Developing a Multi-Criteria Decision Making Model for identifying factors influencing the location of logistic hubs: A case study of Morocco

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Abstract

Logistic hub facilities work as consolidation /deconsolidation, switching and connecting for flows between origins and destinations demand nodes. They are represented as the linchpin of the supply chain, and are designed as a solution to reducing transportation cost, and diminishing CO2 emissions.
The selection of an optimal location of logistic hubs is a multi-criteria decision making problem that involves a set of quantitative and qualitative decision criteria. The aim of this paper is to develop a decision support system using AHP (Analytic Hierarchy Process) that can help to select the most appropriate location of logistic hubs. Hence, various criteria that can effect on the choice of location of logistic hubs are selected from the literature and experts opinions. Seven main perspectives and twenty-one sub-factors are identified and categorized according to PESTEL (Political, Economic, Socio-cultural, Technological, Environment and Legal) model and accessibility factor category.
To the best of our knowledge, this model is introduced to the literature for the first time. The results show that the proposed system is able to provide more accurate location place.
The proposed model is tested with a case study of logistic hubs location in Morocco. The results show that the multiple criteria decision making (MCDM) model can be used to explain the evaluation and decision-making procedures of a logistic hub location. The results give greater importance to the aspects considered in the classical theories of industrial location, which are accessibility and economic factors

Keywords
Logistic hub, Hub location, PESTEL, Multicriteria Decision Analysis, AHP.

1. Introduction

In a high global competition context, firms, industries, and nations are looking for new strategies able to reducing mainly their logistic costs. The cost of logistics operations is sometimes equal to the half of the value of commodities; hence lowering logistics costs is become crucial.

Logistics is defined as ‘the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory through the firm and its marketing channels in such a way that current and future profitability are maximized through the cost effective fulfilment of orders’ [(Christopher)]. Today, logistics costs strongly affect the competitiveness of countries (Kogani, 2001). Moreover, Global logistics costs represented 13.8% of the world’s GDP in the year 2002 (Rodrigues, Bowersox, & Calantone, 2005).

For emerging countries such as Morocco, the development of logistic sector constitutes a major stake, given the impact of this sector on the improvement of the competitiveness of trade in the country as well as its contribution to the country’s sustainable development. The overall performance of the sector is still in the intermediary stage offering a strong potential of growth (“Stratégie nationale de développement de la compétitivité logistique,” n.d.). In this context, a strategy for the enhancement of Morocco’s logistics competitiveness has been defined by the State and the private sector aiming principally at reducing the weight of logistic costs in relation to the GDP.

Developing logistic platforms (hubs) is the first line of the five main lines of the stated strategy. The localization of these centers is an important strategic decision making step in logistic, they play a vital role in the design of efficient supply chain networks, offering economies of scale by reducing transportation costs (Alumur & Kara, 2008).

Logistic platforms are special facilities that work as consolidation centers allowing concentration of flows coming from different origins, and sending them to their corresponding destination (Farahani, Hekmatfar, Arabani, & Nikbakhsh, 2013)

Figure 1 present a network with 11 nodes and three hubs including 7, 3, 9 nodes. As can be seen, by locationg some hubs in the network, the number of edges in the graph (transportation links) is reduced. Hence, demands are satisfied more efficiently in a hub network by using fewer resources, than in a fully connected network.

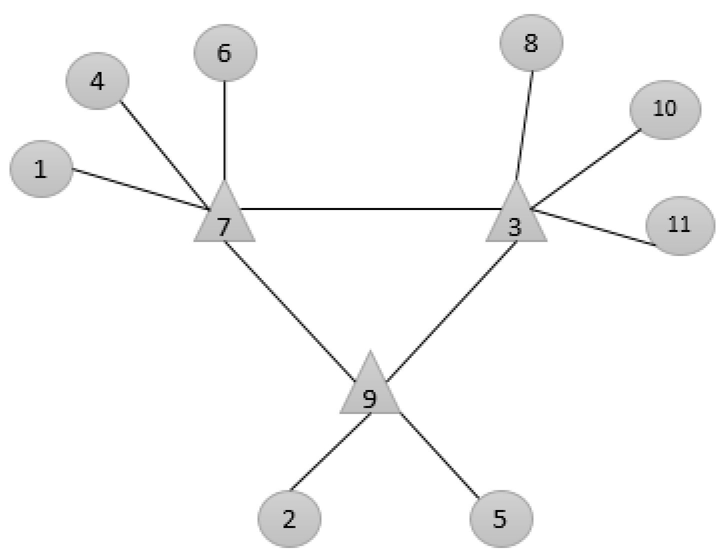

Figure 1. A Hub and spoke network with 11 nodes and 3 Hubs

Hub location problem is represented as an important part of operations research science that aims to optimally locate hubs based on a certain number of criteria. Generally economic aspect (minimizing cost) is the most frequently considered location factor in the literature (Farahani et al., 2013), and fewer researchers applied the multiple criteria decision making methods for selecting logistic hubs. However, several factors as social factors and environmental impact factors should be taken into consideration in order to achieve sustainable logistic platforms location.

In this paper, we aim to develop a decision support system using AHP (Analytic Hierarchy Process) for locating logistic platforms. The proposed system consists of four components:

1) Hierarchical structure development for Analytic Hierarchy Process: in this step we first define national and international criteria , according to the literature, which are essential in the choose of optimal location of logistic platforms. We then group identified criteria in seven main perspectives and twenty one criteria by using a PESTEL analysis.
2) And 3) Weights determination and data collection : these steps consist of determining the level of importance of each location criteria, by conducting a questionnaire survey, thus the corresponding data are collected through an extensive interview process in Morocco. The experts were investigated to prioritise the identified location criteria.
3) Decision making : the propose decision support model allows decision makers and managers to choose the best location of logistic platforms in Morocco.

The rest of this paper is structured as follows: Section 2 present literature review about existed location factors in the literature, a brief description of AHP method and PESTEL analysis; while the methodology and the proposed system are provided in Section 3. Conclusion and future research are shown in Section 4.

1. Literature review

1.1. Logistic platforms location factors

The varieties of different factors required in the location of any industry or logistic platforms has involved researches over the last century to generate models that reveal the complexity of real world.
Weber (1989) was the first who introduced the location theory by considering the problem of locating a single warehouse , with the objective of reducing the total travel distance between the warehouse and customers. For (Vlachopoulou, Silleos, & Manthou, 2001), the main objective when deciding on the location of logistic platforms is the existence of qualified infrastructures. (Kayikci, 2010) considers accessibility to the site as a criteria of location. (Laetitia Dablanc, 2007) takes into account proximities to major trasportation modes (airport, railways, highway…) as location factors. The availability of labour was considered by (Eryürük et al.).

1.2. Analytic Hierarchy Process (AHP)

Analytic hierarchy process (AHP) is represented as a problem solving framework (T L Saaty, 1986). It has been proposed as a decision making process to analyze complex problems involving multiple criteria. This method is considered as an advancement compared to other decision-making methods, see that it allows taking into account subjective factors (Emrouznejad & Marra, 2017).
AHP consist in decomposing the problem hierarchically into various levels of sub-elements in relation from the overall objective (the target) to the sub-objectives (Criteria, factors, and sub-factors). The main steps of this method can be summarized as follows (Thomas L. Saaty, 2008):

- **Step 1:** corresponds to the decomposition of the decision problem into a hierarchical structure composed of a goal at the highest level, criteria and sub-criteria (factors) at the intermediate levels, and options at the lowest level (Kasperczyk & Knickel, 2004).

- **Step 2:** consist in finding corresponding weights of each decision elements by pairwise comparison. For each pair of factors at a particular level, the decision maker provides the relative importance of factor A to factor B using the rating scale in Table1, hence forming a comparison matrix pairs.
- **Step 3:** the relative weights for each elements at various levels are calculated by using an eigenvector analysis.

Table 1. Saaty scale (Thomas L. Saaty, 2008)

Numerical values	Interpretation
1	Equal importance of both factors
3	Moderate importance of one factor over another
5	Strong importance of one factor over another
7	Very strong importance of one factor over another
9	Extreme importance of one factor over another
2, 4, 6, 8	Intermediate value between two adjacent judgments

- **Step 4:** consistency check of judgments. To confirm the consistency of the pairwise judgments, the consistency ratio (CR) is calculated using the mathematical expression (1):

$$CR = CI/RI \qquad (1)$$

Where the consistency index (CI) = $(\lambda max - n)/(n-1)$, (λmax is the maximum average value) and RI is a random consistency index, which is selected from Table 2 depending on value of n: the number of compared elements.

Table 2. Random consistency index table (T L Saaty, 1980)

Number of factors: n	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

- **Step 5:** Establish relative preference (weights) of each decision element

1.3. PESTEL

PESTEL (Political, Economic, Socio-cultural, Technological, Environment and Legal) analysis is a strategic technique which aims to analyse the macro environmental conditions and situation of a company (Yüksel, 2012).
The first form of PESTEL was originally introduced by Aguilar in 1967 as ETPS (economic, technical, political, and social). It was modified later to cover external environment, and was defined as STEPE. Afterwards, the method has been used in various fields.
In this study, we conduct PESTEL analysis in order to examine the external factors that characterizes Logistic Platforms location.

2. Methodology

As mentioned before, the proposed decision system consists of four main components (Figure 2).
The evaluation factors were categorized into seven main dimensions according to PESTEL model from themes political, economic, social, technological, environmental, and legal factors, in addition to accessibility factors. Thereafter detailed sub-factors were decided based on literature survey and knowledge of domain experts. The data collection was performed through questionnaire and published government documents.
The proposed model was evaluated via a case study of Morocco. First, an expert team was constructed, consisting of three experts in the logistic field who are working on the project of location of logistic hubs in Morocco, and three academic researchers in the logistic field.

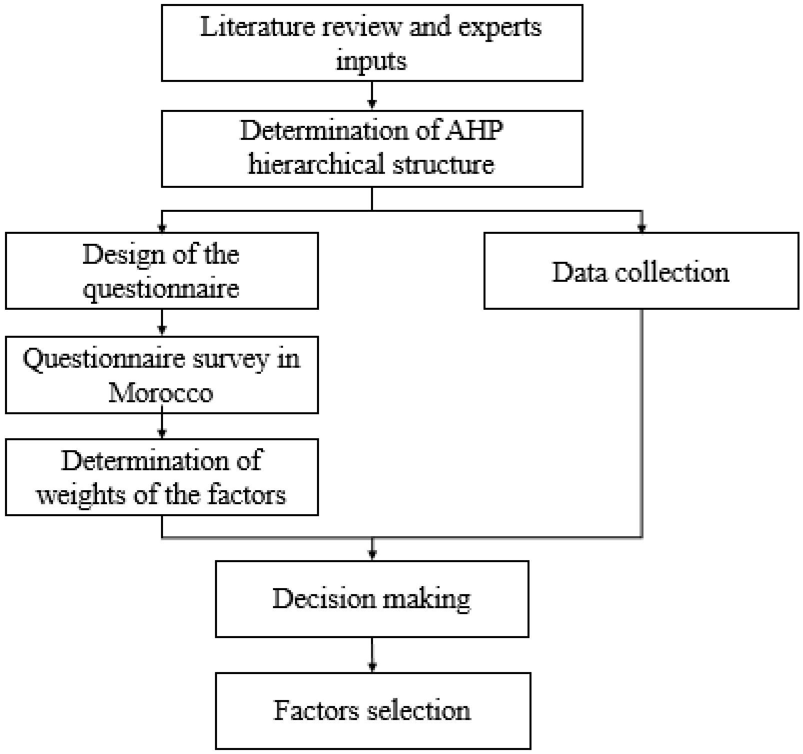

Figure 2. The decision support system for locating a logistic platform

2.1. The hierarchical structure development for evaluation factors

The number of factors affecting the logistic platforms location evaluation is quite large. From the study of references mentioned earlier and discussion with the logistic and location analysis experts, we identified 21 factors for the evaluation of the location of logistic platforms Figure 3.

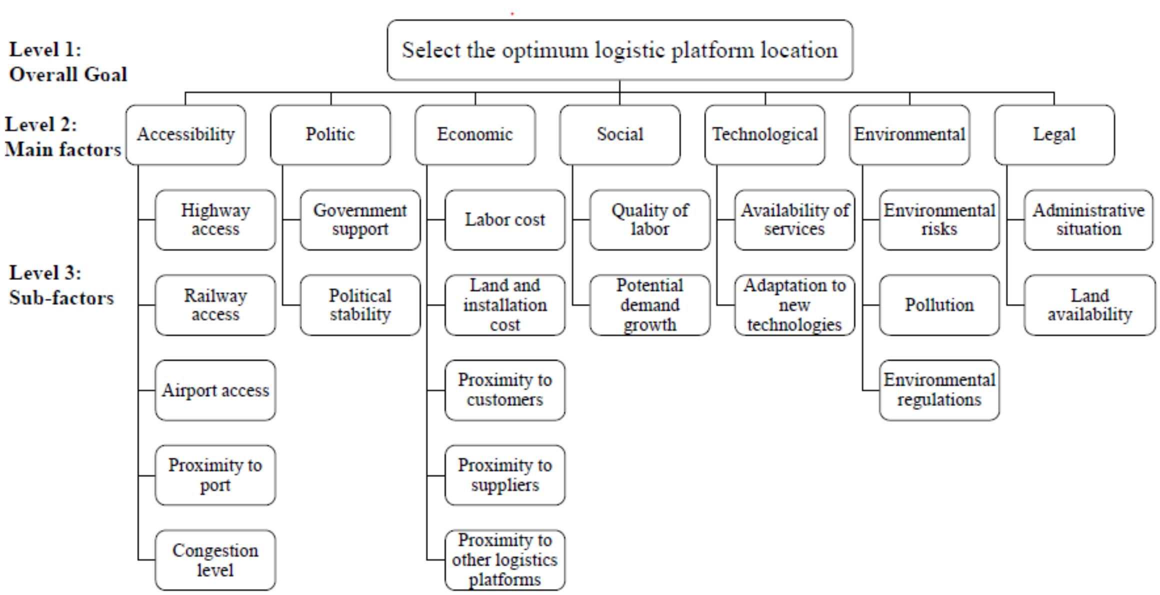

Figure 3. AHP-based hierarchical structure for logistic platforms location

1. Accessibility factor: accessibility factor include the access to highway, railway, port, and airport infrastructures; also considers the congestion level of the candidate region. These sub-factors provide a situation that has the best accessibility to and from the centers of different flows from various origin and destination. It measure a region's capacity to move freight and access to different transport modes (L Dablanc, 2007)
2. Politic factor: this dimension include the evaluation of aspects that might prevent the operation of different logistic activities in the region and the political restrictions that might affect operations (Kalantari, 2013). Thus, it assess the government support and political stability of the candidate land for locating a logistic platform
3. Economic factor: cost is considered as one of the most important factors that is required to be assessed in the location decisions. It appears almost in all of the studies published by different researchers. The earlier theories in location analysis put more emphasize on this factor in a way that some theories suggest that the best alternative is the one that yields the least value for cost.
It include labor cost, land and installation cost, proximity to customers, proximity to suppliers, and proximity to other logistics platforms (Eryürük, S. H.; Kalaoğlu, F.; Baskak, 2012), (Ashrafzadeh, M.; Rafiei, F. M.; Isfahani, N. M.; Zare, 2012), (Uçal Sarı, I.; Öztayşi, B.; Kahraman, 2013), (Awad-Núñez, González-Cancelas, Soler-Flores, & Camarero-Orive, 2016).
4. Social factor: social objectives are becoming a necessity that have to be taken into account when deciding a location. Quality of labor represent the ability of the region to provide skilled labour able to work in the logistic platform. Potential demand growth sub-factor measures the possibility to maintain logistic operation activities during time (Ashrafzadeh, M.; Rafiei, F. M.; Isfahani, N. M.; Zare, 2012).
5. Technological: this category comprise two sub-factors: availability of services and adaptation to new technologies. A good density of services provides the different needs a logistic platform requires (maintenance, restoration, etc ...) (Kalantari, 2013). The different operations utilized in the logistic platforms for handling goods need an adaptation to new technologies.
6. Environmental: environmental aspects (Awad-Núñez et al., 2016) need to be considered, it assess the overall environmental impact such as $CO2$ emissions from freight transportation and noises. It consist of environmental risks Pollution, and environmental regulations.
7. Legal: this factor include administrative situation of the site and land availability (Kalantari, 2013). Land availability represent the expansion capabilities of the region. A new hub development will require more land for warehouses, terminals, and other infrastructures.

2.2. Weights determination of each evaluation factor

After the hierarchical structure has been established, we formulated a questionnaire based on the presented structure to get expert's opinion and collect related data. The main purpose of the questionnaire is to elaborate a pair-wise comparison of each level with respect to each element in the next higher level of the hierarchy, by using Saaty's scale (Table 1). Pair-wise comparison and weights of the main factors are shown in Table 3. The calculations were performed by using super decisions software, dedicated to the AHP method. After determining all the inputs, the software automatically calculates the coherence indices linked to each comparison matrix for checking the consistency of the judgments.

Table 3: Pairwise comparison matrix of factors and corresponding weights

Factors	**AC**	**POL**	**ECO**	**SOC**	**TEC**	**ENV**	**LEG**	**Weights**
Accessibility (AC)	1	6	2	5	3	2	5	0.3
Politic (POL)	1/6	1	1/6	1/5	1/4	1/5	1/3	0.027
Economic (ECO)	1/2	6	1	3	4	4	4	0.271
Social (SOC)	1/5	5	1/3	1	1/3	1/4	3	0.075
Technological (TEC)	1/3	4	1/4	3	1	1/4	4	0.108
Environmental (ENV)	1/2	5	1/4	4	4	1	2	0.173
Legal (LEG)	1/5	3	1/4	1/3	1/4	1/2	1	0.050
CR=0.10								

Based on the results of the survey, accessibility factor is classified first (0.3), followed by economic factor (0.27), environmental factor was ranked third (0.173), technological factor was classified fourth (0.108), social factor was ranked fifth (0.075), legal and politic factors were ranked sixth and seventh respectively (0.05) and (0.02. The consistency Ratio (CR) of pairwise comparison matrix is 0.10, which confirm that the results of the survey are consistent and reliable.
The survey also indicated the importance of sub-factors, and the global weights was obtained by multiplying the local weights by the weights of the major factor for each category. Results are shown in Table 4.
Highway access, Proximity to customers, Proximity to suppliers received the highest weights and are the three most critical factors for locating logistic hubs in Morocco.

Table 4. Computed global weights of sub-factors

Goal	Factors	Importance weight	Sub-factors	Relative importance weights	Global importance weights
Select the optimum logistic platform	Accessibility	0.3	Highway access	0.39	0.117
			Railway access	0.18	0.054
			Airport access	0.04	0.012
			Proximity to port	0.10	0.03
			Congestion level	0.27	0.081
	Politic	0.027	Government support	0.16	0.004
			Political stability	0.83	0.022
	Economic	0.271	Labor cost	0.04	0.01
			Land and installation cost	0.06	0.01
			Proximity to customers	0.37	0.1
			Proximity to suppliers	0.39	0.1
			Proximity to other logistics platforms	0.13	0.03
	Social	0.075	Quality of labor	0.25	0.018
			Potential demand growth	0.75	0.05
	Technological	0.108	Availability of services	0.75	0.08
			Adaptation to new technologies	0.25	0.02
	Environmental	0.173	Environmental risks	0.10	0.02
			Pollution	0.39	0.06
			Environmental regulations	0.49	0.08
	Legal	0.050	Administrative situation	0.25	0.01
			Land availability	0.75	0.03

3. Conclusion and Future Research

This study proposed a decision support system for locating logistic platforms. It evaluated the various relevant factors to decide for the optimum logistic platforms location. 21 sub-factors related to the location decision were identified. Then, an AHP model is developed for selecting logistic platforms and a case study of morocco is carried out.

AHP was used in order to evaluate the degree of importance of factors in terms of seven main categories, which are PESTEL themes plus accessibility factor. The results of pair-wise comparison of logistic platforms location factors show that the priority of these factors are in the followed order: accessibility factor, economic factor, environmental factor, Technological factor, social factor, legal factor, and politic factor.

The main originality of the proposed study is that it allow taking into account the various criteria that represent the macro environment of a location, which can affect the decision of locating a logistic hub.

The most important factor is accessibility and the most important sub-factor for accessibility factor is highway access and congestion level, which indicate that they are critical in locating a new logistic platform. However, accessibility to airports was hardly given any importance; this is because this mean of goods transportation is rarely used and still operating only in urgent transportation.

The fact that the accessibility factors were given greater importance confirms the need to find a location situation that represent maximum accessibility to and from the centers of origin and destination of the various flows.

The next critical factor is economic and the most weighted sub-factors for it are proximity to customers and proximity to suppliers.

In contrast, the factor that has the least importance is the politic factor, this is because the team of experts is Moroccan and the politic stability of the country leads them to think that this factor is not affecting the decision of location of logistic hubs.

In this article, we have revealed that the determination of the optimal location to locate logistic hubs is a multidisciplinary problem, with PESTEL and accessibility aspects. Which help to achieve sustainable development. Future research directions will be focused on fuzzy AHP in order to achieve results that are more accurate, by using fuzzy theory.

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