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Reviewing the use of Multi-Criteria Group Decision Making Methods for Transportation Problems: Case of Transport Mode Selection Problem

Afaf Haial and Abdelaziz Berrado
Research team AMIPS
Ecole Mohammadia d'Ingénieurs,
Mohammed V University in Rabat, Morocco
afafhaial@gmail.com, berrado@emi.ac.ma

Loubna Benabbou
Management sciences Department
UQAR-Lévis Campus, Lévis (Québec). Canada
Loubna_benabbou@uqar.ca

Abstract

Transportation is one of the main subjects in logistics as it is the responsible of connecting the several steps that result in the conversion of resources into useful goods in the name of the ultimate consumer. Thus, making the appropriate and effective transportation decisions to properly make the products arrive safe to customers at right time, right place and right cost, is one of the most important operations that transportation managers should focus on.
Transportation mode selection is one of the most important strategic transportation decisions. Furthermore, deciding on the appropriate transport mode is a complex problem due to the involvement of several stakeholders with different conflicting criteria in making decisions. In this sense, the Multi-criteria group decision making methods have been used by several researchers to determine the appropriate transportation mode. The aim of this paper is to present an overview of the use of Multi-Criteria Group Decision Making methods for the resolution of transportation problems, with a special focus on the transport mode selection problem.

Keywords
Transportation; Transportation mode selection; Multi-criteria group decision making.

1. Introduction

Nowadays, having the best production system, producing with the best quality and selling with the cheapest price are not enough to achieve competitiveness on the market. Besides that, enterprises have to ensure that end-products are delivered to end-customers at the right time and in the optimum way. Therefore, the organizations should work on improving their logistics processes in order to meet customer requirements as efficiently and effectively as possible. Supply chain management is the process of planning, controlling and implementing the overall logistic functions of the supply chain in which the typical goal is producing and delivering the products of right quality and right quantity, at the right time, right place and right cost to all customers (Chopra and Meindel 2003; Manimaran et al. 2011). Achieving the supply chain process's goal involves several decisions relating to flow of information, products, and funds (Vahdat et al., 2017).
Transportation is one of the major logistical drivers as it is the responsible of connecting the several steps that result in the conversion of resources into useful goods in the name of the ultimate consumer (Chopra and Meindel 2003). By means of well-handled transportation system, products of right quality and right quantity could be sent to all customers at right time, right place and right cost (Tseng et al. 2005).
Transportation mode selection is one of the most important strategic decisions in transportation planning. Furthermore, deciding on the appropriate transport mode is a complex problem due to the involvement of several stakeholders with different conflicting criteria in making decisions.

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The movement of products from a source to a destination can be undertaken using one or a combination of the following modes of transport: Air, Package carriers, Truck, Rail, Water, and Pipeline (Chopra and Meindel 2003). Every mode of transport has specific characteristics, and any of them can be considered the best under different circumstances, depending on a variety of criteria. Furthermore, deciding on the appropriate mode of transport requires the participation of different concerned stakeholders. In this sense, the Multi-criteria group decision making methods have been used by several researchers to determine the appropriate transportation mode.

A Multi-Criteria Group Decision Making (MCGDM) is defined as a decision situation in which there are more than one individual involved each with different experience, skills, and knowledge relating to criteria of the problem (Lu et al. 2007) . It has become a popular research topic due to the growing importance of group participation in decision making (Bose et al. 1997). Several multi-criteria group decision making methods have been used in the literature in order to help making high quality decisions (Kabak et al. 2017). The aim of this paper is to present an overview of the use of Multi-Criteria Group Decision Making methods for the resolution of transportation problems, with a special focus on the transport mode selection problem

The remainder of this paper is organized as follows. In the next section, we discuss the components of transport decisions in supply chain, and the transport mode selection decision in particular. Section 3 consists of reviewing the concepts and characteristics of group decision making. Section 4 consists of reviewing the application of the multi-criteria group decision-making methods in evaluating transport problems. An illustration of the need of applying the MCGDM methods for selecting the appropriate transportation mode for the Moroccan pharmaceutical supply chain is presented in section 5. Finally, conclusion and future research follow.

2. Components of transportation decisions in Supply chain

2.1 Role of transport in supply chain

Transportation plays a central role in seamless supply chain operations (Stank et al. 2010). By moving inbound goods from supply sites to manufacturing facilities, repositioning inventory among different warehouses and distribution centers, and delivering finished products to customers, transportation provides the essential service of linking the whole supply chain from suppliers to customers (Jacyna 2013).

Transport system is the most important economic activity among the components of business logistics systems. Around one third to two thirds of the expenses of enterprises' logistics costs are spent on transportation. According to the investigation of National Council of Physical Distribution Management (NCPDM) in 1982 (Chang 1988), the cost of transportation, on average, accounted for 6.5% of market revenue and 44% of logistics costs. Thus, the logistician needs a good understanding of transportation matters (Özceylan 2010).

As one of the major supply chain drivers, transportation has a large impact on both responsiveness and efficiency of the supply chain (Chopra and Meindel 2003). By means of well-handled transportation network and appropriate transportation modes, products of right quality and right quantity could be sent to all customers at right time, right place and right cost (Tseng et al. 2005).

Thus, making the appropriate transportation decisions, that improve the efficiency and responsiveness of the supply chain, is one of the most important operations that transportation managers should focus on.

Developing a successful supply chain's transportation system involves decision making regarding several components. Choosing the appropriate transportation mode, designing an efficient transport network, deciding which part of the transportation process will be outsourced and which one will be insourced, and managing the vehicles routes are the major decisions that must be made in order to design an effective transportation system (Chopra and Meindel 2003).

In the following, we discuss the importance of choosing the appropriate mode of transport as being one of the most important strategic decisions that affect the efficiency and effectiveness of the whole supply chain.

2.2 Transport mode selection problem

The movement of products from a source to a destination can be undertaken using one or a combination of the following modes of transport: Air, Package carriers, Truck, Rail, Water, and Pipeline (Chopra and Meindel 2003). Each of these modes has specific characteristics, and any of them can be considered the best under different circumstances, depending on different criteria.

Air is mainly characterized by safety, high speed and high level of customer service, but its availability is limited and it is considered as the most expensive mode. Thus, air mode is particularly suitable for transport of products of high values for long distances.

Package carriers are transportation companies which use air, truck, and rail to transport time-sensitive smaller packages. It's an expensive mode that offers a rapid and reliable delivery.

Truck transport excels by excellent access, the ability to deliver products "from door to door" without need for further transshipment and by high flexibility. The disadvantage is a lower amount of transmission capacity as well as higher transport costs over longer distances.
Rail transport is suitable for carrying large quantities of heavy, bulky and not very time sensitive goods over long distances.
Water transport is suitable for the transport of consignments of large volume or large amounts of objects transported, especially over long distances, when the delivery time is not much important.
The Pipeline mode is used for the transport of crude petroleum, refined petroleum products, and natural gas, phosphate. It's the best suited when relatively stable and large flows are required.
In the selection of the suitable mode, from the different modes previously described, to use on each part of the transportation network, all the characteristics related to the concerned mode of transport have to be considered. Under certain conditions, the choice of the suitable transportation mode may seem obvious, but a comparison that depends on a variety of criteria may be nevertheless required (Tuzkaya et al. 2008). These criteria can be partly subjective, but varies greatly depending on the characteristics of the goods transported, as well as on transport parameters such as distance, quantity of goods and other requirements. Examples of some qualitative criteria that have been considered by several researchers in the choice of the appropriate mode of transport are: availability, reliability, speed, cost of transport, safety (Majerčák et al. 2018).
However, it has been proved by several authors (Zak et al. 1999; Daganzo et al. 1997; Zak et al. 2011) that transportation system involves so many complex operations and has an important impact on many phenomena and many social groups. A comprehensive analysis of transport system should involve technical, economical, social and environmental aspects, among others (Zak et al. 2011). Thus, deciding on the appropriate mode of transport requires the participation of several stakeholders interested in the efficient, comfortable, and effective operations of the transportation system.
In these circumstances, the use of MCGDM methods seems to be efficient for the evaluation of the transport mode selection problem. In the following, we discuss the concepts and characteristics of group decision making process.

3 Group Decision Making Process

Group decision making (GDM) is defined as a decision situation in which there are more than one individual involved. These group members have their own attitudes and motivations, recognize the existence of a common problem, and attempt to reach a collective decision (Lu et al. 2007). According to (Saaty 2008), when a group of people makes a decision, that decision carries a lot more weight than when just one person does it, and added that GDM is a gift and opportunity to create greater influence through the working together of many minds.. As a result, group settings are required for many real life decision making processes.
Group decision making has become a popular research topic due to the growing importance of group participation in decision making (Bose et al. 1997, Kabak et al. 2017).
GDM includes such diverse and interconnected fields as preference analysis (e.g., Mohamad and Jamil 2012), utility theory (e.g., Huang et al. 2013), social choice theory (e.g., Srdjevic et al. 2015), theory of voting (e.g., Madani et al. 2014), game theory (e.g., Soltani et al. 2016), aggregation of qualitative factors (e.g., Dong et al. 2016), etc. Among these diverse areas, our focus in this paper is Multi Criteria Group Decision Making (MCGDM).
As depicted in figure 1, the GDM approaches can be classified into two kind of basic models (Bui et al. 1987; Kabak et al. 2017). The first one, Process-oriented approach, is based on the observation that the group goes through certain phases in the group decision-making process, and on the belief that there could be an arranged way to effectively deal with these phases (Bui et al. 1987). The main objective is to generate new ideas to understand and structure the problem (Kabak et al. 2017). It provides structured methods to increase the quality of the decisions to be made. Among many others, most well-known methods in this class are brainstorming, brain wring, nominal group technique and Delphi method (Bui et al. 1987; Ervural et al. 2015).
Content oriented approaches, focus on the content of the problem, attempting to find an optimal or satisfactory solution given certain social or group constraints, or objectives (Kabak et al. 2017). These techniques operate under the following assumptions (Ervural et al. 2015): All decision makers share the same set of alternatives, but not necessarily the same set of evaluation criteria. Each decision maker must have performed his own assessment of preferences. The output of such analysis is a vector of normalized and cardinal ranking, a vector of ordinal ranking, or a vector of outranking relations performed on the alternatives.
As seen in figure 1, there are three classes of content oriented approaches: (1) implicit multi criteria evaluation (or Social choice theory), (2) explicit multi attribute evaluation (or Multiple Criteria group decision making), and (3) game-theoretic approach (Kabak et al. 2017).

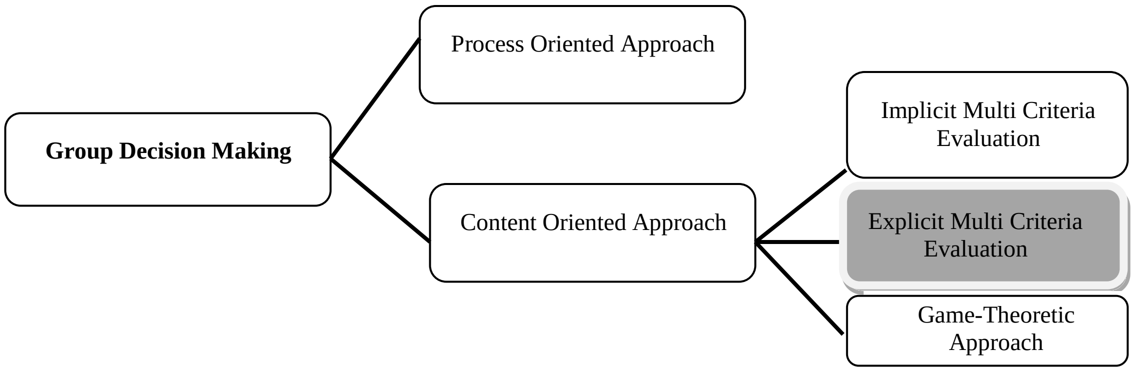

Figure 1. Classification of group decision-making methods (Kabak et al. 2017)

The implicit multi criteria evaluation or Social choice theory aims to aggregate the decisions, preferences, and opinions of decision makers into a final outcome while concerning the total utility of interested decision makers (Bui et al. 1987; Kabak et al. 2017). The criteria or the method of giving the decision is not required nor considered in aggregating the choices of the decision makers.

Game theory, developed by Von Neumann and Morgenster (Morgenstern 2007), is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers. Game theory is concerned with individuals who are pursuing their own personal interest against other individuals who are pursuing their own personal interest (Hwang et al. 1987; Ervural et al. 2015).

Furthermore, the explicit multi criteria evaluation refers to Multi Criteria Decision Making with the involvement of different decision makers (Kabak et al. 2017). It is therefore called the Multi Criteria Group Decision Making (MCGDM).

The MCGDM is an important part of modern decision science (Yue 2012), the aim is to help the decision makers to take all important objective and subjective criteria of the problem into consideration using a more explicit, rational and efficient decision process (Yue 2012). It has been extensively applied to various areas such as transportation, military, management, etc., and has been receiving more and more attention over the last decades (Kabak et al. 2017; Ervural et al. 2015). Many Multi Criteria decision making methods have been proposed to help decision makers in making high quality decisions. In the following, we present a review of the most popular MCGDM methods that are used to solve the MCGDM problems.

4 Relevance of Multi Criteria Group Decision Making methods for transportation problems

4.1 Review across application areas

Multi criteria group decision making (MCGDM) is considered as a complex decision-making process because of involvement of multiple decision makers with different conflicting criteria (Kabak et al. 2017). In recent years, several MCGDM techniques and approaches have been suggested to support the decision-makers in their decision process while prioritizing or selecting one or more alternatives from a set of available alternatives with respect to multiple conflicting criteria (Ozer 2007). Extensions of many MCDM methods into group settings have contributed to the development of MCGDM methods which are capable of admitting and synthesizing information about the group members' preferences and which can therefore offer valuable insights into what alternatives are preferred to others by the participating individuals or the group as a whole (Salo et al. 2010). The utilization of MCDM methods is able to foster group learning ability and it is particularly valuable in handling structured decision making problem (Srdjevic et al. 2006). The MCGDM problem has attracted the attention of many researchers in various fields like Finance, where (Tsai et al. 2001) proposed an integrated Group Decision Making support model for Corporate Financing Decisions by combining three methods: ANP, DEMATEL and GP. In supply chain management, (Chu 2002) applied fuzzy TOPSIS under group decisions for solving the facility location selection problem. In addition, (Boran et al. 2009) proposed a multi-criteria intuitionistic fuzzy group decision making with TOPSIS method for supplier selection. In banking sector, (TanselIç 2012) combined the Fuzzy TOPSIS and Linear Programming approaches for the development of a credit limit allocation model for banks. In management field, (Tavana et al. 1996) proposed a group decision support framework by combining the Analytic Hierarchy Process (AHP) and the Delphi principles for supporting the nurse manager hiring decision at a small privately-owned hospital. In material science, (Shanian 2008) applied ELECTRE III for group material selection.

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4.2 Review across Transport decisions

In transportation sector, several successful applications of MCGDM methods have been reported. Table 1 provides a summary of various studies on the application of MCGDM methods in transportation selection problems.

Table 1. A summary of articles dealing with the application of MCGDM methods in transportation selection problems.

References	MCGDM used	Emphasized issues
(Gercek et al. 1998)	Analytic Hierarchy Process (AHP)	Evaluating different rail transit projects to improve the public transportation system on the European side of Istanbul
(Hsu 1998)	Combining : The fuzzy Delphi method Analytic Hierarchy Process (AHP)	Evaluating the public transport system in Kaohsiung, Taiwan
(Zak et al. 2014)	Analytic Hierarchy Process (AHP) ELECTRE III	Proposing an original methodology of designing and evaluating transportation projects / solutions
(Kopytov et al. 2012)	Analytic Hierarchy Process (AHP)	Evaluating and choice of transportation alternatives in multimodal freight transport system
(Zak et al. 2011)	ELECTRE III	Evaluating four transport alternatives of the mass transit system
(Tuzkaya et al. 2008)	The fuzzy analytic network process (ANP)	Evaluating Transport mode alternatives
(Chen et al. 2008)	The fuzzy Analytic Hierarchy Process (AHP)	Transport mode selection in multimodal transportation
(Shang et al. 2004)	The analytic network process (ANP)	Evaluating transportation projects in Ningbo, China.
(Celik et al. 2009)	TOPSIS	Proposing competitive strategies on Turkish container ports in maritime transportation network
(Özceylan 2010)	The Analytic Hierarchy Process (AHP)	Solving the transportation mode selection problem
(Wey et al. 2007)	The analytic network process (ANP) Goal Programming	selecting the best set of proposed transport infrastructure projects in an organization
(Scannella and Beuthe 2003)	Utility Additive (UTA) method	Evaluating of road projects for the Ministry of Equipment and Transports of the Walloon Region in Belgium
(Hamurcu et al. 2018)	The analytic network process (ANP) TOPSIS	Transport route selection for Ankara, Turkey
(Zak et al. 2015)	The Analytic Hierarchy Process (AHP) ELECTRE III/IV methods	Evaluation of urban transportation projects
(Özfirat et al. 2017)	The fuzzy Analytic Hierarchy Process (AHP)	Selection of the appropriate coal transport mode
(Kumru et al. 2014)	The Analytic Hierarchy Process (AHP)	Selecting the mode of transport for a logistics company
(Odeyale et al. 2014)	The fuzzy Analytic Hierarchy Process (AHP)	Selecting the best mode of transportation in Lagos State metropolis
(Luo and Chen 2012)	Least Squares Combination method ELECTRE II	Transport mode selection
(Wang et al. 2016)	The fuzzy analytic hierarchy process (fuzzy AHP)	Selection of transport modes for Kinmen military logistics

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4.3 Case of Transport mode selection

The literature analysis shows a growing interest in the application of multi criteria group decision making methods for the evaluation of different transport problems. In particular, the transport mode selection problem has been evaluated by several researchers while applying numerous MCGDM methods. For instance, (Tuzkaya et al. 2008) applied the fuzzy Analytic Network Process (ANP) for the selection of the most suitable transport mode of freight. A large number of detailed criteria that interact with each other have been evaluated by a group of decision makers coming from different management levels and functional areas in the sector of logistics with intent to provide a more accurate and mutually acceptable solution. In addition, (Chen et al. 2008) applied the fuzzy Analytic Hierarchy Process (AHP) for the transport mode selection in a multimodal transportation with the presence of different conflicting criteria and multiple decision makers. (Kumru et al. 2014) applied the Analytic Hierarchy Process (AHP) for selecting the most suitable way of transportation mode from among the three alternatives between Çorlu and Mersin, Turkey. A wide range of selection criteria have been used during the evaluations: cost, speed, safety, accessibility, reliability, environmental friendliness, and the flexibility. The expectations and requirements of different groups of stakeholders have been taken into account in the decision making process.

Moreover, (Özceylan 2010) used the Analytic Hierarchy Process (AHP) in determining the best transport mode selection while involving several decision makers with different conflicting criteria.

Furthermore, (Özfirat et al. 2017) applied the fuzzy Analytic Hierarchy Process (AHP) for the selection of coal transport mode among different alternatives: belt conveyors, truck types, suspension rail conveying systems, pipelines and railways. Selection of one of these modes is done with the presence of multiple interested stakeholders with different conflicting criteria: transportation distance, inclination of the haulage road, amount of coal reserve, investment costs, production capacity and unit production cost of the open pit mine. Also, (Wang et al. 2016) applied the Analytic Hierarchy Process (AHP) for the selection of the appropriate transport modes for Kinmen military logistics while taking into account the expectations and requirements of different practical users (i.e., soldiers in Kinmen).

In addition, (Odeyale et al. 2014) applied the fuzzy Analytic Hierarchy Process (AHP) for selecting the best mode of transportation in Lagos State metropolis. Seven transportation alternatives were evaluated with nine decision criteria: low transportation cost, low environmental effect, large capacity, improved safety, high comfort, high accessibility, improved reliability, low number of interchanges required and faster journey time. The expectations and opinions of different commuters have been taken into account in the decision making process.

Ref (Luo and Chen 2012) proposed a transport mode selection model based on Least Squares Combination method and ELECTRE II method. In the selection process, a set of attributes have been considered: transport costs, transport time, transport reliability, transport punctuality, transport security, transport convenience. The preferences and behaviors of different consignors have been taken into account in the decision making process.

Therefore, it seems that there are a growing interest in the application of MCGDM methods for selecting the most suitable transport mode due to the presence of different decision makers with multiple conflicting criteria in the decision making process. In the following, we illustrate the need of applying the MCGDM methods for selecting the appropriate transportation mode for the Moroccan public pharmaceutical supply chain.

5 Illustrative case of Moroccan public pharmaceutical supply chain

5.1 Pharmaceutical supply chain

The vital strategic objective of any healthcare system is proper supply of desired medicines (Ghatari et al. 2013). According to (Xie and Breen 2012), the pharmaceutical supply chain is a special supply chain in which drugs are produced, transported and consumed. It is different from the other supply chains because of its importance, urgency, transportation, regulation, etc. (Bigdeli et al. 2013). Therefore, the pharmaceutical supply chain needs proper management of their overall logistic functions to ensure that products arrive safe to customers at right time, right place and right cost (Moktadir et al. 2018). In this sense, several decisions including facility location, production, inventory and transportation should be made so as to meet customer demands in the most effective and efficient way (Chopra and Meindel 2003).

Furthermore, making the appropriate decisions regarding the pharmaceutical supply chain is a complex and challenging task because it requires the participation of different stakeholders such as pharmaceutical manufacturers, wholesalers, distributors, customers, information service providers and regulatory agencies (Bhakoo and Chan 2011).

Therefore, Multi-Criteria Group Decision Making methods represent one of the most frequently used techniques to aid and support the decision-making process in health care (Adunlin et al. 2015).

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Several research studies have been conducted concerning the use of MCGDM in pharmaceutical supply chain across different countries. A brief summary of some of these studies is provided in table 2.

Table 2. Summary of some studies dealing with the application of MCGDM methods in pharmaceutical supply chain

Authors / year	Contributions	MCGDM used	Country
(Pourghahreman and Qhatari 2015)	Suppliers selection in the Iranian pharmaceutical supply chain	TOPSIS and PROMETHEE Π	Iran
(Jaberidoost et al. 2015)	Risk assessment in pharmaceutical supply chain	-Group analytic hierarchy process (AHP) method -Simple additive weighting (SAW) method	Iran
(Moktadir et al. 2018)	Evaluating risks in pharmaceutical supply chain in the context of Bangladesh	-Analytic hierarchy process (AHP) method -Delphi method	Bangladesh
(Goetghebeur et al. 2012)	Medicines appraisal	EVIDEM framework	USA
(Vishwakarma et al. 2016)	Risk assessment in Indian pharmaceutical supply chain	Fuzzy analytic hierarchy process (FAHP) method	India
(Enyinda et al. 2010)	Risk mitigation in pharmaceutical supply chain	Analytic hierarchy process (AHP) method	Ghana
(Kirytopoulos et al. 2008)	Suppliers selection in pharmaceutical supply chain	Analytic network process (ANP)	Greece
(Asamoah et al. 2012)	Evaluation and selection of suppliers in a pharmaceutical supply chain	Analytic hierarchy process (AHP) method	Ghana

The literature analysis reveals that the MCGDM methods have been successfully applied to solve pharmaceutical supply chain decision problems in many countries. In the following, we illustrate the need of applying the MCGDM methods for selecting the appropriate transportation mode for the Moroccan public pharmaceutical supply chain.

5.2 Moroccan public pharmaceutical supply chain

In Morocco, access to pharmaceutical products and basic health care is a priority of the health system. To ensure the accessibility and availability of pharmaceuticals for Moroccan citizens, the Moroccan ministry of health aims to develop an effective and efficient pharmaceutical supply chain through the proposition of strategic and tactical decisions with respect to the following six dimensions: (1) distribution networks, (2) facilities and installations, (3) inventory management, (4) transportation, (5) outsourcing (Public Private Partnership) and (6) the new technologies and information system (Moroccan Health Ministry, 2014).

In the Moroccan public sector, pharmaceutical products are transported from suppliers to the storage sites of the Moroccan Ministry of Health, which are divided into central and regional warehouses. The Central warehouse usually has copious storage capacity and it's in charge of delivering the received products, either directly or via regional warehouses, to the customer zones including provincial and regional hospitals (CHP and CHR) and provincial delegations (PD) (Moroccan Health Ministry 2014) (see Figure 2).

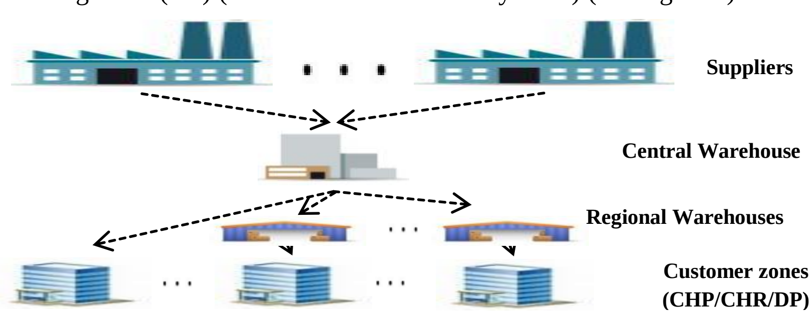

Figure 2. Schema of Moroccan Pharmaceutical supply chain

Developing a successful supply chain's transportation system, for the public sector pharmaceutical products supply chain in Morocco, involves decision making regarding several components including: Choosing the appropriate transportation mode, designing an efficient transport network, deciding which part of the transportation process will be outsourced and which one will be insourced, and managing the vehicles routes.
Choosing the appropriate mode of transport is one of the most important strategic transportation decisions that affect the efficiency and effectiveness of the whole supply chain. It requires a great level of involvement by concerned stakeholders like Ministry of Transport, Local Authorities, Transport Operators/providers, Private Financiers, Citizens, Environmental association, etc. The concerned decision makers have to face and take attention with different conflicting criteria such as: availability, reliability, delivery time, cost of transport, safety, etc.
Thus, the selection of the suitable mode of transport is a complex multi-criteria group decision making problem that requires the application of the MCGDM methods for its resolution.
In our future work, we will choose one of the MCGDM methods to be applied for selecting the appropriate mode of transporting pharmaceutical product in the Moroccan pharmaceutical public sector.

Conclusion

Developing a successful supply chain's transportation system involves decision making regarding several components including: Choosing the appropriate transportation mode, designing an efficient transport network, deciding which part of the transportation process will be outsourced and which one will be insourced, and managing the vehicles routes.
The selection of the most suitable mode of transport is one of the most important strategic transportation decisions. It is a complex multi-criteria group decision making problem due to the fact of involving multiple concerned stakeholders with different conflicting criteria. This paper presented a literature review on the application of multi-criteria group decision making (MCGDM) methods across transport decisions, in particular transport mode selection decision. Based on this review, we were able to highlight the importance of applying the MCGDM methods in the evaluation of transport problems while involving multiple interested stakeholders in the decision making process.
We illustrated the need of applying the MCGDM methods for selecting the appropriate transportation mode for the Moroccan public pharmaceutical supply chain.
Future work will deal with choosing one of the MCGDM methods to be applied for selecting the appropriate mode of transporting pharmaceutical products in the Moroccan pharmaceutical public sector.

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Biography

Afaf Haial is a PhD student in Analysis, Modeling and Integration of Processes and Systems research structure at Ecole Mohammadia d'Ingénieurs (EMI) at Mohamed V University. She received her engineering's degree in industrial engineering from the Ecole Nationale Supérieure des Mines de RABAT (ENSMR) in 2013. Her main research interests are supply chain management, transport policy with a special focus on pharmaceutical products.

Abdelaziz BERRADO, Ph.D., is Department Chair and Associate Professor of Industrial Engineering in EMI School of Engineering at Mohamed V University in Rabat. He holds a Ph.D. degree in Decision Systems and Industrial Engineering from ASU. His research, teaching and consulting interests are in the areas of Big Data Analytics, Industrial Statistics, Operations and Supply Chain Modelling, Planning and Control with applications in healthcare, education and other industries. He published several papers in research journals and conferences with local and international funding. He is member of INFORMS, IEOM and IEEE. He was also a Senior Engineer at Intel.

Dr. Loubna BENABBOU is a Professor of Management Sciences at Université du Québec à Rimouski (UQAR) at Lèvis campus. Her research work lie in the application of decision/ management sciences and machine learning techniques to transform data for making better decisions and improving operational processes. Dr Benabbou has been supervising several undergraduate and graduate students in projects for different Industries related to the areas of Decision sciences, Machine Learning and Operations Management. Her research related to these fields has been published in international scientific journals and conferences' proceedings. Dr Benabbou was an associate professor of Industrial Engineering at EMI School of Engineering. She was also a trader at Casablanca stock exchange and financial analyst and risk manager at the Caisse Marocaine des retraites the Moroccan largest intuitional fund manager. Dr Benabbou is an industrial engineer from EMI School of Engineering, she earned MBA and PhD in Management and Decision sciences from Laval University.

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