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Classification and prediction of port variables using Bayesian Networks

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A B S T R A C T

Many variables are included in planning and management of port terminals. They can be economic, social, environmental and institutional. Agent needs to know relationship between these variables to modify planning conditions. Use of Bayesian Networks allows for classifying, predicting and diagnosing these variables. Bayesian Networks allow for estimating subsequent probability of unknown variables, basing on know variables.

In planning level, it means that it is not necessary to know all variables because their relationships are known. Agent can know interesting information about how port variables are connected. It can be interpreted as cause-effect relationship. Bayesian Networks can be used to make optimal decisions by introduction of possible actions and utility of their results.

In proposed methodology, a data base has been generated with more than 40 port variables. They have been classified in economic, social, environmental and institutional variables, in the same way that smart port studies in Spanish Port System make. From this data base, a network has been generated using a non-cyclic conducted grafo which allows for knowing port variable relationships - parents-children relationships-. Obtained network exhibits that economic variables are – in cause-effect terms-cause of rest of variable typologies. Economic variables represent parent role in the most of cases. Moreover, when environmental variables are known, obtained network allows for estimating subsequent probability of social variables.

It has been concluded that Bayesian Networks allow for modeling uncertainty in a probabilistic way, even when number of variables is high as occurs in planning and management of port terminals.

1. Introduction

Sustainable development is beeing applied emergently by transport authorities and in other activity sectors and industries all over the World. It is proponted by iniciatives which include environmental variables and social responsibility in strategic management of companies (Doerr, 2011). This is port case. Port sustainability is rooted in the proposals of the GRI (Global Reporting Initiative, 2000) and it preserves the four main ideas or dimensions which knock into shape sustainable development – institutional, economic, environmental and social dimensions- It is considered that sustainable management of a company or organism has as main target equilibrate keeping of its function and activity for a long time. So, it is necessary looking for an equilibrate development of economic, social, environmental and institutional dimensions (Serrano, 2015).

This concept is beeing applied emergently by transport authorities and in other activity sectors and industries all over the World. It is proponted by iniciatives which include environmental variables and social responsibility in strategic management of companies (Doerr, 2011). This is port case. Port sustainability is rooted in the proposals of the GRI (Global Reporting Initiative, 2000) and it preserves the four main ideas or dimensions which knock into shape sustainable development – institutional, economic, environmental and social dimensions- (Fig. 1).

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In this context, maritime transport requires an especial attention, because it transports over 80% foreign trade (tonelates-kilometres) (Sánchez et al., 2015). So, sustainable management must be understood in port sector as "management which allows containers traffic, solid and liquid granels, general goods and number of passenger grow up at the same time that energy and natural resources purchase, rubbish volume and negative impacts over social systems and ecosystems decreases in port influence areas" (Crespo Soler et al., 2005).

However, one of the principal challenges to integrate sustainable criterias in management model and port development is broken out

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present inertia which considers economic factor as unique development variable. It is necessary that environmental and social variables gain importance to make port development travels to sustainability (Grupo de Trabajo 23, 2004).

Spanish State Ports and Merchant Navy Law includes sustainability as one of the principles which must regulate planning model and port management. Article 55.4 foresees company planning of each Port Authority must be gone with a sustainability report-it is considered as an analysis and diagnostic tool-. This report use a methodology which is based on GRI's one, but includes specific quality indicators and must be approved by Spanish State Ports and Port Authorities. Redaction of these reports is an important effort to integrate information about Port Authority behavior and information about its environmental, economic and social performance. However, this report does not determine Port Authority behavior, it only describes results using performance quality indicators (Crespo Soler et al., 2007).

These sustainability quality indicators allow an evaluation of sustainable development management. They allow control in an objective way Port Authority management in this material. So, it is obvious that quality indicators must cover four dimensions of sustainability. Implementation of these quality indicators is useful for Port Authorities to control their sustainable management, to evaluate applied programme impacts and to modify them when it is necessary. Quality indicator allow benchmarking sustainable management between different ports to define the best practices and to compare Port Authority performance and similar industry performance. Moreover, it can be a distinguishing element in marketing and a competitive element in market. Widespread application to a port system is useful to perform accurate benchmarking in sustainability between ports in the same region or country (González et al., 2010).

Application of these tools emerge objectives (economics, environmental, socials and institutionals) whose must be achieved by a port authority or port company to assure its sustainable development and its port growth (Autoridad Portuaria De A Coruña, 2008). Economics objectives could be: to increase volume of business, to increase revenue concessions, to reduce debt in order to ensure financial sustainability of the port and to optimize return on investment and of port assets. In environmental dimension, objectives could be to operate with respect for the environment, minimizing the environmental impacts of port activities, minimizing environmental accidents and improve environmental management in the port area. Social objectives could be internal or external and they should be framed in such areas as developing and

Source: Doerr, 2011

Fig. 1. Four dimensions of port sustainability.
Source: Doerr, 2011.

modernizing management systems human resources, to develop a team motivated and committed and sustained and to active support of the surrounding community. For institutional objectives may be seeking to boost certain legal and regulatory changes to modernize way of port development and port operation, reorganizing port market incorporating competition, to management and private investment to better efficiency and capacity expansion, modernization of the labor regime improve competitiveness, to develop port community to increase operational efficiency and quality of processes, institutionalization and optimizing port city relationship, expanding the operational management of port logistics chain to add value and integrate the local community to the development of logistics port (Fig. 2).

Therefore, the objective pursued is that through these four main sustainability ideas, ports conform as a system and not be seen as isolated entities and subject to a specific business situation, but as elements that interact with an environment physical, social and environmental, which are to be integrated effectively, that is, being able to adapt to a changing situation and in turn, pointing to a renewal that will help achieve the best possible future scenarios (Puertos Del Estado, 2011).

The Port Authorities, as administers of port infrastructure, regulators, coordinators of the service provided and, especially as leaders of the community, cannot remain aloof the society they serve and what happens in them; they must understand the environment in which they develop an answer to it in the appropriate manner, contributing in this way to a medium and long-term sustainable development of the port system. Spanish State Ports and Merchant Navy Law (RDL 2/2011) already includes Sustainability as one of the principles that must govern the model of planning and management of Ports. This principle is related to two complementary objectives of great relevance in the port context:

- Reaching a port development committed with environment and according to the available resources
- Contributing to a transport integrated system, which fosters the achievement of a sustainable mobility, in line with the European policy current guidelines

However, a strong methodological limitation has not allowed a wider application of this concept. It is still a critical issue and unresolved for the management of sustainable development, the availability of methodologies for assessing the impact of the actions of institutions and companies in each of the dimensions of sustainability, determining the value and variables that quantify the real contribution or contribution that sustainable development management.

One of the methodologies to be used are Bayesian Networks, from which you can get in a graphical form relationships between variables of each of four dimensions, in order to determine a posteriori values that quantify their contribution sustainability.

Main Works in transport system which have been developed using Bayesian Networks are those included in the next Table (Table 1).

Artificial neural networks are new programming technologies based on computer systems for the analysis and study of learning and automatic processing sustained on the animal neural systems. These technologies are based on the behavior of the human brain. An Artificial Neural Network (RNA) is a computational model based on the structure and functions of biological neural networks. Information flowing through the network affects the structure of RNA, because a Neural Network changes - or learns, in a sense - on the basis of input and output. (see Tables 2–6)

2. Methodology and results

In order to determine the Bayesian network characterising the operation of the main Spanish ports, the following methodology has been developed, divided into two main tasks: one that defines the work environment and the second that develops the artificial intelligence model.

Probabilistic graphical models are graphs in which nodes represent

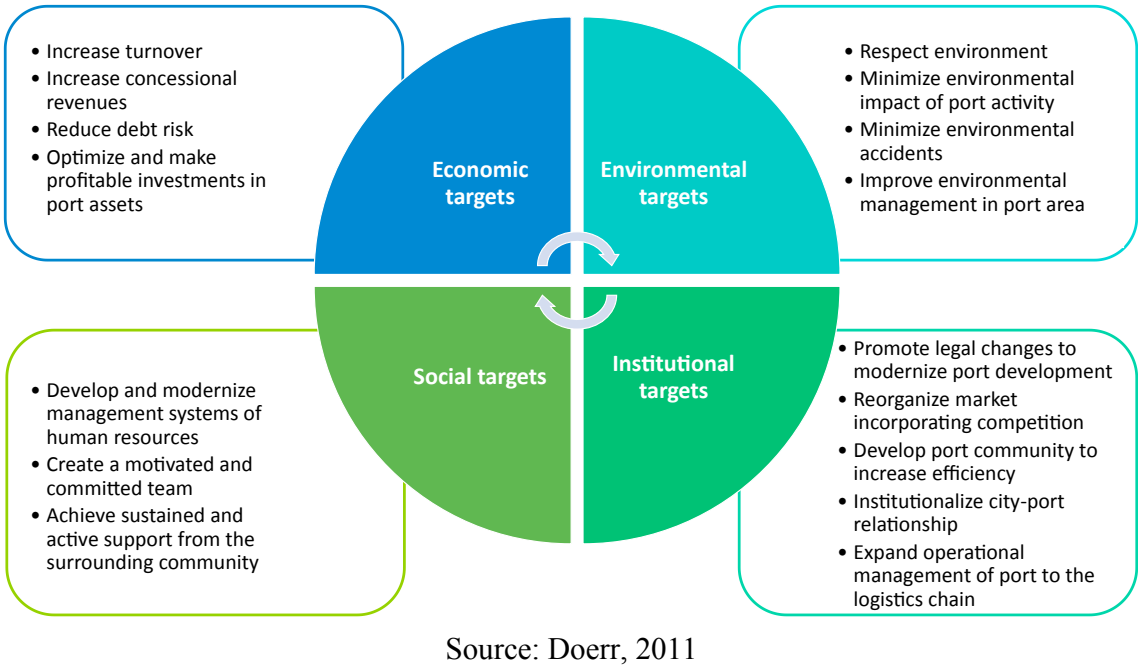

Fig. 2. Principal targets of four sustainability dimensions.
Source: Doerr, 2011.

random variables, and the (lack of) arcs represent conditional independence assumptions. Hence they provide a compact representation of joint probability distributions. Undirected graphical models, also called Markov Random Fields (MRFs) or Markov Networks, have a simple definition of independence: two (sets of) nodes A and B are conditionally independent given a third set, C, if all paths between nodes A and B are separated by a node in C. By contrast, directed graphical models, also called Bayesian Networks or Belief Networks (BNs), have a more complicated notion of independence, which takes into account the directionality of the arcs, as we explain below (Almazán-Gárate et al., 2014). Undirected graphical model are more popular with physics and vision communities and directed models are more popular with AI and statistic communities (it is possible to have a model in which both directed and undirected arcs are included. This model is called chain graph). For a careful study of relationship between directed and undirected graphical models, review references (Castillo et al., 1997; Duda et al., 2001) and (Pearl, 1982).

Building a Bayesian network from data represents a learning process in two steps: the structural learning and parametrical learning (Pearl, 1988) The first step allows obtaining the Bayesian network structure, i.e. the dependence and independence relationships between the involved variables. In the second step, the required a-priori and conditioned probabilities are obtained for a given structure. The following chapters describe the variables discretisation, the model construction, the inference and the classification.

Having selected the variables to be studied, they have to be subsequently discretised to allow the model construction. Bayesian networks usually use discrete or nominal variables; in case they are not, they have to be discretised before constructing the model. Although there are Bayesian network models with continuous variables, these are limited to Gaussian variables and linear relationships. There are two main types of discretisation methods: (i) not supervised and (ii) supervised; thus, different discretisation types are studied and this will be an option of the developed software. In order to apply the Bayesian networks to this study, the variables obtained during the work environment definition will be used. These variables are discrete, so the continuous ones have been discretised according to intervals determined by 25, 50 and 75.

To build the network, the Elvira software has been used, specially developed for Bayesian networks Elvira Consortium, 2002). The computer has been used to study works in Windows 7 operating system, CPU Intel Core i7 3.4 GHz processor and 8 MB of RAM. However, this program does not require such a powerful computer, but if you have JAVA V.5 or later installed software.

The code Elvira uses its own format to encode the models, a reader-interpreter module for codified models, a graphical interface for network construction – with specific options for the case of canonical models, exact and approximate (stochastic) reasoning algorithms for both discrete and continuous variables, reasoning explanation methods, decision-making algorithms, model learning based on databases, networks fusion, etc.

Selected variables in the study are listed in Tables, which are included below:

National Spanish Port System is composed of 46 ports of general interest, managed by 28 Port Authorities, whose coordination and efficiency control corresponds to the Public Spanish Agency called “State Ports”. It depends on Ministry of Fomento and it has attributed execution of Government Port policy (www.puertos.es). Variable values uses to construct Bayesian network model correspond to data from the Sustainability Reports published annually by Spanish Port Authorities and they have been supplemented by information provided by the Public Agency State Ports, which corresponds to the historical record since the year 2010 - counting on almost 3000 records.

Using this sustainability reports, State Ports and Port Authorities materialize their commitment to transparency in their management. It let them to provide a broad vision of its achievements and challenges in many aspects such as competitiveness, quality of service delivery, efficiency in the use of resources and their impact on their economic, social and natural environment.

Since 2010 the 28 Port Authorities integrated in the port system of general interest introduce a Sustainability Report based on the Guide for the development of the sustainability report of the port authorities approved by State Ports. These documents allow us to know the current situation and the evolution that each have suffered at an institutional, financial, social and environmental level, by means of a series of common indicators that allow us to standardize the methodology. The current report collects the aggregated information of the port system and has a

double function:

- Inform on one hand to stakeholders of the strategies, commitments and achievements of the port authorities, reflecting their value only as financial operators but also as social and environmental operators.
- Become on the other hand a management tool that allows us to detect risks and transform them into opportunities, guaranteeing the medium-long term sustainable development and creation of value. The report is divided in four dimensions: institutional, financial, environmental and social, in accordance as well with the Guide for the development of the sustainability reports of the port authorities approved by State Ports.

The institutional dimension describes the main challenges and achievements of sustainability in relation with aspects such as: infrastructures, objective market, financial feasibility, institutional communication, operational efficiency or service quality.

The financial dimension, are gathered every indicator regarding the financial situation of the port authority as well as the level and a structure of investments and some indicators regarding productivity.

The social dimension is based mainly in the human resources policy, including the training actions developed under the scheme of the competency-based management (which has as a goal obtaining an optimal efficiency of the human resources of the company, by means of developing the individual and collective competencies), the quality plan and the efforts made regarding safety and health.

Last and with regard to the environmental dimension, although the port authorities do not have environmental competencies, they do develop a key role in the adequate environmental management of the port (due to the fact that operate as administrators of infrastructure, regulators, coordinators of the service provided and, especially, as leaders of the community).

The activity of the port causes an impact not only in the aquatic environment but also in the land and air, and such chapter assesses the impact on the measures carried out to reduce them.

Although directed models have a more complicated notion of independence than undirected ones, but they have several advantages. The main advantage is that everyone can regard an arc from A to B to indicate A "causes" B. This can be uses as a guide to build graph structure. Moreover, directed models can encode deterministic relationships, and they are easier to learn (fit to data). In addition, it is necessary to specify parameters of the model to define graph structure. In a directed model Conditional Probability Distribution (CPD) must be specify for each node. If variables are discrete, it can be represented as a table (CPT) in

Table 1
Main works in transport systems which have been developed using Bayesian Networks.

Authors	Year	Title
Friedman, N., & Goldszmidt, M.	1996	Building classifiers using Bayesian networks
Jara-Díaz, S., Martínez-Budría, E., Cortes, C., & Vargas, A.	1997	Marginal costs and scale economies in Spanish ports
Tebaldi, C., & West, M.	1998	Bayesian inference on network traffic using link count data
Cain, J.	2001	Planning improvements in natural resource management. guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond
Conati, C., Gertner, A. y VanLehn, K.	2002	Using Bayesian networks to manage uncertainty in student modeling. User Modeling and User-Adapted Interaction
Bromley, J., Jackson, N. A., Clymer, O. J., Giacomello, A. M., & Jensen, F. V.	2005	The use of hugin® to develop Bayesian networks as an aid to integrated water resource planning
Sun, S., Zhang, C., & Yu, G.	2006	A Bayesian network approach to traffic flow forecasting
Zheng, W., Lee, D. H., & Shi, Q.	2006	Short-term freeway traffic flow prediction: Bayesian combined neural network approach
Janssens, D., Wets, G., Brijs, T., Vanhoof, K., Arentze, T., & Timmermans, H.	2006	Integrating Bayesian networks and decision trees in a sequential rule-based transportation model
Castillo, E., Menéndez, J. M., and Sánchez-Cambronero, S.	2008	Traffic estimation and optimal counting location without path enumeration using Bayesian networks
Castillo, E., Menéndez, J. M., & Sánchez-Cambronero, S.	2008	Predicting traffic flow using Bayesian networks
Trucco, P., Cagno, E., Ruggeri, F., & Grande, O.	2008	A Bayesian Belief Network modeling of organisational factors in risk analysis: A case study in maritime transportation
Klemola, E., Kuronen, J., Kalli, J., Arola, T., Hanninen, M., Lehikoinen, A., … & Tapaninen, U.	2009	A cross-disciplinary approach to minimizing the risks of maritime transport in the Gulf of Finland.
Kaluza, P., Kölzsch, A., Gastner, M. T., & Blasius, B.	2010	The complex network of global cargo ship movements.
Hofleitner, A., Herring, R., Abbeel, P., & Bayen, A.	2012	Learning the dynamics of arterial traffic from probe data using a dynamic Bayesian network
Cancelas, N. G., Flores, F. S., & Orive, A. C.	2013	Modelo de eficiencia de las terminales de contenedores del sistema portuario español
Camarero, A., González-Cancelas, N., Soler, F., & López, I.	2013	Utilización de redes bayesianas como método de caracterización de parámetros físicos de las terminales de contenedores del sistema portuario español
Flores, F. S., Cancelas, N. G., Orive, A. C., Gárate, J. L. A., & Monzón	2014	Diseño de un modelo de planificación de zonas de actividades logísticas mediante el empleo de redes bayesianas
Li, K. X., Yin, J., Bang, H. S., Yang, Z., & Wang, J.	2014	Bayesian network with quantitative input for maritime risk analysis

Table 2
Selected factors. Institutional dimension.

ID	Timestamp	Description
dimins	Institutional dimension	Set of sustainability goals and indicators that reflect strategic priorities in the field of sustainability for the entire Spanish port system of general interest
herramgestion_dimins	Tool management support	Management systems to support decision-making: quality management systems, scorecards, market characterization campaigns, etc.
geninfraortuaria_dimins	Port infrasestructure generation	Port Authority role as infraestructure dealer
mercservidos_dimins	Served Markets	Structure and evolution of main good traffics
dinamact_dimins	Port sector role as revitalizing of port activity	Main sector or activities which are relevant in local economic development
servicios concauto_dimins	Services and licenses of concessions/ authorizations	Types, delivery framework and regulation
inicprivada_dimins	Private iniciative presence	Number of companies operates in port, Número de empresas que operan en el puerto, land area occupied, characterized as commercial concession, etc.
transconcu_dimins	Transparency and free competition	Initiatives to ensure that any operator wishing to provide services in port or to qualify for a concession to hear a transparent manner the conditions to operate port and administrative mechanisms governing this process
calidserv_dimins	Service quality	Initiatives promoted by Port Authority to improve efficiency, to service quality and to performance of services rendered to goods
intetrans_dimins	Port integration in transport system	Deficiencies which are coordinated different transport modes that converge at the port

which there is listed probability of a child node takes on all its different values for each combination of its parent's values.

2.1. Parameter learning

In order to specify Bayesian Network and thus fully represent the joint probability distribution, it is necessary to specify probability distribution for X conditional upon X's parents in each node X. Distribution of X conditional upon its parents may have any form. It is very common using discrete or Gaussian distributions when this simplifies calculations. Sometimes, only constraints on a distribution are known; in this case, one can use maximum entropy principle to define a single distribution. The one which has greatest entropy gives constraints. Analogously, in a specific context of a dynamic Bayesian Network, it is usual that one specifies conditional distribution of hidden state's temporal evolution to maximize entropy rate of implied stochastic process.

These conditional distributions often include parameters which are unknown and must be estimated from data. Sometimes, parameters are estimated using maximum likelihood approach. Maximization of likelihood (or posterior probability) in a direct way is often complex when there are unobserved variables. A typical approach of this problem is the expectation-maximization algorithm. This algorithm alternates computing expected values of unobserved variables which are determined by observed data, and maximizing full likelihood (or posterior) considering previous computed expected values are correct. Under mild regularity conditions, this process converges on parameter values of maximum likelihood (or maximum posterior).

A deeper Bayesian parameter approach is treating parameters as additional unobserved variables and computing a full posterior distribution over all nodes conditional upon observed data to integrate out parameters. This approach can be expensive and lead to large dimension models, so in practice it is more common use of classical parameter-setting approaches.

2.2. Learning

It is necessary to specify two things to describe a Bayesian Network: graph topology (structure) and parameters of each Conditional Probability Distribution (CPD). It makes possible to learn both of them using data. However, learning structure is harder than learning parameters. Also, when some of nodes are hidden or there are missing data learning is harder than learning when everything is observed.

Bayesian Network is unknown in many practical setting and it is needed to learn it form data. This problem is known as Bayesian Network learning problem. It ca be stated informally as follows: given training data and prior information (e.g. expert knowledge, casual relationship); estimate graph topology (network structure) and JPD parameters (joint probability) distribution in Bayesian Networks.

Learning Bayesian Network structure is considered a harder problem than learning Bayesian Network parameters. Moreover, another obstacle arises in situation of partial observably in case of nodes are hidden or when dais missing.

Table 3
Selected factors. Economic dimension.

ID	Timestamp	Description
dimecon	Economic dimension	Economic and financial situation of Spanish Port System
sitecofin_dimecon	Economic and finatial situation	Other indicators: return on assets, EBITDA/ tonne debt service, operating expenses and related revenues, etc.
inv_dimecon	Level and structure of investments	Other indicators: public investment relative to cash flow, foreign investment towards public investment, asset renewal
negserv_dimecon	Business and service	Other indicators: income occupancy rates and activity, commercial use of the surface, use of docks, etc.
vgenprod_dimecon	Generated value and productivity	Other indicators: productivity of labor income, labor productivity as EBIDTA, etc.

Table 4
Selected factors. Social dimension.

ID	Timestamp	Description
dimsoci	Social dimension	Human capital and employment
caphum_dimsoci	Human capital of port activity	Employment, internal communication and participation, training, staffing structure and equity, health and safety at work, etc.
empl_dimsoci	Employment and job security in the port community	Employment in port community, job security and training services, port concessions, etc.

Simple case is a Bayesian Network which is specified by an expert. Then, it is used to perform inference. In other applications, task of network definition is too complex for human people, so network structure and local distribution parameters must be learned from data. Automatically learning of a Bayesian Network graph structure is a challenge pursued within machine learning. In this case, obtained network is displayed by K2 algorithm. It can be observed that variable has been pulled away (Fig. 3).

Topology needs to identify factors that are relevant, to determine how those factors are causally related to each other. The arc cause-effect does mean that cause is a factor involved in causing effect. In this case, for example, parent of the variables inv_dimecon and geoinfraortuaria_dimins is the node herramgestion_dimins. Then, when herramgestion_dimins is known, inv_dimecon and geoinfraortuaria_dimins, are conditionally independent (Fig. 4).

Herramgestion_dimins is a resolution variable which appears in network as a "node". Some arcs started on it, so this variable generates a divergent connection. This way, herramgestion_dimins is a parent node which projects arcs to several sons, that is to say, arrows start in this variable and diverges to its sons (Fig. 2). As it can be remembered: herramgestion_dimins, timestamp tool management support, it's management systems to support decision-making: quality management systems, scorecards, market characterization campaigns, etc.

When parent variable state is known, there is a dependence relationship between variables. However, when a parent state is unknown, son variables are taken in an independent way and information will not spread along network if some evidences are included over son nodes (Fig. 2). An effect that has two or more ingoing arcs from other vertices is a common effect of those causes. A cause that has two or more outgoing arcs to other vertices is a common cause (factor) of those effects. The effects of a common cause are usually observables.

Following the Bayesian Network independence assumption, several independence statements can be observed in this case, in respect to each of the factors. When mercservidos_dimins is known, sitecofin_dimecon, servicios concauto_dimins, inicprivada_dimins, ecoef_dimma, vgenprod_dimecon, empl-dimsoci, inv_dimecon, negserv_dimecon, gestamb_dimma, and caphum_dimensoci are conditionally independent of its ancestor's geoinfraortuaria_dimins (Fig. 5).

Casual graph: The variable mercservidos_dimins has ten common effects: sitecofin_dimecon, servicios concauto_dimins, inicprivada_dimins, ecoef_dimma, vgenprod_dimecon, empl-dimsoci, inv_dimecon, negserv_dimecon, gestamb_dimma, and caphum_dimensoci (Fig. 5).

3. Conclusions

The most decision-making category, as network obtained by using the algorithm K2 shows, is institutional category, then economic and social at the same height, and finally environmental category.

Management systems supporting decision-making includes quality management systems, scorecards, market characterization campaigns, etc, and they are represented by herramgestion_dimins. It is considered as a parent variable in network, so arrows only start on it. The same goes for transconcu_dimins which represents initiatives to ensure that any

Table 5
Selected factors. Enviromenal dimension.

ID	Timestamp	Description
dimma	Enviromental dimension	Enviromental quality and management
gestamb_dimma	Enviromental management	Degree of implementation of environmental management systems (EMAS, ISO 14001 and PERLS) and expenses invested financial resources and investment where appropriate, associated with implementation, certification and maintenance of an environmental management system
calaire_dimma	Air quality	Main sources of port emission involving significant emissions, changes in number of complaints or complaints registered by Port Authority from ovine and caprine interest groups dust emissions or air quality in general, measures implemented by Port Authority to control emissions linked to entire port activity
calagua_dimma	Water quality	Main source discharges located at port have a significant impact on water quality and sediment from docks, measures implemented by Port Authority to control emissions linked to entire port activity, surface area service that offers collection and treatment of wastewater
calacust_dimma	Sound quality	Major emission sources (point and diffuse) port involving significant noise pollution, changes in number of complaints or complaints registered by Port Authority from stakeholders, preparation of noise maps and noise action plan
residuos_dimma	Rubbish management	Waste generated by Port Authority are segregated and recycled, activities or sources of waste generation within port, initiatives promoted by Port Authority to improve waste management in port community
ecoef_dimma	Eco-efficiency	Efficiency in land use, water consumption and electricity by Port Authority
comport_dimma	Port community	Conditions or requirements on environmental issues in specifications of particular technical requirements for port services, in terms of grant and concession titles or authorization

operator could provide services in port or qualify for a concession because operator can know, in a transparent way, conditions to operate and administrative mechanisms governing this process. It is a father node in network. Furthermore, transcocu_dimins is decision-making variable, so it appears in network as a "node" variable and bows only start on it. So, a divergent connection is created and this father node throws its bows toward several of its sons, that is to say, arrows start on it and go to its sons.

Other essential variable in network structure is mercservidos_dimins. 10 arrows star on it and go to 10 different nodes. These are effects of structure and main good traffic evolution, so they are social, economic, institutional and environmental effects. That is to say, served markets have effects on rates, delivery framework and regulation of port services the number of companies operating in the port (institutional category). It has effects on EBITDA, EBITDA/tonne, public investment relative to cash flow and: income from employment and activity rates among others too (economic category). Even, about social status, it has effects on variables representing port community employment, job security and training services and health work, among others. Finally, in environmental category, served markets causes different grades of environmental management systems implementation (EMAS, ISO 14001 y PERLS), economic resource investment and investments associated to implementation, certification and maintenance of environmental management system. Therefore, served markets are a very important variable in planning from a sustainable perspective.

In other hand, institutional variables are interconnected. Economics ones are important as cause-effect because they are effects of served markets which belong to institutional dimension. Generated value and productivity depend on kind of business and service (fee income occupation and activity, commercial use of the surface, use of docks, etc.). Moreover, social variables are effects of institutional variables but they have not a direct relationship with their same dimension, social one. Finally, environmental variables are closely interconnected in Bayesian Network and they are principally effects of institutional category. Therefore, economic, social and environmental variables are effects of institutional ones.

As a conclusion, key issue is that Port Authorities start to incorporate sustainable elements-included in Spanish State Ports and Merchant Navy Law - in their tools, used to regulate port services and public possession management.

Using relationships between variables that describe each of the four axes of sustainability, obtained using Bayesian networks, it has been determined that these axes can not be considered as isolated entities and subjected to a concrete commercial conjuncture. They are interrelated with a physical, social and environmental environment, in which they must be effectively integrated to make ports create a system. This system lets ports are able to adapt to a changing conjuncture and at the same time and to point to a renewal that contributes to achieve the best of the possible future scenarios. It is only possible through knowledge of the relationships between different variables.

Sustainability should be then understood as an element contributor of value for the entities and for the society as a whole. It is a transversal and multidimensional concept that must be integrated in the strategy policies and actions of the port authorities to answer the social, environmental and business needs. It will simultaneously allow us to increase the capacity of value creation of the organizations and their condition of long-term success factor, focusing in improving the aspects in an internal and external level.

Considering current port system structure, institutional variables are those that take greater weight in achievement of sustainability objectives, because dependence relationship between these variables that has been obtained using a Bayesian network model developed. For this reason, port system will be able to act on sustainability variables if it acts on environmental dimension variables. To see possible effects, it is necessary to know about what parameters Port Authority can act from the institutional point of view. The basic functions of the port authority are the planning, projection, construction, conservation and operations of the works and services of the port, collaboration with official bodies, and coordination of the port private companies and management of the

Table 6
Sons of mercservidos_dimins variable.

Son of *mercservidos_dimins*	Explanation
serviciosconcauto_dimins	Types, delivery framework and regulation
inicprivada_dimins	Number of companies operates in port, and area occupied, characterized as commercial concession, etc.
vgenprod_dimecon	Other indicators: productivity of labor income, labor productivity as EBIDTA, etc.
sitecofin_dimecon	Other indicators: return on assets, EBITDA/tonne debt service, operating expenses and related revenues, etc.
inv_dimecon	Other indicators: public investment relative to cash flow, foreign investment towards public investment, asset renewal
negserv_dimecon	Other indicators: income occupancy rates and activity, commercial use of the surface, use of docks, etc.
empl_dimsoci	Employment in port community, job security and training services, port concessions, etc.
caphum_dimensoci	Employment, internal communication and participation, training, staffing structure and equity, health and safety at work, etc.
gestamb_dimma	Degree of implementation of environmental management systems (EMAS, ISO 14001 and PERLS) and expenses invested financial resources and investment where appropriate, associated with implementation, certification and maintenance of an environmental management system
ecoef_dimma	Efficiency in land use, water consumption and electricity by Port Authority

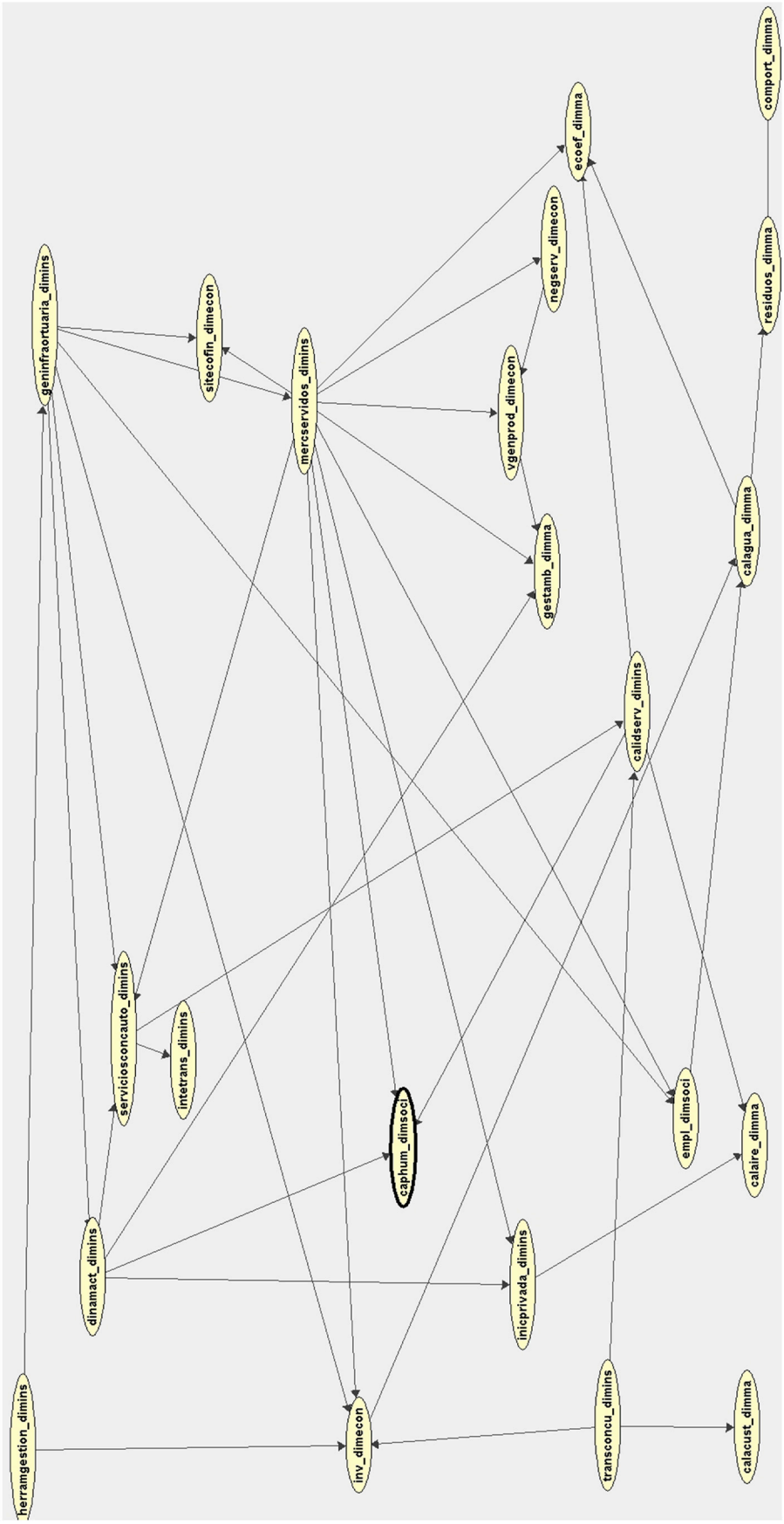

Fig. 3. Bayesian network. Algorithm K2.

port domain. The competencies of the Port Authority are:

- Management and control of the port and commercial services
- Provision of the general port services
- Ordinance of the port service area and the port uses
- Promote, maintain and operate the port infrastructures
- Manage the port public domain
- Optimize the financial management and profitability of its patrimony and resources
- Foster commercial activities, logistics and, in its case, industrial, related with the shipping or port traffic.
- Coordination of the operations of the different types port transport.
- The ordinance and coordination of the port traffic, in the water as well as on the land.

In this framework, the management of the state port public domain is oriented, guaranteeing the general interest, to the following:

- Provide and manage basic port infrastructures.
- Promote the economic activity of the port.
- Promote and increase the participation of private initiative in the funding, construction and operations of the facilities, by granting licenses, authorizations and concessions to operate in the port public domain.
- Guarantee the service provided by the port to the shipping cargo traffic in conditions of safety and quality, optimizing the cost of the cargo in its way through the port.
- Managed infrastructure and the public port domain with profitability and efficiency criteria.
- Manage support sustainability criteria, boosting such principal in the totality of the port community.

Relationships between private initiative and public body are decisive in achievement of sustainability objectives, using institutional dimension. In regards to the different types of investments (Port-City, safety, environment or business promotion), its right identification and analysis presents a challenge. Looking into the future, it will become necessary to go deeper into defining its criteria, due to the large number of concepts that intervene in this type of actions and the confusion that this involves for its proper analysis and report. As for institutional transparency, it is relevant to mention that Spanish State Ports and Merchant Navy Law establishes different mechanisms to guarantee that companies operating in the port public domain deliver their service in a regimen of free competitiveness and free concurrency. In regards to the quality of the services it is also worth mentioning that some authorities count with mechanisms to boost quality improvements and competitiveness of their services, and with mechanisms to assess their quality. It is worth to emphasize the wide group of social, financial and administrative nature collectives that are affected by the activity of the Port Authorities and that themselves affect the development and performance of such Port Authorities' activities. Because of their institutional commitment, most of the ports identified their expectations and define communication or participation frameworks with each of those groups.

In addition to the bodies established by norm, there are different management tools to assist in the decision-making, goals definition and their follow-up in the Port Authorities. These tools are, among others:

- Balanced Scorecards for the implementation of strategies and goals definition.
- Quality Management Systems according to norm ISO 9001
- Occupational Risks Management Systems according to standard OSHAS 18001
- Environmental Management Systems according to standard ISO 14001◦ EMAS
- Management Excellence Standards such as EFQM (European Foundation for Quality Management) In Graph1.1 is shown the degree of implementation of some of these management standards in different port authorities, along 2013.

Staff competencies correspond to governmental bodies of the Port Authorities, in other words, to Management Boards, without more limits than those regulated by Labour and Budget Regulations. Personnel of Port Authorities are linked to these by a relation subject to the Labour or private Law rules that are applicable. Recruitment is carried out according to systems based on the principles of merit and capacity, and with the exception of directive or trusted staff, through public call. The regimen of remuneration and non-compatibility adjusts to what is in general established regarding staff of Public Law Entities which article 6 of the amendment Budget General Law refers to. So, in case of social dimension, it seems less probable to influence in a direct way.

Therefore, if a Bayesian network is built in a port environment which are based on the four pillars of sustainability: economic, social, environmental and institutional, a tool that lets actuate on sustainability of global port system will be obtained because relationships between different variables are known. This tool is very necessary because the environmental management is clearly constrained by the exploitation scheme public-private. The port's environmental efficiency does not exclusively rely on the Port Authority, but also on how rigorous the concessions, service providers and port users are regarding environmental management. It is important to keep in mind that the Port Authority does not have environmental competencies, neither does it have the ultimate responsibility to enforce the environmental legislation in the port. In general, this competency relies on the Autonomous Communities, who are provided with a sanctioning regimen that allows them to act against possible violations. However, Port Authorities develop a key role in the adequate environmental management of the port due to the fact that they act as administrators of infrastructures, regulators, coordinators of services provided and, specially, as leaders of the port community.

It is worth mentioning that in the last three years the number of Port Authorities which have an environmental management system (EMS) implemented has evolved from 9 to 25. However, the environmental efficiency of the port is strongly conditioned by the private companies that operates in it. Despite great efforts made by Port Authorities by

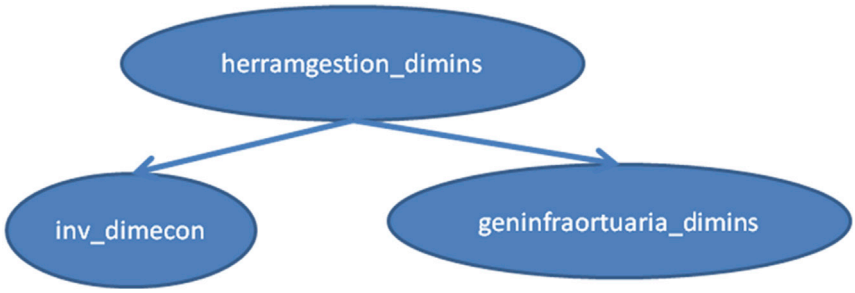

Fig. 4. Relationship 1.

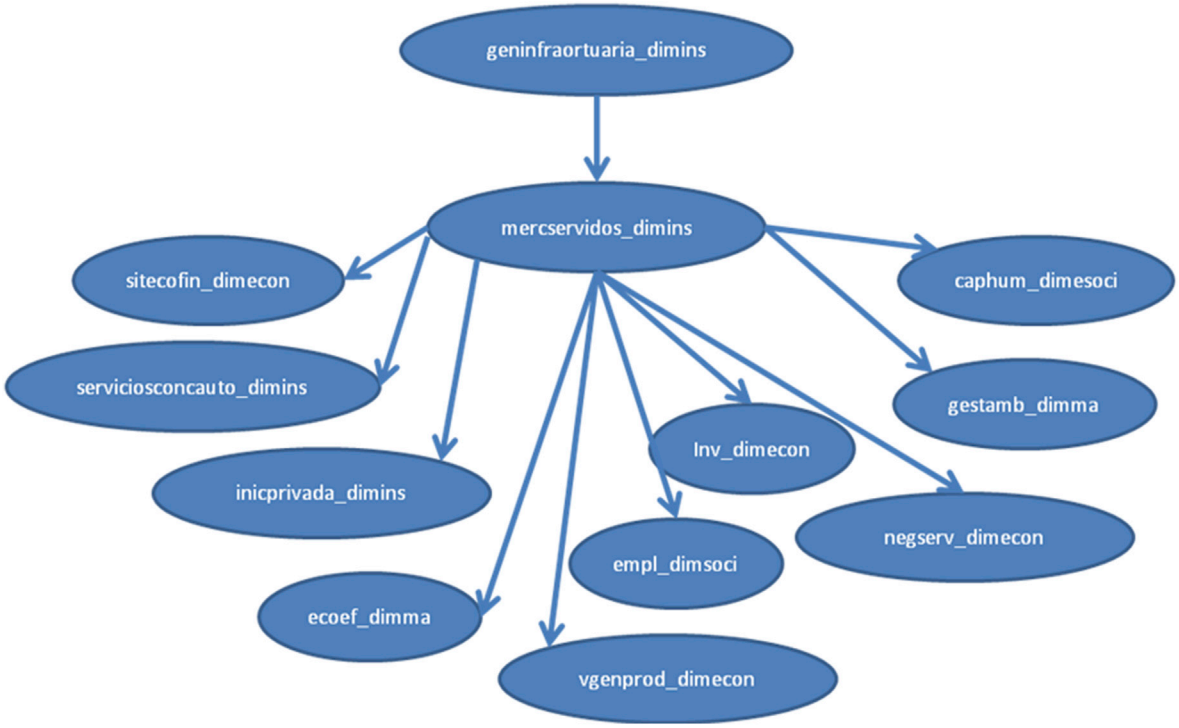

Fig. 5. Relationship 3.

demanding these enterprises to be in possession of a certification, most of the Marpol, stowage or technical service delivery companies do not count yet with an EMS. Another challenge is extending the training regarding environmental matters, due to the fact that only 35% of the personnel took it. In regards to air and water quality, Port Authorities actively contribute launching different initiatives to reduce dust and particle emissions and improve the quality of water and the acoustic quality. However and regarding waste, there is a strong possibility to improve as regards to control and valorisation.

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