Arévalo Quijada, M. T. and Guerrero Casas, F. (1999); Arévalo Quijada, M. T., Gómez Domínguez, D., Vázquez Cueto, M. J. and Zapata Reina A. (2002), Zopounidis, C. and Pendaraki, K. (2003); or Pla Santamaría, D. and Ballestero, E. (2003).

paper are a novel contribution, as the use of the multicriterion method overcomes one of Cost-Benefit Analysis main constraints, namely the need to translate problem variables into monetary units in order to build the utility function.

Leaving aside these considerations and returning to the context of our study, we will focus on the transformation processes in which the Spanish Harbor System was generally immersed during the Nineties, facing the new economic challenges of the XXI century. To the changes occurred in this period, with respect to organization, operation and operation model of Port Authorities, we must also add a positive underlying economic situation, which influenced positively marine traffic evolution.

The most relevant changes during the last decade, were the ones introduced by new regulations, established by Law 27/1.992 (November 24) about State Ports and the Merchant marine, and Law 62/1.997 (December 26), which modified it. In a general sense, the application of both laws transformed basic operating conditions for the economic agents in the port space, contributing to reduce the high intervention degree existing until then.

Law 27/92 created the Port Authority figures, with legal ability and their own patrimony independent from the state, whose activity is coordinated by the public Office for State Ports (*Ente Público Puertos del Estado*), which has a holding role. In addition this law establishes a new economic-financial regime for Spanish ports, based on self-sufficiency of resources generated by the system itself. For this, our port system set of incomes is based on two pillars: incomes coming from concessions and commercial and industrial activities within the harbor precinct (considered public prices), and port service fees (private prices).

In summary, this law measures intend to promote the effectiveness, quality and safety of the services provided by each Port Authority, leading to greater agility and coordination among them, and establishing a system of harbor income that allows the financial self-sufficiency of system; in the mid term in the case of each Port Authority.

The change introduced by Law 62/97 represents a new attempt to adapt our port organization to an environment that is ever more changing and more competitive. To do that, a new organizational frame is defined that equips Harbor Authorities with greater functional and management autonomy. Also, Regional Governments are granted greater participation in Port Authorities decision making and naming of its governing boards.

Another fundamental aspect introduced by this law, is the greater acting autonomy of Port Authorities. This is translated into a considerable extension of their functions: approval of their own budget, performance program, investment and financing, deciding on their own human resource needs, self management of outer commercial decisions..., and, mainly, a wide range of price freedom, thus introducing a high liberalization degree in the sector. The free fee-structure that each port can apply, granting a positive yield rate and avoiding as much as possible abusive or discriminatory practices, evidently provides a new environment of inter-harbor competition, which going beyond the self-financing of the harbor system as a whole, looks for profit in each individual Port Authority.

These legal changes are also reflected in the Spanish ports statistical information. In this sense, one can notice a lack of uniformity in the economic and accounting data we have consulted through our work. This shows the transition Port Authorities have gone through in this decade, from a public accounting regime to the general accounting plan, complying with the legal changes of the period, which were oriented towards a private business management model and a greater degree of financial autonomy.

Taking these circumstances into account, we intend to analyze the effects of this new legal context. To do this we perform a relative comparison of the relative orderings among Spanish ports, using criteria representative of their economic management and of the most relevant marine traffics.

We chose discreet multicriterion decision techniques (given that the number of alternatives, that is, of general-interest Spanish ports, is finite). More concretely, we chose the PROMETHEE method because it is the method best suited to our optimization problem from the range of available methods currently being used. In this we follow the guidelines set by Al-Shemmeri, Al-Kloub and Pearman[6].

The work has the following structure: first, we present the methodological bases of the study, commenting briefly on the Promethee method most important aspects, the sources used, and the definition of the variables considered. Then we present the elaborated ratios and the hierarchical structuring criteria proposed for the evaluation of the Spanish Port Authorities. Finally, we gather the results and the conclusions derived from them, considering the ports individually ports, and as a function of the various maritime facades that make the Spanish Harbor System. The two appendices respectively contain diagrams with the alternative orderings and sensibility analysis of the proposed solutions.

2. METHODOLOGY AND VARIABLES

As we have mentioned, this work studies the changes in the ordering relationship among the twenty-seven Spanish Port Authorities at different strategically-considered time points, caused by the external changes referred to in the previous paragraph.

We have focused our study on certain economic aspects (described below) that define both their real and potential activity, and also on their traffics, with special attention to container traffic as we consider it quite representative of present and future international trends of marine transportation. Thus it is a proxy variable of a port competitiveness level. Economic information and traffic statistics for the whole Port System are available from the *Management*

[6] For these authors the choice of the most appropriate multicriterion decision method is itself a multi-decision problem. See Al-Shemmeri, T., Al-Kloub, B., and Pearman, A., (1997) for guidelines to determine the most suited technique based on the available information and the objectives desired.

Reports and *Statistical Yearbooks* [7]published by the Ente Público Puertos del Estado, a division of the Ministerio de Fomento (Ministry of Public Works)

Despite of these publications, we emphasized that compiling the necessary data has been far from easy. Although we have enjoyed the collaboration and material support of the *Ente Público Puertos del Estado* from the start, we have in fact encountered a number of difficulties, sometimes unsolvable, that have largely limited our work's time horizon and goals. These obstacles are mainly due to the lack of uniformity in the harbor economic statistics, as a result of the changes happened throughout the Nineties in the information reporting procedures[8].

Due to this heterogeneity in the sources consulted, it has been impossible to work certain management ratios for the years considered despite their interest, either by lack of uniformity or the nonexistence of the statistical data. Thus we have decided to take three years as the basis of our study to which we will apply the Promethee multicriteria methodology:

- 1.991: Year before the change introduced by Law 27/92, November 24, for State Ports and the Merchant Marine.
- 1.997: After the necessary adaptations to that legislation change and before the effects caused by the next law, Law 62/97.
- 2.001: Alter Law 62/97, December 26, which modified Law 27/92.

After presenting the basic aspects of our work, we now describe the main magnitudes we have used, taking into account that the periodicity referred to corresponds to the three strategic moments chosen for our study (t = 1.991, 1.997, 2.001). Given these variables we obtain the ratios used in the evaluation of the Spanish Port System as described below.

[7] Ministerio de Fomento, Ente Público Puertos del Estado (several years).
[8] See Nombela Merchán, G. and Trujillo Castellano, L. (1999) for details on the effects of these legal changes on the accounting of economic data by the Port Authorites.

- BN_{it}: Net profit in port i for year t (Operation Result) = Operation Income - Operating expenses.

- AT_{it}: Total assets according to the balance sheet in port i for year t.

- $TEUs_{it}$: Number of containers equivalent to 20 feet moved in port i for year t.

- $TRAF_{it}$: Total traffic (in thousands of tons) in port i for year t.

- $TRAF\ TOT_t$: Total traffic (in thousands of tons) moved by the Harbor System, i.e. by the set of ports in the System, for year t.

- $INMOV_{it}$: Total immobilized according to the balance sheet in port i for year t.

- $INGPM_{it}$: Income of port i for year t, from fees due to passenger traffic (T-2) and merchandise traffic (T-3). These fees are described below.

- $INGTAR_{it}$: Income of port i for year t, from port service fees = T-0, T-1, T-2, T-3, T-4, T-5, T-6, T-7, T-8 and T-9. These fees are described below.

- $CIFNEG_{it}$: Total net amount of port's i business for year t = Income from port service fees + Income from concessions.

- GTP_{it}: Personnel expenses in port i for year t.

- R_i: Provincial rent, for port i's immediate or surrounding influence area (*umland).*

A subindex will be added when it refers to year t[9], that is, the variable will be R_{it}.

- R_{Pj}: Rent for the j provinces that are adjacent or border port i, which form its mainland influence area *(hinterland)*. A subindex will be added when it refers to year t[10], that is, the variable will be R_{pjt}.

With respect to port service fees, which appear in some of he variables defined above, we make the following distinctions based on Law 27/92 (developed in Ministry Ordinances of 19/4/1995 and 30/1/1996):

[9] We use provincial gross domestic product (GDP) at market prices, available as historical series from the Instituto Nacional de Estadística.
[10] See previous footnote.

FEE	CONCEPT	DEFINITION
T-0	Marine signaling	Depends on ship's tonnage. Paid for signal and beacon services services, which help navigation.
T-1	Ships	For use of waters, channels, logs, works of port protection and drainage, and any other facilities that allow loading and unloading. Depends on ship's tonnage, length of stay, and port section used..
T-2	Passage	General port use by passengers or vehicles that embark or disembark as passengers. Refers to use of not only docks, but also ground access, roads and maritime stations.
T-3	Merchandise	Use of port waters, dock, ground accesses, maritime stations, general police services, etc. Depends on tonnage and type of merchandise, and also on navigation and operation type.
T-4	Fresh fishing	Use of port waters and facilities by fishing boats.
T-5	Sport and pleasure boats	Use of port waters, dock, anchor areas, mooring line, berths and police services. Depends on maximum boat length and length of stay.
T-6	Overhead cranes	Use of such infrastructure, depending on maximum height and length of time.
T-7	Warehouses, space and buildings	Depends on surface size and length of time.
T-8	Supplies	Use of water and electricity. Depends on amount supplied.
T-9	Other services	

Source: prepared by the authors based on 1992 Law of State Ports and Ordinances 19/4/1.995 and 30/1/1.996, Public Works and Transportation Ministry.

TABLE 1

Note that a distinction can be made between "*general fees*" charged for port facilities use (T-0, T-1. T-2, T-3, T-4, T-5) and "*specific fees*" to cover the costs of particular services (T-6, T-7, T-8 and T-9). Within general fees, fees T-0, T-1, T-2 and T-5, fall on the ship, and T-3 and T-4 on the merchandise. Specific fees are set instead depending on the case. All except T-0 and T-3, depend on the length of time during which the infrastructure is used.

As mentioned, we have chosen the PROMETHEE (Preference Ranking Organization for Method Enrichment Evaluation) method developed by Brans and Mareschal[11], because, according to Al-Shemmeri and others[12], it is the most adequate procedure for alternative ordering and it is easy to use, and also because of the importance of its parameter interpretation and the stability of its results. For calculations, we have used the Decision Lab 2000 program.

[11] Brans, J. P. et al, (1.984), Brans, J. P and Vincke, P. H. (1.985), and Brans, J. P., et al (1.986).
[12] Al-Shemmeri, T; Al-Klomb, B.; Pearman, A: (1.997).

This is one of most recent procedures in the Improvement Relations category of methods, whose main purpose is to help the decision-maker in problems involving selection or hierarchical structuring of possible alternatives subject to a multicriteria evaluation where there are in general conflicting criteria. Given that when one considers several criteria, establishing a total ordering in not possible and, thus there is no optimal solution (i.e. an alternative that simultaneously satisfies all the criteria), the method we use provides two ways of solving the ordering: a *partial preorder* (PROMETHEE I) and a *complete preorder* (PROMETHEE II), both over the set of feasible alternatives. Using both techniques, PROMETHEE makes a binary comparison of the alternatives, to sort them according to their dominance or weakness with respect to the others.

In general, we can formulate the problem as follows:

$$\text{Max} \ / \ \text{Min} \ \{f_1(a), f_2(a),...f_j(a),..., f_k(a) / a \in A\}, \qquad (1)$$

where A is the finite set of feasible alternatives and $\{f_j(.), j = 1,...k\}$ the set of criteria under which the alternatives are evaluated[13]. From the combination of criteria and alternatives evaluated according to the criteria, we obtain a table called *decision matrix,* which the decision maker faces, with elements $\mathbf{f_j(a_i)}$ (i = 1,2,... n; j = 1,2,... k),.

Each criterion $\mathbf{f_j}$ has an associated *preference function* $\mathbf{P_j}$ which refers to the degree of preference of alternative **a** over another **b** for criterion $\mathbf{f_j}$, as a function of the alternatives for that criterion $\mathbf{d_j = f_j (a) - f_j (b)}$, and which defines the pair called *generalized criterion* or *pseudocriterion* (f_j (.), P_j (.,.)). Thus

$$P_j (a,b) = P_j (d_j (a, b)) \ \forall a, b \in A$$

[13] Note that although we refer to a maximization problem, usually the problem is a mixed optimization one, where several criteria have to be minimized and maximized simultaneously.

Thus the deviation width between alternatives and scale effect are taken into account. There are six generalized criteria[14]. To choose among them both the decision maker and the analyst have to contribute, taking into account the degrees of preference when choosing at most two parameters with a clearly economic meaning: a *preference threshold* and an *indifference threshold*.

After a generalized criterion has been established, the program defines a multicriteria preference index $\pi(a,b)$ of **a** on **b**, in all the criteria, as:

$$\pi(a,b) = \sum_{i=1}^{n} w_j P_j(a,b) \qquad \left(\sum_{i=1}^{n} w_j = 1\right) \qquad (2)$$

where $w_j > 0$ (j=1,...,n) are the criteria priorities, weights.

For each alternative the procedure defines two flows: the *outgoing flow*, representing the power of dominance of an alternative, its dominant character; and the *incoming flow*, that expresses its weakness, its dominated character. From these flows two orderings of alternatives are naturally deduced, which give rise to the *partial preorder*. Considering the *net flow* as the difference between the previous two flows, a *complete preorder* of the alternatives is deduced, in which all the alternatives are comparable, although it does not provide as much information as in the previous one.

This method also generates a powerful qualitative tool, as a visual complement to these orderings, that is, the *GAIA plane* (*Geometrical Analysis for Interactive Aid*), a bidimensional representation of the problem, where the location of the alternatives (points) with respect to the criteria (vectors), depending on their respective weights, can be observed.

The following keys are useful for the interpretation of its information: "good" alternatives with respect to some criterion will be located in the direction of the axis

[14] See: Brans, J. P., Mareschal, B. and Vincke, P. H. (1984) (1986); Brans, J. P. and Vincke, P. H. (1985) for the formulation of these generalizad criteria.

corresponding to that criterion. Criteria represented by axes with similar directions indicate that they have similar discrimination power with respect to the alternatives. If they appear in opposite axes, they are conflicting.

This descriptive plane also shows the k-dimensional vector, π, or *Promethee's decision axis*, which represents the objective resulting from weighing the criteria after making them homogeneous. If vector π has a large long length, it has a strong decision power, and the best alternatives are those further away in its direction. If π is short, it has a weak decision power. If π is almost orthogonal to the plane, there is a strong confrontation among criteria.

The fidelity of our ordering problem representation in plane GAIA is given by the δ parameter, which refers to the amount of information preserved by the resulting projection.

Finally, we note that the descriptive analysis of the GAIA plane is relatively stable. If the weights are modified, the locations of criteria and alternatives are not affected. However the decision axis π will reflect these changes, allowing us a visual examination of sensitivity.

In this sense, it is quite advisable to perform a *sensitivity analysis*, through the simulation of scenarios for different weight values for the criteria considered.

3. DEFINITION AND JUSTIFICATION OF DECISION CRITERIA.

We have developed various ratios to evaluate the different Port Authorities. These ratios are referred to economic management, port traffic and labor productivity. Basically, these ratios have the property of being easily interpretable in order to draw conclusions, and in addition they are closely connected to the economic aspects we want to analyze[15]. Still, as we mentioned before, their choice was largely conditioned by the available information.

Altogether we have used six criteria to order the ports considered:

[15] To construct these ratios we have used as orientating reference both Gil Lafuente, A. M. (2.001), and some management ratios used in some of the statistical data published on the State Ports.

- R_1: ECONOMIC YIELD = BN_{it} / AT_{it}

Among all the existing indices in the financial literature to quantify the business yield we have chosen a standard formulation. Based on it, we measure the operation influence on the business assets.

- R_2: DYNAMISM OF PORT ACTIVITY = $(TRAF_{it} – TRAF_{it-1}) / TRAF_{it-1}$.

With this rate of relative growth of total traffic of port i along consecutive years, we can notice each Port Authority's evolution, through the degree of dynamism in its activity. Thus a high value will be a symptom that a port has increased its movement.

- R_3: SPECIALIZATION IN CONTAINERS = $TEUs_{it} / TRAF_{it}$

The goal is to quantify the degree of relative specialization of each Port Authority in container movement. From all the usual harbor traffic classifications, we chose container traffic. Given the gradual increase of container use in international commercial navigation[16], container traffic contributes information about the greater or smaller participation of each port in this world-wide trend. We are aware of the a priori discriminatory character that this criterion could have, given that traditionally this traffic is not equally consolidated in every port. Nevertheless, we consider its use to be of great interest in order to appreciate the greater or smaller ability of each port for integration in the world-wide circuits of this traffic.

- R_4: CAPITALIZATION = $INMOV_{it} / AT_{it}$

Processes of fixed-capital investment are fundamental in this sector, so that the offering of infrastructures and port services can adapt efficiently to demand changes. Thus determining the fraction of port assets that stays in immobilized seemed relevant.

- R_5: HARBOR BUSINESS = $INGPM_{it} / CIFNEG_{it}$

Port facilities offer a variety of services. Thus there are diverse income-producing fees. In this case we focused on fees T-2 and T-3, corresponding respectively, to passenger and

[16] See Rueda Alameda, F. J., (1.995).

merchandise traffic, given the traditional conception of port area as an "*element of connection between different means in the transportation chain, servicing merchandise and passenger transfer*."[17] Therefore, this criterion will evaluate ports based on the dependency of its total income (from fees and from concession or rented land surface) on the activities that constitute a port's traditional reason d'etre: the transport of passengers and merchandise.

- R_6: PRODUCTIVITY OF THE LABOR FACTOR = $INGTAR_{it}$ / GTP_{it}

In order to quantify port staff productivity, we take income from port service fees as representative of the obtained "port throughput"[18].

- R_7: POTENTIAL CAPACITY OF THE HINTERLAND (PORT'S MAINLAND INFLUENCE AREA) =

$$\Delta_{t-1}^{t} R_i \frac{R_{it}}{R_{it} + \sum_j Rp_{jt} * \alpha} + \sum_j \Delta_{t-1}^{t} Rp_j \frac{Rp_{jt} * \alpha}{R_{it} + \sum_j Rp_{jt} * \alpha} \quad , \qquad (3)$$

where:

- $\Delta_{t-1}^{t} R_i$ and $\Delta_{t-1}^{t} Rp_j$, are respectively the rates of relative increase of variables R_i for years *t-1* and *t*.

- α is the part of the rent for the port umland adjacent provinces which we consider that can be captured by the given port's activity.

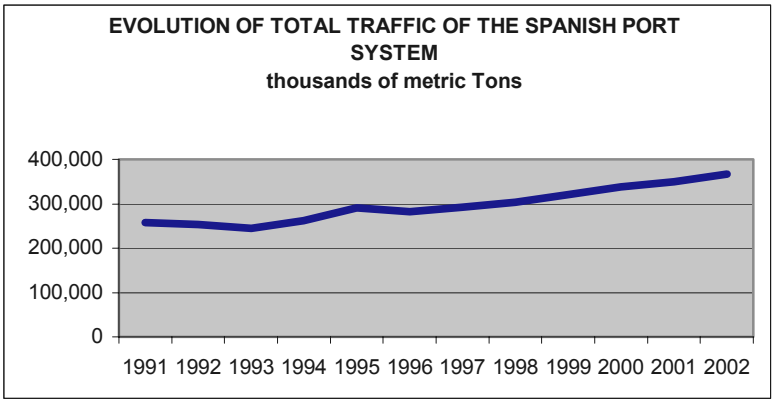
Now, this is a more qualitative ratio. Given Port Economics basic premise that port services demand is a demand derived from the evolution of economic activity itself, we try to quantify the potential capacity of port i in order to capture economic growth of the province where it is located and its adjacent ones. Thus it is an approximation to the part of the hinterland's rent that is channeled through port activity. α allows us to consider only the relevant proportion of the rent of the neighbor province to the port's province, that is, the part

[17] For details on this definition, commonly accepted by port orthodoxy, see Zubieta Irún, J. L., (1.978).
[18] Properly speaking, since a port does not produce any amount of particular goods, the port's activity generates no output, but what is known as *port throughtoutput.*

that can be attracted by the port. We have chosen this value to be 50% if the neighbor province has any general interest port and 75% otherwise. On the other hand, we must note that when port i is located in a province with another general interest port, we use a criterion to distribute among them the province rent (port umland) as a function of each port relative weight in the total provincial port traffic. As a result, the percentage obtained for each port will determine in each case the part of the rent $R_{it.}$

Note that we perform an ordering of alternatives according to criteria expressed in relative terms. That is they are ratios indicative of each port's respective situation, of the activity each one performs in its own context. This is why the results must be interpreted with due caution. A high ranking of a small or medium size port can be deceiving with respect to its real situation in the port set. Thus we must consider that its place in the resulting arrangement corresponds with its relative activity volume, with its specificity.

We could repeat the analysis using absolute values, but the ordering would probably be different, as it would be a comparison of Port Authorities of different importance. In this case, it would be advisable to first group the ports considered, based on characteristics suitable to make variables homogeneous: business quota, specialization in each type of commercial traffic, area size, etc. To locate this study in the evolutionary context of marine traffics, we show in **figure 1** the Spanish Port System progress from a total traffic perspective.



Source: Prepared by the authors. Ministerio de Fomento. Anuarios Estadísticos.

FIGURE 1

It can be seen that the analyzed period has been one of generalized growth in port activity. This is mainly due to a growth trend in our economy and the fact is that port services demand has the nature of derived demand. The goal of our work is better understand the distribution of these gains and the evolution and current relative situation of the ports in the Port System.

Since most of the variables chosen (labor factor productivity, yield...) provide information on both the present context and the ports potential, the ordering presented here has a prospective side. Thus we have also attempted to measure possible future growth of the various ports.

4. SPANISH PORT SYSTEM ORDERING USING THE PROMETHEE METHOD AND THE TRADITIONAL CRITERION

This study of the Spanish Port System is based on the comparison of two types of orderings:

- A *traditional ordering* in Port Economics, which takes as criterion, for year t, the relative weight of each port i, on the port set total traffic: $TRAF_{it}$ /TRAF TOT_t.

- An ordering using the *PROMETHEE method* and the six criteria already mentioned: economic yield, traffics rate of growth, container traffic specialization, capitalization, port business and labor factor productivity.

In the latter case, given that the criteria relative importance needs not be the same, when the Promethee multicriteria method is used the importance of the criteria has to be established by associating some weights to them. This weighing will depend on the main ordering criterion. This article sets two possible Promethee ordering scenarios, depending on the characteristic we want to emphasize:

- SCENARIO I: Financial autonomy (resources self-sufficiency): given that the legal changes that have affected the Spanish Port System in general have introduced a private business management model, granting greater importance to yield, traffic dynamism and port business indicators seemed appropriate.

- SCENARIO II: Competitiveness: in this case we weighed heavier criteria of container traffic specialization, capitalization and labor productivity, as we considered them more significant in order to determine the port competitiveness degree.

Table 2 shows the traditional ordering for the years considered.

TRADITIONAL ORDERING OF THE SPANISH PORT SYSTEM

PORT AUTHORITIES	1.991	ORDER. 91	1.997	ORDER. 97	2.001	ORDER. 01
Algeciras, Bahía de	0,11518	2	0,13737	1	0,15085	1
Alicante	0,01009	24	0,00752	24	0,00941	22
Almería-Motril	0,03518	13	0,02059	16	0,02442	15
Avilés	0,01529	20	0,01286	21	0,01085	21
Baleares	0,02468	15	0,04775	8	0,03115	12
Barcelona	0,07274	4	0,08743	3	0,09112	2
Bilbao	0,12694	1	0,07917	4	0,07750	4
Cádiz, Bahía de	0,01238	23	0,01197	22	0,01340	19
Cartagena	0,05387	5	0,03376	12	0,05826	6
Castellón	0,02831	14	0,02875	14	0,02951	13
Ceuta	0,01893	16	0,01546	18	0,00694	23
Ferrol-S. Ciprian	0,01827	17	0,02513	15	0,02496	14
Gijón	0,05113	7	0,04618	9	0,05492	7
Huelva	0,03667	10	0,05038	7	0,05337	8
La Coruña	0,04992	8	0,03920	11	0,03369	11

Las Palmas	0,03653	11	0,04276	10	0,05154	9
Málaga	0,03562	12	0,03041	13	0,00551	24
Marín-Pontevedra	0,00288	25	0,00481	25	0,00545	25
Melilla	0,00214	26	0,00255	26	0,00218	27
Pasajes	0,01547	19	0,01317	20	0,01350	18
Tenerife	0,05172	6	0,05130	6	0,04900	10
Santander	0,01666	18	0,01573	17	0,01480	16
Sevilla	0,01319	21	0,01381	19	0,01399	17
Tarragona	0,09457	3	0,10677	2	0,07692	5
Valencia	0,04669	9	0,06259	5	0,08206	3
Vigo	0,01310	22	0,01038	23	0,01176	20
Villagarcía	0,00186	27	0,00221	27	0,00293	26

Prepared by the authors.

TABLE 2

Using the multicriteria Promethee method the *Decision Lab 2000* software provides the orderings corresponding to the years studied: 1.991, 1.997 and 2.001. Out of the two resulting orderings for the Spanish Harbor System, we have considered the complete preorders, in SCENARIO I (financial autonomy), and in SCENARIO II (competitiveness).

Comparing the three proposed orderings gives raise to the following comments:

- Regarding the scenarios analyzed using the Promethee method, no great differences are found. The ports on the first and last positions of the orderings hardly vary between years in scenarios I and II, although differences of between one and three places exist for the ports in intermediate positions. Actually, one could think that there exists certain complementarity between both orderings, as the competitiveness degree of a port is closely related to its flexibility in adapting to the new legal model of business organization, and thus to its ability to self finance.

- Regarding the traditional ordering criterion, in general one can see some discrepancies with respect to Promethee method's results. Still these differences decrease throughout the period analyzed, and so that in the last year considered a higher correspondence between the traditional ordering and the Promethee method ordering can be observed.

If we focus only on Promethee multicriteria ordering results, we see that the Bahía de Algeciras, Valencia and Barcelona trio stays within the seven top places, successively exchanging places. This reveals the fact that those Port Authorities have adapted uniformly to the new business exploitation and competitiveness schema, and none of them has gone down from the top places in the national ranking after the changes, maintaining their primacy over the rest of the System ports. This homogeneous behavior calls for our attention as these ports are located within economies with theoretically different growth rates. It leads us to reaffirm the role of port infrastructure as a local factor of dynamism, independent from the starting point of its area of influence.

At the opposite end no great variations appear throughout the years, as Port Authorities such as Villagarcía always end at the last positions in both scenarios.

Cartagena and Castellón, for example, are interesting among the ports that improve during the period considered. This improvement is a symptom that their management has been able to fit in the novelties introduced by legal changes. Cases such as Santa Cruz de Tenerife and Sevilla are interesting because they have stayed in a similar place throughout the period, which means that neither their self-financing degree nor their relative competitiveness have been affected in their particular adaptation to the new laws.

Regarding ports that, on the other hand, still have to make a great effort to meet these requirements, it is worth noticing the decrease in ranking of the Malaga port, fundamentally as

a consequence of the crisis of the bulk liquid traffic, although in the last year studied one could see some recovery signals with respect to competitiveness.

In addition to graphical orderings the Decision Lab 2000 software generates a snapshot, the *GAIA plane*, which represents the location of all alternatives (Port Authorities) with respect to criteria (ratios) globally considered. The following **figures 2 and 3,** show the GAIA planes for year 2.001 for the Promethee scenarios considered.

SCENARIO I

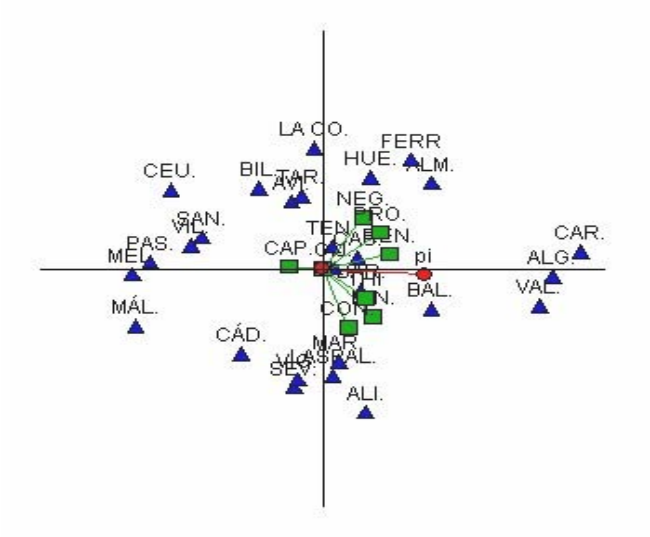
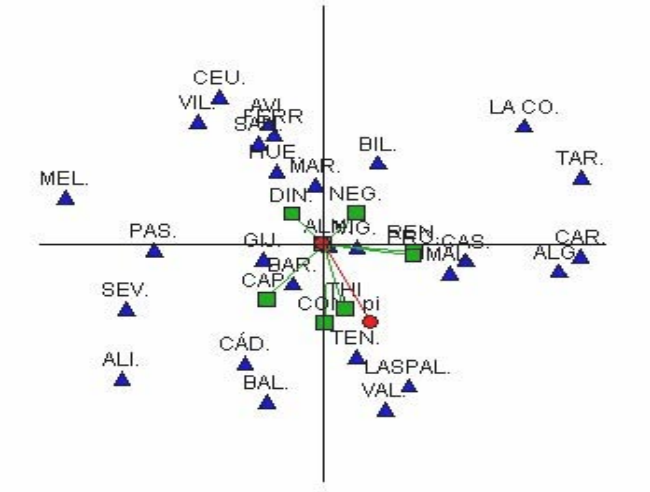


FIGURE 2

SCENARIO II



Prepared by the authors.

FIGURE 3

In both cases, the ratios studied are represented by a green square, whereas the alternatives are blue triangles. The red circle refers to vector π, which captures all the criteria considering their weights, and helps us visualize the relative situation of the alternatives.

Looking at both scenarios together we see a difference in the vectors for the decision criteria. In the first case all but capitalization are concentrated, indicating a discrimination degree similar to all the alternatives. That is, there is no grave conflict among the considered ratios. Instead all but capitalization are relevant for the Financial Autonomy objective

Regarding the alternative positions, we need to take into account the following aspects: the greater (smaller) the distance between a port´s coordinates and the origin of coordinates (in the direction of vector π), the better (worse) located the port is. In this case one can easily observe, as mentioned above, that Valencia and de Bahía de Algeciras ports predominate (triangles further away in the direction of vector π), and that ports such as Villagarcía y Melilla occupy lower places (triangles located further to the left opposite to vector π). Avilés and Tarragona ports, in Scenario I, and Avilés and Ferrol-San Ciprián ports, in Scenario II, exhibit similar behavior, as they are represented by closer dots on the plane.

5. EVALUATION OF THE SPANISH PORT SYSTEM USING MARINE FACADES

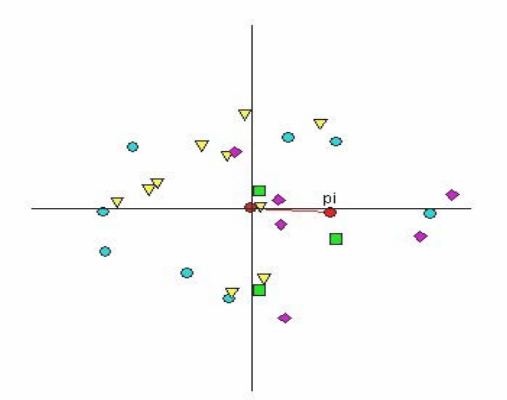
We can extend our multicriteria analysis from another perspective, considering the natural ascription of the ports studied to the different marine facades that make up the Spanish Port System. We now present how they are composed, considering that there is certain heterogeneity in their integrating elements:

- *North-Atlantic Facade*: composed by the Avilés, Bilbao, Ferrol-San Ciprián, Gijón, Coruña, Marín-Pontevedra, Pasajes, Santander, Vigo and Villagarcía Port Authorities

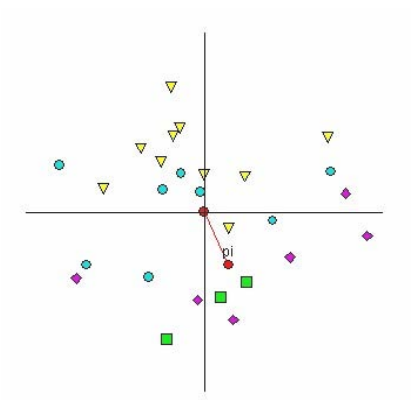
- *Islands Facade*: composed by the Baleares, Las Palmas and Santa Cruz de Tenerife Port Authorities.
- *Southern Facade*: including the Almería-Motril, Algeciras Bay, Cadiz Bay, Ceuta, Huelva, Malaga, Melilla and Seville Port Authorities.
- *Mediterranean Arc Facade*: including the Alicante, Barcelona, Cartagena, Castellón, Tarragona and Valencia Port Authorities. For the accomplishment of the analysis we such maintain methodologic assumptions explained in the beginning of this work, applying again the decision procedure multicriteria Promethee. The arrangement obtained for the scenes of financial autonomy and competitiveness, are exposed next.

Before performing the Promethee analysis using facades, we perform an intuitive approximation of their relative positions. To do that, we show again the GAIA planes for year 2.001 and scenarios I and II. In this case the ports or alternatives to be sorted are classified in categories or facades represented by different symbols and colors. (**Figure 4**)

GAIA PLANE 2.001 SCENARIO I



GAIA PLANE 2.001 SCENARIO II



Source: prepared by the authors.

FIGURE 4

LEGEND: - Solid green square: Islands

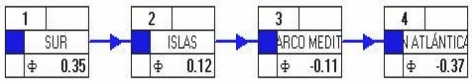
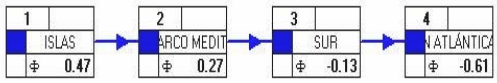
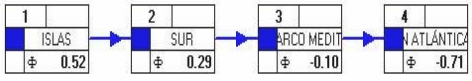
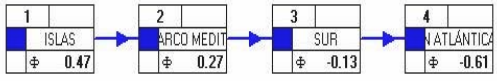
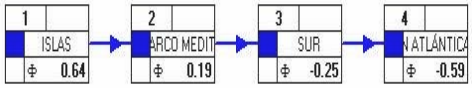
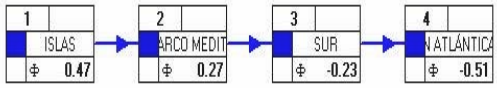
- Solid fucsia diamond: Mediterranean Arc.

- Solid yellow triangle: North Atlantic.

- Solid blue circle: South.

Comparing the category location with respect to the π axes, we can verify that, according to what was explained above, at least in the year considered the best located ports are the island and Mediterranean ones.

To verify this assertion and extend our analysis to the other years considered, we maintain the same methodological assumptions from the beginning of this paper and apply again the Promethee multicriteria procedure. The ordering obtained for the financial autonomy and competitiveness scenario are as follows, (**Table 3**).

SCENARIO I FINANCIAL AUTONOMY	**SCENARIO II** COMPETITIVINESS
YEAR 1.991	**YEAR 1.991**
	
YEAR 1.997	**YEAR 1.997**
	
YEAR 2.001	**YEAR 2.001**
	

Prepared by the authors.

TABLE 2

As the net flow diagrams show, there are hardly differences between scenarios. The Islands facade dominates in practically all years and scenarios, followed most of the time by the Mediterranean Arc. This is doubtless because their ports have always been well positioned in the individual orderings and there are no elements that can counter the optimal location of the facade. The South facade appears next most of the time. This reveals it is not a compact group

and has great differences. This is because despite the natural strength of the Algeciras port other ports such as Málaga are in the last positions of the national set.

The most interesting result we can establish comes from the comparison of the net flows of each facade. For Scenario I, the net flow of the dominant alternative progressively increases. This produces some relative increase in the interval width between the maximum and minimum net flow, which reveals a little uniform behavior across the facades in the Port System. This behavior has progressively increased making the differences among them more significant. In Scenario II, the Spanish port facades have a more integrated behavior, as the net flow of the dominant alternative is constant, and that of the weakest alternative is progressively decreasing.

6. CONCLUSIONS.

To summarize, the legal changes affecting the Spanish Port System during the nineties hardly had any consequences for ports traditionally located in the top or bottom places of the national ranking. This was different for ports in intermediate positions. Nevertheless, we must qualify this conclusion. The order between ports at the ends of the ordering might not change because the legal reforms would have similar individual effects which would maintain the relative distance among them.

In order to clarify this circumstance, we look at the relative comparison of net flows obtained for each alternative or port and notice that for each scene and year almost the same group of ports is at the first and last positions of the resulting arrangements.

Considering however the difference between each port net flow and that of the other ports, we will know whether, despite staying at the same places, their management is more homogenous, more integrated (reduction in the distance between net flows), or on the contrary, more different, with a greater difference amount them (the distance between net flows increases).

Looking at their joint behavior, the increasing size of the intervals between maximum and minimum net flows makes us affirm that Spanish general interest ports show a more varied behavior after the modifications mentioned. This conclusion comes from the different adaptation rhythm of Port Authorities to the new management and organizational context. Looking at Marine Facades, the result depends on the Scenario analyzed. The situation is less integrated in terms of Financial Autonomy than in terms of Competitiveness.

These results should not make us infer that a higher position in the ordering is representative of the absolute leadership of a port over the rest. It just tells us that this is a port managed according to the legal changes mentioned.

Finally we want to emphasize the complementarity among the orderings based on traditional Port Economics criteria and those using the multicriteria decision method. The information provided by the latter widens the field of feasible studies and allows us for a better characterization of Port Authority performance.

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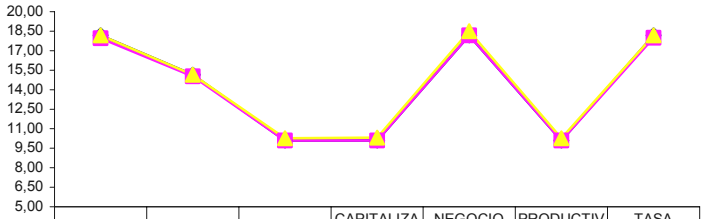
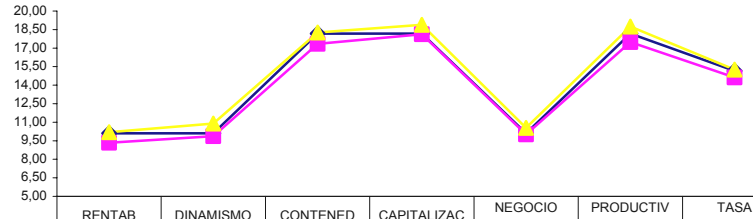
SENSIVITY TEST 1991 SCENARIO I



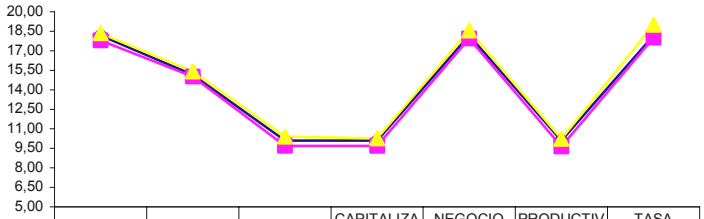
	RENTAB	DINAMISMO	CONTENED	CAPITALIZAC	NEGOCIO PORT	PRODUCTIV LAB	TASA HINTERLAN
Ponderación (%)	18,18	15,15	10,10	10,10	18,18	10,10	18,18
MIN	17,96	15,03	10,10	10,10	18,18	10,10	18,00
MAX	18,18	15,15	10,27	10,31	18,50	10,27	18,18

SENSIVITY TEST 1991 SCENARIO II



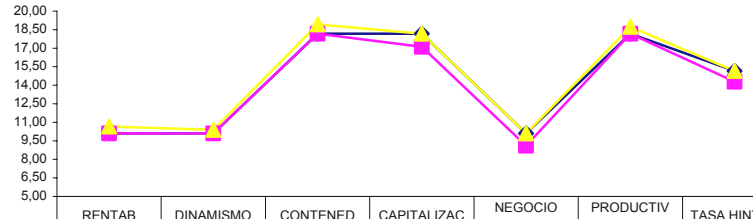
	RENTAB	DINAMISMO	CONTENED	CAPITALIZAC	NEGOCIO PORT	PRODUCTIV LAB	TASA HINTERLAND
Ponderación (%)	10,10	10,10	18,18	18,18	10,10	18,18	15,15
MIN	9,34	9,87	17,35	18,12	10,01	17,49	14,63
MAX	10,19	10,90	18,26	18,88	10,55	18,75	15,26

SENSIVITY TEST 1997 SCENARIO I



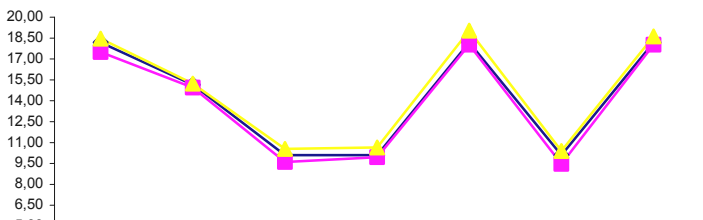
	RENTAB	DINAMISMO	CONTENED	CAPITALIZAC	NEGOCIO PORT	PRODUCTIV LAB	TASA HINTER
Ponderación (%)	18,18	15,15	10,10	10,10	18,18	10,10	18,18
MIN	17,80	15,02	9,69	9,69	17,95	9,64	18,01
MAX	18,35	15,41	10,40	10,27	18,56	10,23	19,00

SENSIVITY TEST 1997 SCENARIO II



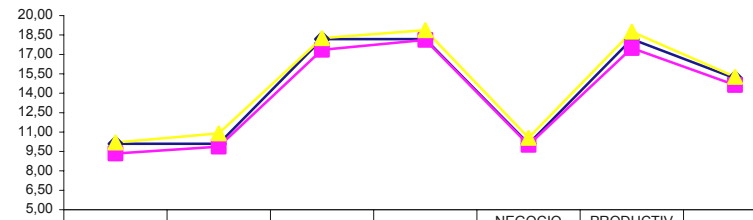
	RENTAB	DINAMISMO	CONTENED	CAPITALIZAC	NEGOCIO PORT	PRODUCTIV LAB	TASA HINTER
Ponderación (%)	10,10	10,10	18,18	18,18	10,10	18,18	15,15
MIN	10,10	10,10	18,18	17,11	9,11	18,18	14,29
MAX	10,66	10,39	18,93	18,18	10,10	18,73	15,15

SENSIVITY TEST 2001 SCENARIO I



	RENTAB	DINAMISMO	CONTENED	CAPITALIZAC	NEGOCIO PORT	PRODUCTIV LAB	TASA HINTER
Ponderación (%)	18,18	15,15	10,10	10,10	18,18	10,10	18,18
MIN	17,50	14,95	9,61	9,95	18,02	9,47	18,02
MAX	18,46	15,23	10,55	10,65	19,04	10,40	18,62

SENSIVITY TEST 2001 SCENARIO II



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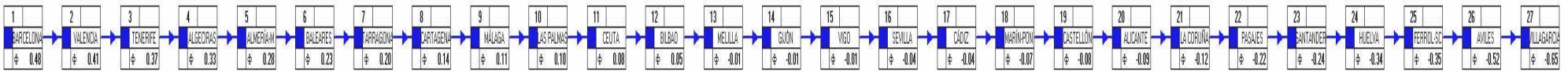
Ponderación (%)	10,10	10,10	18,18	18,18	10,10	18,18	15,15
MIN	9,34	9,87	17,35	18,12	10,01	17,49	14,63
MAX	10,19	10,90	18,26	18,88	10,55	18,75	15,26

NET FLOW FIGURES:

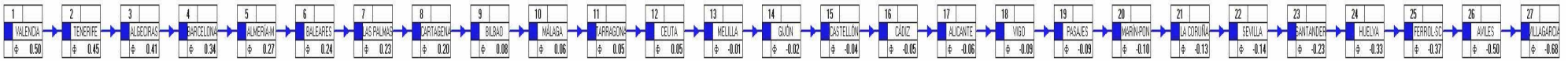
1991
SCENARIO I

SCENARIO II

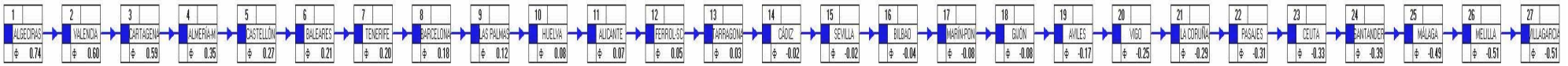


1997
SCENARIO I

SCENARIO II



2001
SCENARIO I



SCENARIO II