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Research Article

Towards Mathematical Modeling for Selecting Logistics Service Providers: Case of Moroccan LSP

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Abstract

With the global market's growing competition, the use of logistics services in Morocco has become an urgent necessity to optimize costs and improve service quality. To succeed in this strategy, guidelines are proposed for the accompaniment of contractors. One of the fundamental pillars of this strategy is based on the choice of an efficient partner, which we call Logistics Services Provider (LSP). Indeed, the bibliography contains numerous decision-making methods, so decision-makers are faced the challenge of selecting the most relevant method. The main challenge is to always seek the effectiveness and sustainability of the relationship in a network of potential partners, often very complex. To this purpose, an eminent need to model this relationship linking the actors of this network is required. The study carried out involves modelling the problem of LSP selection and the assignment of the service to be outsourced to the appropriate LSP. The linear model developed takes into account both qualitative and quantitative criteria. The model developed aims to optimize the overall cost of selecting the suitable LSP. The resolution method chosen for this problem is the Branch and Bound method and the tool used for the coding of this linear program is CPLEX.

Keywords : Contractors; Logistics Services Providers; Decision Making Methods; Mathematical modelling approach; Linear programming ; Linear model

1. Introduction

From the 1990s onwards, the emergence of business networks has materialized the strategic alliances that companies must forge to solidarity and to share financial risks as well as to find industrial and technological complementarities, necessary for their development.

However, due to the market volatility and the evolving requirements of competitiveness, several companies have found themselves forced to use logistics as a competitive weapon, enabling them to optimise costs and improve the quality of their services (McGinnis et al., 2002). Therefore, by using outsourcing, the company is able to save a substantial amount of money because the company does not need to invest in costly logistics-related assets (Souza et al., 2019).

In addition, the uncertainty and complexity of the status of the network's inputs of this, is one of the important challenges of designing supply chain networks.

As a result, contractors tend to gradually outsource their logistics activities to competent LSP for reasons of rationalisation and optimization (Lieb et al. 2007a) and (Lieb et al., 2007b), thus optimisation has been considered as a core element of any decision-making problem.

Currently, controlling all of the activities involved in manufacturing finished goods is the primary concern of supply chain management (Naji et al., 2021). Hence many LSP are required. In fact, the ordering companies are in choose the most suitable one for their needs. So, because of the multiplicity of different suppliers in today's competitive industrial world, choosing a suitable supplier is fundamentally importance. As a result, the role of LSP and their management of the chain are fatally important since a wrong decision can lead the company to higher costs and significant damage to the relationship of the supply chain (Alireza et al.,2020).

The sustainability and effectiveness of this relationship has a favorable impact on supply chain management by making it easier to maintain a competitive advantage (Horvath et al., 2001; Paché et al., 2007).

In addition, building a trustful relationship between supplier and buyer organizations generate a healthy atmosphere that will lead not only to a competitive advantage for the organizations and improve their access to resources, but also to eliminate the uncertainty of the business environment (Aliakbari et al.,2011).

To this purpose, an eminent need to model this relationship linking these two actors is required.

The literature is rich in modelling methods grouped into several categories (Frichi et al., 2022). Similarly, many academic studies deal with the modelling of the choice of the best provider using numerous mathematical models regarding the problem and the data concerned.

It then appears that the problem of choosing the best provider boils down to a decision problem referring to the strategic objectives set up by the contractor's company, the decision makers' power restrictions and the

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interdependencies associated with this decision (Marc-André, 2012). This decision is a strategic one, that will have a significant impact on the company's performance.
Therefore, it entails deciding the portfolio of LSP to be retained.
Following on from past work carried out previously that has developed the MultiCriteria Decision Making (MCDM) methods, and which has revealed weaknesses that the next approach attempts to remedy. These weaknesses appear in the decision-makers' inability to describe their demands as constraints in general, especially since these methods are based on human judgment, which often has a non-objective instinctive character. As well as the limitations of human analytical capacity to consider simultaneously the possible compensation and substitution effects associated with thousands of interdependent choices (Marc-André, 2012). So this time we chose for mathematical modeling approaches, specifically linear programming in binary numbers.
Our modelling approach is part of applications of Operational Research Methods to enhance and assist decision-making processes. Our approach falls within a mathematical modelling, which makes it possible to formally evaluate different alternatives and predict their consequences (Roy, 1996).
Therefore, the decision support systems for the supply chains management services may be highly impacted by the method that is chosen to be successful and feasible (Hajiabolhasani et al., 2018).
The study carried out consists in the modelling of the problem of provider selection as well as the assignment of the service to be outsourced to the appropriate LSP as part of the success of the logistics outsourcing strategy. To the best of the authors' knowledge, this is the first study of its kind about LSP operating in Morocco. The current study fills this gap by conducting a literature review and responding to the following research question (main RQ): How the problem of LSP selection and the assignment of the logistic services can be correctly evaluated?
The paper is structured as follows, the section 2 focuses on the literature review dealing with the issue of LSP selection by opting for mathematical modelling as a decision-making method. We also present in the second part of this section some methods of mathematical optimization, before proceeding in section 3 to the presentation of the selected method and the elaboration of the model while taking into account the contractor's criteria and constraints.
Then, in section 4, we'll present the tool used as well as the algorithm established for solving the problem. An assessment is given to the model developed for dealing with data collected from a sample of LSP operating in Morocco.
These data concern some aspects characterizing and distinguishing these LSP, they are in the form of qualitative and quantitative criteria. The results we have reached will be presented in the second part of Section 4 of this work as well as the software tool used to solve the problem. We will conclude with the presentation of the limitations as well as the prospects and the improvements envisaged.

2. Review Literature

The literature aimed at the study of the logistics outsourcing of Moroccan companies as well as the management of the relationships between all the stakeholders contributing to the success of this strategy is almost absent (Aboudrar et al. 2014). Indeed, the ensuing supply chains involve a large and a rising number of logistical actors, which subsequently require robust methods for the selection porpuse. Their roles are becoming increasingly important (Azzouz et al., 2020a; 2020b). The established model will be used to assist the contractors, allowing them to opt for this strategy without hesitation regarding fears for LSP choice. So we are seeking to develop a model allowing the evaluation of certain criteria by including them as restrictions and to make an adequate choice for the LSP.
Several categories of methods for the problem of LSP selection exist are used, however mathematical modeling methods are considrred in the present paper. In fact, they offer a robustness to the decision and prevent decision-makers from making arbitrary judgments (Marc-André, 2012). This is made possible thanks to the application of linear programming technique.
Furthermore, the lack of MCDM methods for the integration of constraints in the model has prompted authors to propose mathematical programming methods for solving LSP selection issues.
However, the literature review shows the need for a full system of measurement indicators to assess the performance of actors emanated from the supply chain as a whole (Akgün et al., 2010).
The problem of LSP selection is a multi-criteria problem in the sense that LSP evaluation and decision-making is frequently seen account being taken of several criteria at the same time. This paper focuses on the presentation of mathematical optimization methods allowing the integration of several criteria.
Indeed, mathematical programming models are the most widely used for modelling in logistics network planning and for evaluating 3PL's providers (Ko et al., 2006; Ko et al., 2007).
An optimization model for the selection of LSP in the transportation filed was developed by (Moore et al., 1991), for the case of "Reynolds Metal Company", by opting for the method (Mixed Integer Programming) for the selection and deployment of carriers.
Similarly, a mathematical programming model for the selection of a 3PL for outsourcing storage was established by (Chen et al., 1991). However, (Kumar et al., 2006) used a multi-objective programming model for the problem of LSP selection involving a set of multi-objective criteria that are often contradictory.
Other researchers have developed approaches to solve the problem of selecting transportation service providers. It is a multi-objective mathematical programming model, acting on the minimisation of the total cost (Liao et al., 2007).
In addition, (Huang et al., 2011) addressed the problem of selecting carrier-type LSP with the reliability of the transportation system in order to find the best choice using (Optimal Carrier Selection problem based on Network Reliability).

In order to outsource a part of the production and model the fixed and variable costs related to the purchase and production, (Ahmadi et al., 1994) used binary functions.
In furthermore, Degraeve et al. (1999) used mathematical programming and Total Cost of Ownership (TCO) to construct a mathematical optimization model with several suppliers across multiple planning periods for the problem of supplier selection.
Weber and Current (1993) have developed a multi-objective supplier selection model. Thus (Anupindi et al.,1993), (Ganeshan et al., 1999), and (Ngwenyama et al., 1999) have proved the advantages of using multiple providers through mathematical modelling.

3. Material and Methods

3.1 Mathematical optimization methods

Many academic works deal with the problem of selecting the best provider by opting for mathematical models which are in turn numerous according to the problem posed, the type of data involved and the structure studied (Bounif, 2015).
Optimization problems are solved by mathematical methods designed for supply chains and cost optimization. They entail modelling a real system using a set of equations that represent constraints and objectives.
The optimization of the supply chain is therefore an objective for any company wishing to achieve operational excellence through the optimization of its industrial and logistic resources, as well as the improvement of the flow between the different actors of the supply chain.
There is a diversity of methods of solving mathematical problems. Exact methods that generate optimal solutions, are punished by the execution time which is sometimes intolerable. Other methods which are approximate methods providing solutions in a reasonable time, but do not ensure the quality of the solution (Frichi et al., 2002). Matter of fact, the decision between these two approaches depends on the size of the problem, its relevance, its complexity and the importance of the time factor in obtaining a solution.
In addition, at the modelling level, operational research is one of the popular analytical methods within the scientific community (Parunak et al., 1999), based on optimization theories, game theory, statistics and algorithmics.
We can therefore state that mathematical optimization methods are among the most widely employed methods in scientific research for the handling of selection problems.
These methods are frequently formalised as one or more objective functions which are then minimized or maximized subject to a set of constraints. The models generated might be linear, or non-linear, and can include integer, real, mixed or binary variables, etc (Hammami 2013).
Resolution techniques of this sort of modelling include linear programming (Pan 1989), mixed integer programming (Fayoraman et al. 1999; Narasimhan et al. 1986; Bender et al. 1985; Nam et al. 1995) and multi-objective mathematical programming (Weber et al. 1993; Buffa et al. 1983).
The formulation of a mathematical model requires choices of type of modelling, by determining the number and shape of objective functions that have a deep impact on the nature of the model. Subsequently, this choice will have a decisive impact on the nature of the algorithms used to solve the models elaborated (Marc-André 2012).

3.2 Study context

In the industry in general, the cost of outsourcing represents a significant portion of the overall cost of an asset but the cost of the design, transformation or assembly operation represents only a smaller portion of the overall cost (Malcom 1997).
As a result, the interest will be initially to optimize the cost criteria in order to develop a general mathematical formulation of the problem that minimizes the overall cost of outsourcing one or more services.
Although the choice of LSP can be made according to a variety of criteria, focusing solely on an evaluation taking into account only quantitative criteria undervalues the importance of qualitative criteria. The latters provide a long-term benefit (MacCormack et al.1994).
These two types of criteria create a competitive advantage for supporting the company's strategy.
After elaborating previous work based on qualitative criteria for the most suitable LSP selection, a cost-based analysis can be adopted to refine the choice, and decide on the best alternative by also incorporating the qualitative side in the constrained part.
The Outsourcing-Internalisation options in our case concerns the selection of an effective LSP panel and the assignment of each service to the appropriate LSP.
As a result, our problem consists to model LSP selection using two types of data: qualitative data such as traceability, technological level, level of services offered, range of transportation, and type of LSP, and quantitative data such as the fixed cost of LSP selection and the cost associated with the service provided.
The approach can be summarized in this form

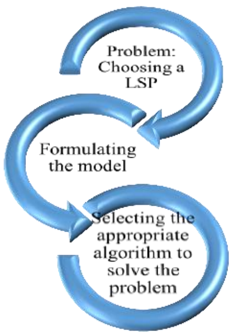

Fig 1. LSP choice approach

A decision-maker must first have a clear understanding of his or her company's situation in order to determine strategic and operational objectives, its internal and external environment and the nature of its operations.
To do so, the identified problem must be represented in the form of a model to uncover possible alternatives and reduce the choice problem's inherent complexity.

After having developed the model taking into account the constraints as well as the potentials of the contractors, a validation or resolution step must be performed in order to identify the optimal options.

3.3. Scenario adopted

In terms of the LSP selecting problem, we assume that we have (i) LSP to choose among them to provide (S) services. The scenario adopted is to consider a predetermined number of services, each LSP offering a single service, as well as a service is only handled by a single LSP.
However, the cost of outsourcing is divided into four categories: a cost associated with the choice of LSP, a cost associated with the fulfillment of service S by the LSP (i), a risk cost associated with the incorrect choice of LSP (i) and a risk cost associated with the inappropriate affectation of LSP (i) for the S service.
Overall, we are thus placing ourselves on the contractor side, which attempts to minimize the overall cost resulting from the choice of better LSP and the assignment of service to be outsourced to the appropriate LSP, while seeking in the meantime to maximize criteria.
Our contribution is about the application of mathematical modelling to combine qualitative and quantitative variables to fill the gaps left by only using one type of data without considering others. So our study is not only to assess the services costs that comprise both the cost of providing the service and the cost of the risk that may occur, but we will also evaluate the qualitative aspect of the few criteria considered interesting in preliminary studies for the LSP selection (Azzouz et al. 2021). This aspect will be illustrated as a constraint in the model developed.

3.4 The mathematical formulation

We will present the model developed as well as the specifics around it, likewise the method of suitable resolution is described.

- *Data*

I : the number of LSP panels
S : the number of services to be outsourced
J : criterion index
Cv_{is} : Cost of outsourcing the service (s) by the PSL (i)
Ct_s : cost of providing an in-house service
Cf_i : fixed cost of choosing an LSP (i)
Q_3 : third quartile of LSP score distribution
W_j : criterion weighting j
S_{ij}: the score of the LSP (i) for criterion j
Cr_{is} : the risk-related cost of a service provided by a LSP (i)
Cr_i : the cost associated with the risk of a bad choice of a LSP (i)
ξ : a tolerance margin
p_i : the multiplication of the S_{ij} core by the weighting of the j criterion W_j for all services.

- *Decision variables*

$\boldsymbol{Y_{is}}$= 1 if the LSP (i) supported the (s) service.
$\boldsymbol{Y_{is}}$= 0 if not
$\boldsymbol{X_i}$= 1 if the LSP (i) is retained
$\boldsymbol{X_i}$= 0 if not

- *The objective function*

The objective is to minimise the costs of selecting an adequate LSP and the affectation of service(s) to the correct LSP then the risk assessment cost incurred whether it is the risk related to the bad choice of PLS as a whole or the incompatibility of the assignment made between the service and the chosen LSP.
The cost is the criterion optimized in principle and represented in the objective function at the level of the model stated, but we have also specified qualitative criteria that will be highlighted afterwards in the constrained part
The objective function is as follows:

Minimise $Z = \sum_i \sum_s (Cv_{is} + Cr_{is}) * Y_{is} + \sum_i (Cf_i + Cr_i) * X_i$

Contraints

$\sum_i X_i = S$ (1)
$Y_{is} <= X_i \quad \forall s \in S\ , \forall\ i \in I$ (2)
$\sum_s Y_{is} <= X_i \quad \forall\ i \in I$ (3)
$\sum_i Y_{is} = 1\ \forall\ s \in S$ (4)
$Cf_i * X_i + Cv_{is} * Y_{is} <= C_t s + \xi * (C_t s)$
$\forall s \in S\ , \forall\ i \in I$ (5)
$Q_3 \leq \sum_j (S_{ij} * W_j) * X_i \quad \forall\ i \in I$ (6)
$X_i \in \{0,1\} \quad \forall\ i \in I$ (7)
$Y_{is} \in \{0,1\} \quad \forall\ i \in I \quad \forall\ s \in S$ (8)

The objective function minimizes the total cost of choosing the best LSP and assigning it to the most appropriate service. This cost includes two terms: the first is associated with the selection LSP and the fulfillment of a service, and the second is associated with the cost of risk that may occur as a result of a bad choice of LSP or the cost of non-homogeneity of LSP for such a service.
The constraint (1) ensures that there will be (S) LSP selected which will correspond exactly to the number of services to be outsourced. The constraint (2) ensures that a service can only be outsourced if a LSP is retained. The constraint (3) requires that a LSP cannot support at most one service (0 or 1). The constraint (4) ensures that a service must be supported by a single LSP. For the constraint (5), outsourcing is only possible if the cost of outsourcing is lower or just slightly more, with a small tolerance, than the cost of of internalizing such service. The constraint (6) achieves a limitation of the LSP that will be the subject of the study by picking only the third quartile in our case. However, depending on the size of the sample employed, one can go up to the second quartile in the event of a big sample. This quartile will be compared with the product of the LSP score calculated by combining the 5 previously staed criteria which are (traceability, technology, type of PL, service range and types of transport), and the weighting of each criterion based on the contractor’s opinion. The two constraints (7) and (8) relate to the binary nature of the decision variables associated with the selected LSP and the assignment of each service to the correct LSP. This model is a binary-variable linear program.

4. Resolution and Explotation of Model

4.1 Resolution

The method of solving a selection problem formalised in the form of a mathematical optimization's model is to detect the type of model obtained (linear model, mixed linear model, non-linear model, multi-objective mathematical programming model, etc.).

For linear single-lens models, the simplex method is recommended since it gives one or more optimum solutions. The Branch & Bound approach is the most widely used and appropriate exact resolution method for generating an optimum mixed single-lens linear models, notably in the case of binary variables (Murray 2016).

Several software tools are available on the market to solve linear and some non-linear problems.

Our model may be solved with a Branch and bound method since these are binary variables. This method, in its execution process, at each iteration associated with the different nodes obtained, we precede a cut of the predecessor node to explore the different possible solutions.

This approach is used to solve a number of NP-hard problems, such as knapsack problem, integer programming, nonlinear programming, travelling salesman problem, quadratic as- signment problem, nearest neighbor search, cutting stock problem, and false-noise analysis (Ryan Firdiansyah Suryawan et al., 2022).

This method in turn uses the simplex method to find the optimal solution and to eliminate nodes that do not produce good solutions.

As a result, a simplex approach will be used to solve our problem by generating a relaxation for decision variable that are of binary origin. Since we are dealing with a significant volume of data, we utilize a CPLEX software for automatic resolution.

The choice of the CPLEX was motivated by its ability to process important data, however other software or other solvers remain limited in terms of variable capabilities and constraints such as the Excel solver.

Due to the volume of data to be processed, we opted for the CPLEX software more precisely (IBM ILOG CPLEX Optimization Studio which gathers together a set of tools for mathematical programming and constraint programming:

- Integrated Development Environment (IDE) called Cplex Studio IDE.
- Modeling language: Thanks to a syntax that is similar to the mathematical formulation, the Optimization Programming Language (OPL) makes writing linear (or quadratic) algorithms simple.
- Two solvers: IBM ILOG CPLEX for mathematical programming (resolution of linear programs in fraction number, mixed or integer numbers and quadratic programs) and IBM ILOG CP Optimizer for constraint programming.
- The CPLEX solver and the Simplex method are enabled by default.

The model developed was written in OPL (Optimization Programming Language) and implemented under the IBM ILOG CPLEX 12.10 software. The CPLEX code for both models is enclosed in the appendix. The models run on a hp PC, 11th Gen Intel(R) Core(TM) i7-1165G7 @ 2.80GHz,2803M … RAM 8GB.

- *Data*

In our case, and depending on data availability, we will limit ourselves to the following scenario, omitting the cost of risk and keeping the cost of LSP selection and the cost of providing related to the volume of the outsourced service.

So we consider that the LSP has unlimited capacity where they can be able to supply a service in its whole without sharing it with another LSP.

For our case we consider 28 LSP that will be the subject of our study and our choice, one of these LSP will provide only one service. Matter of fact, we first considered the outsourcing of four services that are (service 1, service 2, service 3, service 4) due to the discretization of the companies surveyed. SO, ultimately there will be a choice of four Lsp that match the four services. Our model will be available to a contractor to manipulate according to its strategy and its potentials, for example, but are not restricted to these services precisely whether in numbers or types.

- *Estimation of the costs involved in outsourcing logistics services*

In fact, in order to gather the information required for the validation of our model, we initially chose to disseminate a questionnaire to the main contractor model. However, due to of the heterogeneity of these data from one contractor to another and the limited amount of replies., we looked at the data simulation approach in order to validate the model developed.

The estimate made relates to the costs applied by the LSP operating in Morocco. The study focuses in a sample of 28 most active LSP on the national territory, moreover these LSP are distinguished by the fact that the least amount of information necessary to create an accurate estimate is available, in particular for the following elements:

- o Visibility: the presence of a website with the ability to access useful information and provide contact options.
- o The offer of services is interesting and meets at least one of the outsourced services, the subject of our study.
- o Notoriety: Possess a certain amount of reputation gained from local, national, or worldwide experience

For the calculations we have standardized the unit costs on the basis of 100 and considering that these prices vary in a random way within a confidence interval having as 90 and 110 terminals. We deliberately biased the calculated values by taking into account elements likely to influence prices such as the level of traceability, the level of Party Logistics (PL).

We have standardised the unit costs on the basis of 100 for the computations, taking into consideration that these values vary at random within a confidence range with endpoints between 90 and 110. We voluntarily adjusted the computed values to account for factors that are likely to affect pricing, such as amount of traceability and level of Party Logistics (PL).

These criteria were scored on a scale of 5, so the final estimate is weighted by the total score using the formula:
P=E*(X+S) (9)
With: *X* is the random number between 90 and 110, S is the score ranges from 1.. 5 and E = 0 or 1 depending on whether the service is offered or not.
Given that our model is to seek the most appropriate LSP with an optimized cost while taking into account other parameters related to assignment constraints as well as constraints on qualitative criteria, the estimated cost for a service not provided by an LSP is voluntarily assessed at a maximum value (999 in our case) to avoid that this LSP will be selected, in particular that the costs generated by estimation being in the range [90-120].
Additionally, we considered that the fixed cost can be reduced to two primary components: Collaboration cost and transaction cost. In project management theory, the fixed cost of collaboration should be about 10% of an operation while the negotiation cost shouldn't exceed 5%.
In order to comply with these restrictions, we have adopted an estimation formula using as a basis of calculation, for each LSP, the average outsourcing costs of the services offered by a LSP weighted reciprocally by a random rate between 8% and 12% for the fixed cost of collaboration and a random rate between 4% and 6% for the fixed cost of negotiation.
But for the estimate of the cost of internalization, and in view of our survey of some contractors, this is generally 10% more than the estimated cost of outsourcing for each LSP.
This is the exact rate we used to estimate the cost of outsourcing. We chose this approach so that the overall internalisation cost is at the center of gravity of all offers so that the estimate does not favour any LSP over another one especially since this cost depends only on the company.
In summary, given the variety of the units, for a good standardization of all costs.

- Since everything has been scaled back to a base of 100, the estimate is based on the assumption that the value falls within a confidence interval [90;110] is slightly biased by the score.
- The score for the price estimate is based on only two criteria: Traceability and Level (PL) rated out of 10.
- The fixed cost is computed based on transaction costs, for example, if the LSP does not provide a service, in which case it is valued at 999.
- The cost of internalization is estimated based on the average value offered by all LSP for a service, slightly increased to include additional contractor's costs, as well as the information collected from LSP on the average difference between the internalization costs and the outsourcing costs.

The modeling will be done on twenty eight X_i variables that constitute the panel from which our four LSP will be operated. Thus 28 Y_{is} variables correspond to the assignment of the 4 services to be outsourced to suitable LSP. For our example of 4 services and 28 LSP, we consider 140 variables and 425 constraints in our decision making model. LSPs are chosen based on the offer cost, the fixed cost related to relationship management and to weighted qualitative criteria.

4.2. Results and discussions

Based on CPLEX, we were able to test our previously developed model by converting it into the OPL language associated with CPLEX (*see alogirthm 1 and 2 in appendix)*. The table 1 summarizes the results obtained:

Table 1
The solution of the model

solution (optimal) with objective	443
The variable xi	[0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0];
The variable yis	[[0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [1 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 1] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 0 0 0] [0 1 0 0] [0 0 0 0] [0 0 0 0] [0 0 1 0] [0 0 0 0] [0 0 0 0]];

The first line corresponds to the the optimised total cost obtained from the objective function according to the data entered which equal to 443, which is nothing other than a base of 100. Indeed, for the sake of data standardization, the size effect resulting from the heterogeneity of the units practiced by the LSP was vouluntary deemed a cost truncated to 100.
The second line gives the result of the Xi chosen and which correspond to the selected LSP denoted by the value 1, their position indicates that the LSP chosen is the one that corresponds to its rank in the input table holding the LSP name and other data.
The third line gives the yi which results from the assignment of services to outsourced to the appropriate LSP, comprising the quarter-plet of each LSP, the position of number « 1 » associated with the outsourced service in accordance with the order launched in the table of data on the names of the services as well as the names of the LSP.
In our situation, the LSP selected are those occupying positions 7,11,23 and 26. Thus the assignment of the 1st service to LSP number 7, the second service is affected to the LSP number 23, the 3rd service is assigned to LSP number 26 and the fourth service is associated to the 11th LSP.
Indeed, the introduction of multiple selection criteria makes the selection operation a bit rigid, especially with the introduction of the notion of quartile in the selection operation, but if a contractor can make tolerances on some criteria and wants to expand the selection field, it can opt for a quartile 2 if it has a large enough sample of LSP.
In this article, we are interested in the problem of the decision to address the problem of selecting appropriate LSP. We have adopted an approach based on the mathematical modelling for selecting the best LSP and allocating services to outsource to them based in principle on the cost, but also taking into consideration other qualitative criteria that we have included at the constraints level.
We have defined the cost relative to each part of the outsourcing operation, some costs are given by LSP and contractors, while others are simulated. The model developed will help us to make a better choice of LSP as

well as assign services to the right LSP chosen while minimizing the total cost corresponds to this operation.

We opted for a relaxation of the problem due to the limitation of the data collected in the sense that we would not allow the sharing of a service with many LSP or the provision of a service by several LSP. So according to the data gathered and the nature of our problem, we have resulted in a linear problem with binary variables that we tested by the CPLEX software.

5. Conclusion

In this article, the study carried out involves modelling the problem of LSP selection and the assignment of the service to be outsourced to the appropriate LSP as part of a contractor's outsourcing strategy's success. We formed an opinion based on LSP and services modeling in a supply chain.

Thus we studied the design models of these in a supply chain in order to develop a mathematical model of the decision problem based on the cost criterion as well as other qualitative criteria that we discussed in the model.

Furthermore, the costs relating to each case of outsourcing each service to a certain LSP are compared to the cost of developing the same service in-house.

The purpose of this mathematical modelling is to allow the company to choose, for part of its activities, between doing in-house or doing by choosing the LSP that will be solicited from a candidate panel. This puts us on the side of the contractor company, which is attempting to minimize the total cost of the two options, as well as maximising the existing quality criteria of LSP and minimising the risk that may be generated as a result of the selection of an inappropriate service to be outsourced or the bad choice of LSP for this mission.

The constraints are related to the cost of carrying out services in-house, also to respect a certain threshold of some qualitative criteria such as traceability, the technology used…. Other constraints imposed to avoid the monopoly of a single LSP for the outsourcing of all services…

So we evaluated the scenario we chosed according to the data's accessibility tested with CPLEX. The model developed has some limitations. Apart from the difficulty in resolving in certain cases where the data are important, the model developed has certain limitations, in the case where certain information is not available or rather is not accessible for certain LSPs due to their confidentiality. In addition, the information concerning the sharing of services between several LSP in the multi-sourcing strategy compelled us to focus on a very specific scenario.

The number of service providers and selection criteria have been identified as some of the limitations of this work. This is why, in perspective, it would be interesting to develop another scenario based on the case of service sharing between various LSP and the fact that an LSP can provide more than one service, or the consideration of the cost associated with the different types of risks, are all possible study situations.

Appendix

Algorithm OPL :

```
/*********************************************
 * OPL 12.10.0.0 Model
*********************************************/
//variables
range S=1..4;
range I= 1..28;
dvar boolean x[I];
dvar boolean y[I][S];
  //data
 int nbr_PSL=...;
 int nbr_services =...;
 {string} PSL =   ...;
 {string} services=...;
 int Ct[S]=...;
 int Cv[I][S]=...;
 int Cf[I]=...;
 float p[I]=...;
 float quartile=...;
// expressions
dexpr int cost = sum(i in I)Cf[i] * x[i]+sum(s in S, i in I)
Cv[i][s] * y[i][s];
//model
 minimize cost;
  subject to {
   sum (i in I) x[i] == nbr_services;
    forall (i in I , s in S)
      ( Cf[i]*x[i]+Cv[i][s]*y[i][s] ) <= (Ct[s]*1.2);
  forall (s in S)
        sum (i in I) y[i][s] == 1 ;
  forall (i in I)
         sum (s in S) y[i][s] <= x[i] ;
  forall (i in I, s in S)
y[i][s] <= x[i];
  forall(i in I)
  0 <= (p[i]-quartile)*x[i];
 }
```

File.dat

```
/*********************************************
 * OPL 12.10.0.0 Data
*********************************************/
nbr_PSL= 28;
nbr_services =4;
SheetConnection my_sheet("C:\\Users\\Desktop\\mod-
validation\\Data_validation.csv");
 PSLfrom
SheetRead(my_sheet,"'Data_validation'!A3:A30");
 services from
SheetRead(my_sheet,"'Data_validation'!B1:E1");
 Cf from SheetRead(my_sheet,"'Data_validation'!F3:F30");
 Cv from SheetRead(my_sheet,"'Data_validation'!B3:E30");
 Ct from SheetRead(my_sheet,"'Data_validation'!G3:J3");
 p from SheetRead(my_sheet,"'Data_validation'!K3:K30");
 quartile from SheetRead(my_sheet,"'Data_validation'!L3");
```

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