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A methodology for measuring sustainability of dry ports location based on Bayesian Networks and Multi-Criteria Decision Analysis

Samir Awad-Núñez*[,a], Nicoletta González-Cancelas[a], Francisco Soler-Flores[b], Alberto Camarero-Orive[a]

[a]*Department of Transportation, Technical University of Madrid, Spain*
[b]*Dept of Mathematics and Computer Science applied to Civil and Naval Engineering, Technical University of Madrid, Spain*

Abstract

The decision of where to locate a dry port requires the analysis of the whole logistics supply chain, with the objective of transferring the largest volume of goods possible from road to more energy efficient means of transport, like rail or Short Sea Shipping, that are less harmful to the environment. However, such decision ought to cope also with the sustainability of the site inland. The objective of this article is to investigate the variables influencing sustainability of dry port location and how this sustainability can be evaluated. We propose a methodology based on Multi-Criteria Decision Analysis (MCDA) and Bayesian Networks (BNs). MCDA is used as a way to establish a scoring, whilst BNs were chosen to eliminate arbitrariness in setting the weightings using a technique that allows us to prioritize each variable according to the relationships established in the set of variables. In order to determine the relationships between all the variables involved in the decision, giving us the importance of each factor and variable, we built a K2 BN algorithm. To obtain the scores of each variable, we used a complete cartography analysed by ArcGIS. As case studies, the sustainability of all of the 10 existing dry ports in Spain has been evaluated. In this set of logistics platforms, we found that the most important variables for achieving sustainability are those related to environmental protection, so the sustainability of the locations requires a great respect for the natural environment and the urban environment in which they are framed.

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Keywords: Dry ports; Industrial location; Sustainability; DELPHI; Bayesian Networks; Multicriteria Decision Analysis; Geographic Information Systems

* Corresponding author. Tel. +34 91 336 6657
E-mail address: samir.awad@caminos.upm.es

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1. Introduction

The global economic structure, with its decentralized production and the consequent increase in freight traffic all over the world, has led shipping to become the most suitable and cheapest way to transport goods. Ports are nodes of critical importance in the logistics supply chain as link between two transport systems: the sea-side and the land-side (Nuzzolo et al., 2013). The growth of the activities at seaports is producing three undesirable effects: increasing road congestion, lack of open space in port installations and a significant environmental impact. These adverse effects can be mitigated by moving part of the activities inland. In this respect, the implementation of dry ports is a possible solution and would also provide an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain, acting as a link between road and railway networks. Moreover, it allows the separation of the links of the transport chain, thus facilitating the shortest possible routes for the lowest capacity and most polluting means of transport.

The dry port concept is based on moving intermodal terminals further inland from the port areas (Jaržemskis, A., Vasiliauskas, A. V. 2007). This logistics platform is presented as a solution to the most important problems arising from the accumulation of activities in port areas: increasing road congestion, lack of open spaces in port installations and the significant environmental impact of seaports (Rodrigue 2006).

Connecting cargo handling from the port to a logistics centre helps achieve a better port operation, which leads to a greater efficiency in ship operations (reduction in ship time in port) and to energy efficiency issues in shipping and, particularly, to operational issues such as the minimisation of fuel consumption and resulting greenhouse gas emissions (Moon, D.S.H.,Woo, J. K. 2014). It helps also to avoid traffic bottlenecks, which relates to a decrease in road and railway emissions. In addition, dry ports allow the separation of the various links of the transport chain. Thus, they are also presented as an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain, allowing for the shortest possible routes for the lowest capacity and most polluting means of transport (Roso 2007; Regmi, M. B., Hanaoka, S. 2013).

All these conditions present dry ports as a solution that provides a more sustainable logistics supply chain. But while taking into account the sustainability of the logistics supply chain it is also necessary to ensure the sustainability of the site. The main goal of this article is to investigate the variables influencing the sustainability of dry port location and how this sustainability can be evaluated.

2. Factors influencing the location of dry ports

The diversity of factors involved in the location of industry has prompted economists over the last century to build models that try to explain the complexity of the real world. For Weber (1909), the main objective when deciding on the location for any industry is to reduce the transport and labour costs. Hotelling (1929) and Reilly (1931) include the presence of competitors. Christaller (1933) adds the “minimum demand threshold” in order for the location to be profitable. As a result of this threshold, the best locations are close to large population centres. But for Lösch (1940), the relationship between population size and type of industry is very important because the impacts on a big population density could lead to social problems. In 1979, Smith introduces the concept of “subtracted value”, which consists of the negative externalities that must be considered against the positive. According to Brown (2005), accessibility to and from the centres of origin and destination of the various flows should be maximised, which is achieved through the connection with the transportation and communication systems, generally located alongside transportation facilities forming hubs.

As can be seen, location problems are multi-objective problems and the implications on levels of economic growth, social welfare, environmental acceptability, accessibility and territorial conditions must all be taken into account. From the research of Pons (2008), and incorporating the elements described above, the set of variables of this study is presented in Table 1. These 41 variables are grouped into 17 factors which in turn correspond to 4 categories: environmental factors, economic and social factors, accessibility factors, and location factors (gathered in Table 1). The variables can be considered as either a Profit, when a higher value is better in geographical analysis, or a Cost, when a lower value is better, and where w_k are the weights of each factor and $W_{\bar{k}}$ are the weights of each variable.