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Problem solving product distribution in a supply chain using a multi-criteria method

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ABSTRACT

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One of the objectives that a company sets for itself is customer satisfaction. This is a priority element, which clearly shows that the concerns of companies are geared towards the customer and the speed with which it will be served. The work deals with the problem of the distribution of final products in the various warehouses, scattered throughout the national territory. The problem dealt with in this paper is multi-criteria, taking into account the following criteria: the neighboring population of customer, condition of the path taken by the truck, the length of the path taken from the depot to the customer (distance traveled by transporting a product) and Traffic on the way. The multi-criteria method used in this work is Electre III.

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1. Introduction

The logistics sector has grown strongly in recent years and is becoming a major player in the current economic organization. It allows the Traffic and management of goods and information flows between the different links in the production and distribution chain. The opening of the national market, the development of infrastructures and the importance of new possibilities in terms of data exchange are leading an increasing number of companies to define their activity in terms of material and information flows. Logistics must integrate supply, production and distribution flows into a global, coherent and profitable system . It must also ensure the management of this system, its rapid and flexible adaptation to market developments. Freight transport is one of the most obvious manifestations of logistics activities.

Transport represents an important budget item for companies, it is considered as <strate- gic> in the global logistics of the company, it is often treated as an external <basic> service which must respond with very little flexibility to the constraints imposed on both by the sender and by the recipient.

The transport of goods plays a major role in a logistics chain, in fact the main entities (suppliers, distribution factories and end customers) that are in a logistics chain are linked together by connections involving different modes of transport.

The cost of transport is a very sensitive parameter for a society which directly affects the price of the product and the profit generated by the product it- self. These forces transport networks to regularly improve their distribution circuit and to review their industrial organization. This tendency led them to act on the minimization of all the costs relating to the distribution and which can have an important influence. So you have to know how to optimize distribution and delivery to stay in the competitive world. The goal of any business is to distribute products with minimal cost, that is, to minimize the total transportation cost of a shipping plan. A transportation problem is a program to minimize the cost of transportation and calculate the optimal route for distribution, reliably and accurately. Its aim is to transport goods at low cost from m origins to n destinations. Our work affects the field of multi-criteria decision support, or we offer alternative solutions which may or may not be retained in order to help the decision maker (in our case the person in charge of vehicle movements: manager) to find the best path for the evolution of the operating costs of the company's vehicles or its carriers and this we take into consideration four criteria: the neighbouring population of a warehouse, the state of the road taken to transport a product, The distance travelled, and the traffic on the path taken.

The present work is to propose a tool essentially made up of a multi-criteria decision support method allowing the identification of the best transport solution according to the demand at the level of each distribution center. The latter makes it possible to minimize the cost of transport in the network while guaranteeing the satisfaction of customer orders, while respecting the four criteria: the neighbouring population of customer, state of the path taken by driver, length ofthe path taken from depot to the customer (Distance travelled by transporting a product) and Traffic on the way.

2. Related Work

Freight transportation is a complex system. Whichever method is chosen, the purpose of the transport is the delivery of a product to the right destination, on time adequate and respecting its integrity.

Optimizing transport involves thinking and mixing different techniques or possible modes. From factory direct to customer delivery for full driver to small packages there are various usable techniques which are dependent on a number of factors like distance, size of shipment or pickup, constraints of handling, types of equipment and vehicles used.

The authors present in this section a global view of recent research on the distribution problem in the supply chain management.

Hokey and Gengui (Hokey, 2002) synthesized past supply chain modelling efforts and identifies key challenges and opportunities associated with supply chain modelling. In this research paper authors provided various guidelines for the successful development and implementation of supply chain models.

In the research work of Labarthe (Labarthe, 2006) a definition of an agent oriented approach to model and simulate supply chains in a mass customization context was proposed. A methodological framework structured according to three levels of abstraction: Domain Model, Conceptual Model and Operational Model was done.

Eddoug and elhaq (Eddoug, 2015) addressed the issue of flow management in a multi distribution logistics chain level in a stochastic environment. This work aims to implement delivery flow management solutions, replenishment, inventory allo- cation and transshipment for a combined optimization of the costs of stocks and transport. The methodology adopted in this work is based on a simulation approach. Indeed, the approach based on modelling and simulation for the evaluation and analysis of performance of complex systems has been proven for years, in various fields of scientific research.

Trujillo (Trujillo et al., 2015) presented design of the Multicriteria Decision Network (MCDN), used to support decision-making by managers of goods and transportation companies for modes or carriers selection in the Supply Chain.

The work of Bessid (Bessid et al, 2018) aimed at studying the optimization of distribution costs in the supply chain through minimization of storage costs and transport in the distribution chain and to study problems of application of formal scientific methods.

3. Positioning the Contribution

The particularity of this work is articulated in the proposal of two basic contributions, which are:

- A decision support model for solving the problem of distribution of final product.
- The Electre III method for founding the best path to send a product.
- This work takes into account four criteria: the neighboring population, the state of the road taken, the distance travelled and traffic on the way.

The contribution is to propose a model for decision support that helps us to make predictions for different paths using a multi-criteria method Electre III.

The authors of this article are interested in the research in the fields of Decision Support Systems (urban, road, maritime transportation, and health), Logistic, Optimization, Simulation, Cooperative and Distributed System, Knowledge bases and Multi Criteria Decision Making. This work forms part of the research work in the field of multi criteria decision applied to transport (Yachba et al.2015), (Yachba et al. 2016), (Yachba, 2017), (Yachba et al.20 17) (Belayachi et al. 2017).

4. Design and Modeling

Our study concerns the product distribution operation known as the travelling sales man problem (PVC), which is an almost real-time decision-making process, which determines a shorter path that visits each city one and one. Only once and that ends in a warehouse. To facilitate and accelerate the distribution operation at the warehouse level, we use an Electre III multi-criteria decision support method. The determination of the best path obtained using this method must be carried out in such a way as to reduce the distances travelled by the carriers.

This work has the following objectives:

- Best process for visiting customers,
- Reduction of transport costs
- Minimize the time required to deliver the product to the customer,
- Improve the organization of customers in relation to their Cities by avoiding assigning the customer to two or more warehouses,
- Help the manager to make the best decision regarding the distribution of products.

5. The Proposed Model

The decision support model presented in this study for product distribution is inspired by that proposed by Bouamrane (Bouamrane, 2005). This decision model proposed for the case of a warehouse manager who manages a transport network is broken down into four distinct phases. Each of these phases includes a set of steps as shown in Figure 1.

Step 1 (Allocation of customers to warehouses): After configuring the initial state, each customer is assigned to a warehouse which is located in the same city before receiving the order for the products.

Step 2 (Decision support method to minimize the cost of distribution): In this phase, the manager has the possibility of launching a mechanism that allows him to build solutions for finding paths at a lower cost. This mechanism offers an optimal feasible solution using Electre III which is invisible to the manager.

Step 3 (Choice and validation of a solution) :This is a step in choosing one of the solutions proposed by the decision support system. Once the manager has made his choice, he must validate it.

Step 4 (Adoption of the chosen solution): This phase essentially aims at social acceptance of the result given by the decision support system. It is an implementation of the decision adopted by the manager. The manager (decision maker) is free to accept one of the solutions offered by the system or to ignore the help offered.

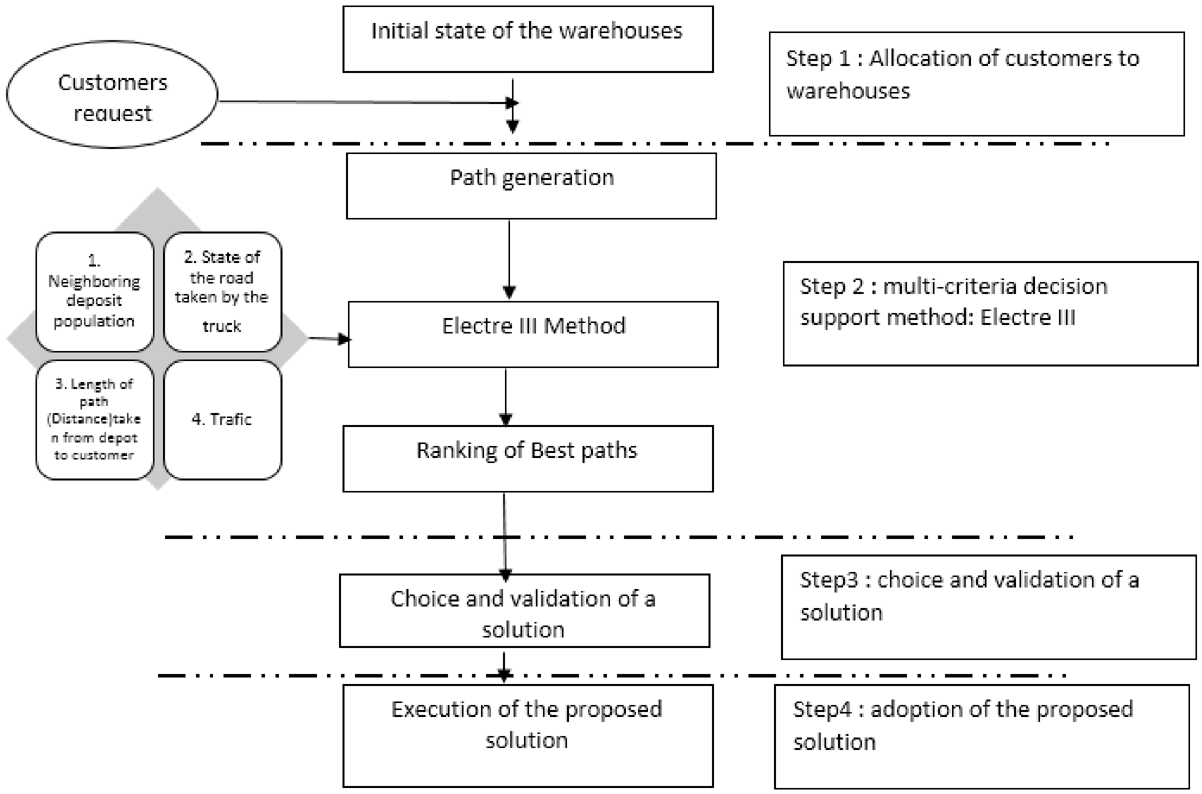

Figure 1– The Proposed Decision Model

6. Description of the Electre III Method and Adaptation to the Case Study

Electre III Allows to classify the actions from best to the worst then select the (or them) Action (s) that seem (s) the most adequate (s). To do this, Electre III processes an evaluation matrix containing actions and pseudo criteria. The upgrade treatments provided on this matrix will make it possible to establish a partial final pre-order (Martin , 2005).

6.1. General Algorithm of Electra III

The general principle of the operation of Electra III is given by the flowchart illustrated in the Figure 2 (Martin, 2005):

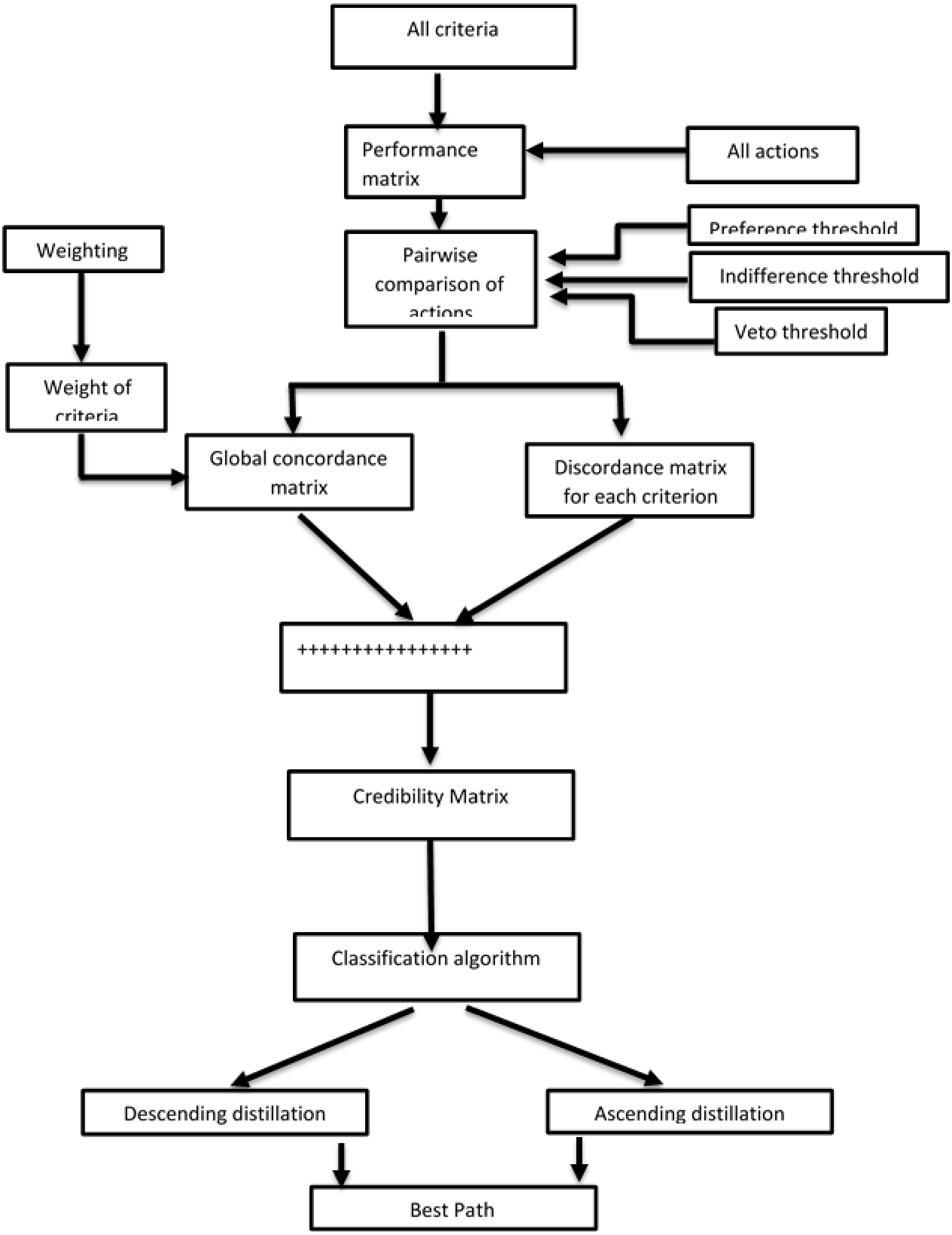

Figure 2– The Electre III Method Application Process

6.2. Determination of the Performance Table and Subjective Parameters

The construction of the criteria is a delicate step which requires an understanding of the problem posed and an interaction with the actors involved in the decision-making. It is a question of identifying the stakes and the nature of the possible consequences on the object of the decision, ie the actions considered. Defining the criteria then requires an assessment of the contribution and influence of each criterion in the final decision.

This results in weights which are defined by the actors involved or obtained by an iterative process following interaction with the actors concerned [Nafi et al, 2009]. In this study each action represents a possible path from any station to any depot, and we consider the following criteria:

- Cr1: Neighbouring Customer population
- Cr2: State of the road taken by the driver
- Cr3: Length of the path taken from depot to customer
- Cr4: Traffic

For the Cr2 and Cr4 criteria we make a discretization to facilitate the task such as:

$$\text{State of the road} = \begin{cases} 1 & \text{If State of the road = Good} \\ 2 & \text{If State of the road = Medium} \\ 3 & \text{If State of the road = Bad} \end{cases}$$

$$\text{Traffic} = \begin{cases} 1 & \text{If Traffic = Strong} \\ 2 & \text{If Traffic = Average} \\ 3 & \text{If Traffic = Low} \end{cases}$$

In the frequent case, where the analysis of the consequences of potential actions has led to the construction of several criteria, it is the multi-criteria analysis which makes it possible to give answers to the problem posed. For each action considered, and for each criterion, a preference threshold p, of indifference q and a veto threshold v are estimated. Each criterion is assigned a weight k reflecting its contribution in the final decision.

For the case study the performance matrix is illustrated in the following table:
In line we have 20 possible paths, and we collate we have the four criteria. The intersection between row and column represents the evaluation of criteria in relation to actions.
The result of the consequence analysis is presented in a performance table [Nafi al, 2009]. The evaluation of each criterion is contained in the table 1.

Table 1 : Performance Chart

	Cr1	Cr2	Cr3	Cr4
Action 1 : Path1	923654	2	0.00806	1
Action 2 : Path2	342567	3	0.07650	3
Action 3 : Path3	142678	1	0.0123	2
Action 4 : Path4	345765	2	0.0654	1
Action 5 : Path5	473124	2	0.1765	2
Action 6 : Path6	543654	3	0.2340	1
Action 7 : Path7	132456	1	0.2078	3
Action 8 : Path8	765000	3	0.9876	3
Action 9 : Path9	129009	2	0.6543	1
Action 10 : Path10	123987	3	0.0456	2
Action 11 : Path11	354098	1	0.0876	2
Action 12 : Path12	234987	2	0.0543	1
Action 13 : Path13	345698	3	0.09876	3
Action 14 : Path14	3546890	3	0.0765	1
Action 1 5 : Path15	321587	2	0.0564	3
Action 16 : Path16	349290	1	0.0231	2
Action 17 : Path17	300456	1	0.0122	2
Action 18 : Path18	453987	2	0.0112	1
Action 19 : Path19	432156	3	0.0778	2
Action 20 : Path20	222999	2	0.0666	3

The importance of criteria in decision-making is assessed by a set of weights K = {k1, k2, ..., kn}. For the Electre III method, the indifference, preference and veto thresholds depend on the evaluation of the action (path) for each criterion. For an action a, evaluated by gj (a) for criterion j, in this case the indifference threshold is noted qj (gj (a)), the preference threshold by pj (gj (a)) and the threshold of veto by vj (gj (a)). These three thresholds are shown in the table 2:

Table 2 : Subjective Parameters

	Cr1	Cr2	Cr3	Cr4
Indifference :Q	1	1	0.25	0.5
Preference : P	3	2	0.75	1.5
Veto : V	4	3	2	1
Weight :W	0.5	1.5	2	0.2

6.3 Concordance Matrix

In a first step, the method Electre III computes matrix coefficients which summarize the information of concordance and discordance between actions of the problem. In a second step, the coefficients are used to build two pre-rankings, a first one which classifies solutions from the best to the worst and a second one which classifies from the worst to the best. The outranking matrix and the table rank are then deduced by crossing the two pre-rankings results.

The concordance and discordance indices implement the principles of majority and respect for minorities in order to affirm the upgrade (or not) from a to b. This can be done in different ways and with more or less high levels of requirement.

The concordance matrix: this result displays the indexes of the concordance matrix computed with the following equation.

$$C(a_1, a_2) = \frac{1}{P}\sum_{j=1}^{r} p_j c_j(a_1, a_2) \quad (1)$$

Where:

$$P = \sum_{j=1}^{r} p_j \quad (2)$$

$$c_j(a_1, a_2) \begin{cases} 1 & \text{if } g_j(a_1) + q_j \geq g_j(a_2) \\ 0 & \text{if } g_j(a_1) + p_j \geq g_j(a_2) \quad j= 1,2,\ldots..,r \\ \frac{\rho_j + g_j(a_1) - g_j(a_2)}{p_j - q_j} & \text{Otherwise} \end{cases} \quad (3)$$

With:

a_1, a_2: two different actions.

p_j: the weight of criterion j.

$g_j(a_1)$: the evaluation of criterion j for action a_1.

j: the index of the criterion.

p, q: the preference and indifference thresholds respectively**.**

The values of the concordance index $c_j(a_1, a_2)$ belong to the interval [0, 1]. The following table (Table 3) represents the concordance matrix.

Table 3 : Concordance Matrix

	Action 1	**Action 2**	**Action 3**	**Action 4**	**Action 5**	**Action 6**	**Action 7**	**…**
Action 1	0.001	0.9524	0.9762	1.0	0.9762	1.0	0.9524	…
Action 2	0.881	0.0	1.0	0.881	0.881	0.881	1.0	…
Action 3	0.881	0.5	0.0	0.881	0.881	0.5238	0.9762	…
Action 4	0.881	0.9524	0.9762	0.0	0.8571	0.881	0.9524	…
Action 5	0.881	0.9762	1.0	1.0	0.0	0.881	0.9762	…
Action 6	0.881	0.9524	0.9762	1.0	0.9762	0.0	0.9524	…
Action 7	0.881	0.5238	0.881	0.881	0.881	0.5238	0.0	…
…	…	…	…	…	…	…	…	…

6.4 Discordance Matrix

This result displays the indexes of the discordance matrix computed with the equation given in the description section of the method. This principle is introduced by the following formulas:

$$d_j(a_1, a_2) = \begin{cases} 0 & \text{if } g_j(a_1) + p_j \geq g_j(a_2) \\ 1 & \text{if } g_j(a_1) + v_j \leq g_j(a_2) \quad j = 1,2,\ldots,r \\ \frac{g_j(a_2) - g_j(a_1) - \rho_j}{v_j - p_j} & \text{Otherwise} \end{cases} \tag{4}$$

Discordance matrices are then realized for each criterion (m matrices n × n including the discordance indices $d_j(a_1, a_2)$). The following table (Table 4) present the discordances matrix of the case study.

Table 4 : Discordance Matrix

	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	Action 7	…
Action 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 2	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…
Action 3	1.0	1.0	0.0	1.0	1.0	1.0	0.0	…
Action 4	1.0	0.0	0.0	0.0	1.0	1.0	0.0	…
Action 5	1.0	0.0	0.0	0.0	0.0	1.0	0.0	…
Action 6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 7	1.0	1.0	1.0	1.0	1.0	1.0	0.0	…
Action 8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	…
Action 10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	…
Action 11	1.0	0.0	0.0	0.0	1.0	1.0	0.0	…
Action 12	1.0	1.0	0.0	1.0	1.0	1.0	0.0	…
Action 13	1.0	0.0	0.0	1.0	1.0	1.0	0.0	…
Action 14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 15	1.0	1.0	0.0	1.0	1.0	1.0	0.0	…
Action 16	1.0	0.0	0.0	0.0	1.0	1.0	0.0	…
Action 17	1.0	1.0	0.0	1.0	1.0	1.0	0.0	…
Action 18	1.0	0.0	0.0	0.0	1.0	1.0	0.0	…
…	…	…	…	…	…	…	…	…

6.5 Credibility Matrix

If the concordance index> the discrepancy index the degree of credibility = the concordance index.

If the concordance index <the discrepancy index the degree of credibility = the weakened concordance index of the Discordance indices.

The degree of credibility for each pair $(a_1, a_2) \in A^2$ is determined as follows:

$$S(a_1, a_2) = \begin{cases} C(a_1, a_2), & \text{if } d_j(a_1, a_2) \leq C(a_1, a_2) \quad \forall j \\ C(a_1, a_2) * \prod_{j \in J(a_1, a_2)} \frac{1 - d_j(a_1, a_2)}{1 - C(a_1, a_2)} & \text{where } J(a_1, a_2) \text{ the set of criteria such that } d_j(a_1, a_2) \rangle C(a_1, a_2) \end{cases} \quad (5)$$

A matrix of credibility degrees is then generated (matrix n × n including credibility degrees S (a_1, a_2) for each pair $(a_1, a_2) \in A^2$) (Table 5).

Table 5: Credibility Matrix

	Action 1	**Action 2**	**Action 3**	**Action 4**	**Action 5**	**Action 6**	**Action 7**	**…**
Action1	0.0	0.0	0.0	1.0	0.0	1.0	0.0	…
Action 2	0.0	0.0	1.0	0.0	0.0	0.0	1.0	…
Action 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 5	0.0	0.0	1.0	1.0	0.0	0.0	0.0	…
Action 6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	…
Action 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 8	0.0	1.0	1.0	1.0	1.0	1.0	1.0	…
Action 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 11	0.0	0.0	1.0	1.0	0.0	0.0	0.0	…
Action 12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	…
Action 13	0.0	1.0	1.0	0.0	0.0	0.0	1.0	…
Action 14	1.0	0.0	0.0	1.0	0.0	1.0	0.0	…
Action 15	0.0	0.0	1.0	0.0	0.0	0.0	1.0	…
Action 16	0.0	0.0	1.0	1.0	0.0	0.0	0.0	…
Action 17	0.0	0.0	1.0	0.0	0.0	0.0	0.0	…
…	…	…	…	…	…	…	…	…

6.6 Final Ranking and Discussion of Result

The Final ranking of this case study is represented in the table 6.

Table 6: Final Ranking

	Upward distillation	Downward distillation
Action1	2.0	7.0
Action2	4.0	4.0
Action3	11.0	12.0
Action4	10.0	10.0
Action5	2.0	2.0
Actio16	5.0	8.0
Action7	7.0	11.0
Action8	1.0	1.0
Action9	3.0	14.0
Action10	8.0	14.0
Action11	5.0	6.0
Action12	12.0	13.0
Action13	2.0	3.0
Action14	1.0	6.0
Action15	5.0	5.0
Action16	6.0	7.0
Action17	9.0	9.0
Action18	7.0	9.0
Action19	4.0	4.0
Action20	6.0	8.0

The final ranking (classification) of the different paths is illustrated in the Table 6 The actions (Action i) represent the paths (path i) such that is the path index. Two types of ranking are presented in the previous table.
Upward distillation: ranks the measurements from the worst to the least bad; **Downward distillation:** ranks the measurements from the Best to the least good;. Path 8 (Action8) represents the best path among the different possible paths followed by path 14 (Action8).

7. Conclusion

The transport activity is not limited to simple physical movement of goods which should be optimized in terms of costs, time or non-monetary costs (security, comfort...). The transport activity is in fact combining more and more other operations (processing of information flows, operation of processing of goods...) which makes it difficult to represent it uniformly through physical flows, and to process it. Regardless of logistics. We therefore observe a variety of transport situations, depending on the logistics services added. If transport and logistics must be considered together, they must also indicate their links with the operating modes of companies. Logistic processes must indeed deal with a certain number of productive constraints (nature of demand, production models, types of resources used, and types of products...) which result for their part from the characteristics of trade and interactions between actors. Relations with other actors in the production chain (suppliers, customers, subcontractors, etc.) condition the organization of flows, and therefore transport needs.

In this article the authors have used the multi-criteria decision support method Electre III in order to find the best routes for the delivery of final products to different customers. This research method allowed us to find solutions that best respond to our problem in a reasonable time.

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