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RESEARCH PAPER

Designing A Generic Decision-Making Model for Supply Chain Planning in an Uncertain Environment: Viability Mathematical Modeling

Sofia Kassami[1*], Abdelah Zamma[2]& Souad Ben Souda[3]

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ABSTRACT
Modeling supply chain planning problems is considered one of the most critical planning issues in Supply Chain Management (SCM). Nowadays, decisions making must be sufficiently sustainable to operate appropriately in a complex and uncertain environment of the market for many years to beyond the next decade. Therefore, making these decisions in the presence of uncertainty is a critical issue, as outlined in many relevant publications over the past two decades. The purpose of this investigation is to model a multilevel supply chain problem and determine the constraints that prevent the flow from performing properly, subject to various sources and types of uncertainty that characterize the flow. Therefore, it attempts to establish a generic model that relies on the stochastic approach. Several studies have been conducted on uncertainty in order to propose an optimal solution to this type of problem. Thus, in this study, we will use the method of "Mixed integer optimization program" which is the basis of the algorithm that will be employed. This inaccuracy of the supply chain is handled by the fuzzy sets. In this paper, we intend to provide a new model for determining optimal planning of tactical and strategical decision-making levels, by building a conceptual model. Therefore, it enables us to model the mathematical programming problem. We investigate in this attempt, attention to solving the mathematical model. So, in the resolution we are going through the algorithm in machine learning, therefore providing as in the end an optimal solution for the planning of production.

KEYWORDS: *Supply chain; The mixed integer optimization program; Optimal planning, production plan; Generic model; Mathematical model; Uncertainty; Machine learning.*

1. Introduction

In the beginning of the 1980s, SCM was initiated as an answer to the aggressive competitiveness among companies [1]. In a competitive environment, supply chain management has become a major challenge for companies to maintain profitability and stay connected to their customers who demand products tailored to their specific needs. Nevertheless, manufacturing production planning and decision-making in each level have emerged as challenges for companies faced with volatile markets. Thus, the ability to effectively match supply and demand is fundamental to every supply chain management process.

Ensuring an effective match between demand and supply is fundamental to successful supply chain management processes. In this context, demand forecasts are used to match demand and supply in a "push" strategy. [2], describe a set of enhancements to fit the previously published mixed integer programming models (MIP) with the specific demands placed by an electronics supply chain. [3] propose a mixed integer linear programming model (MILP) that is integrated into a dynamic procedure simulating a moving horizon planning process, which allowed them to evaluate different planning strategies to face the flexible demands. [4] proposed a model of mixed integer nonlinear programming as a method to minimize transportation costs and maximize time utilization over the planning horizon.

* **Corresponding author: *Sofia Kassami***
sofiakassami@gmail.com

1. *Faculty of science and Technology- Normal School of Technical Education Mohammedia Morocco.*
2. *Faculty of science and Technology- Normal School of Technical Education Mohammedia Morocco.*
3. *Faculty of science and Technology- Normal School of Technical Education Mohammedia Morocco.*

Numerous investigations have been performed in order to propose an optimal solution to make a tactical level planning decision, thus by determining the batch sizes according to the ‘lot sizing’ algorithms from the level of study, one-level planning (master plan for the production of finished products) or multi-level planning (component planning) and one-site planning Or multi-site. Multi-level planning, the "Multi Level Capacitated Lot Sizing Problem (MLCLSP)" is recognized as a reference model. The Single-Level Capacitated Lot Sizing Problem and the Multi-Level Capacitated Lot Sizing Problem (MLCLSP), formulated in the Big-Bucket model, are limited to determining production quantities and periods, with no attention to the true timing of production in a determined period. However, the advantage of this modeling approach is that it permits a flexible reorganization of orders during a period, although at the cost of the need to generate a complete production plan in a later planning phase. In another side, many models fully integrate sizing and lot sequencing decisions, which represents a substantial calculation cost. The Discrete Lot Sizing and Scheduling Problem (DLSP), are the source of These so-called "small bucket" models. They are also known as the Continuous Setup Lot Sizing Problem (CSLP) and the Proportional Lot Sizing and Scheduling Problem (PLSP), as well as others. [5]and [6]. In this stage, [7], propose a mathematical and metaheuristic multilevel model of "lot sizing" enabling the tactical planning of a hybrid supply chain of flow shop type. In the same way [8], point out the absence of a generic model for multi-site problems. This approach was not able to solve problems with a high level of variability and randomness in a supply chain. In this regard, a lot of research related to uncertainty measurement as carried out to solve this type of problem. [9] provided a model for strategic planning of a multiple supply chain which enabled them to obtain optimal strategies in the supply chain.

To design a reliable supply chain and perform the indicators several research were done to provide an optimal model, therefore [10], collect almost all the important researchers done and provide a summary by their literature review, where they focuses in showing different methods and approaches helping to design a supply chain relate to a new product, to measure the reliability of a model in uncertain environment [11], provide a comparison between a classical model and a developed approach based on a linear regression algorithm which allowed them to measure the reliability of a modal in uncertain environment. in this regard [12] provided a deep analysis of data by making a lot of measures relate to uncertainty and check by statistical efficiency analysis in order to unsure the validity of these results.

The approach of uncertainty measurement in demand, process, and supply determines the most reliable production plan and provides the decision-maker with a more efficient interval in the decision-making process. [13], the effectiveness of a fuzzy linear programming approach for Supply Chain (SC) planning under uncertainty, [14] It is shown that the developed fuzzy Aggregate Production Planning model can reduce the time required to execute production and warehousing operations and improve supplier performance. the analysis of these behaviors leads us to the analysis of the data that represents the source of this uncertain environment.

The most common approaches of planning problems classified the decision levels according to their level of complexity and difficult, that characterize their algorithms. [15] proposed a classification of the problems of "lot sizing" in order to determine the scope of the issues addressed.

[16], proposed a new approach of standard linear programming software to solve the multi choice or mixed integer linear programming problem. Where their purpose was to transform a complicated problem in an easy and simple one, by using a standard linear programming method. [17], proposed a hybrid optimization model between a fuzzy sets and genetic algorithm in order to solve the multi-objective train scheduling problem. [18], proposed a new model of hybrid optimization to handle all types of uncertainty in input data, based on a mixed integer linear programming model aim to determine the strategic and tactical level of decisions. [19], proposed a model of fuzzy mixed integer linear programming in order to reduce the gap between respond orders and the planning, thus proposing a new shortage planning. The remainder of this papers organized as follows: Section 2 presents literature review supply chain management. In the first part, we present the several definitions of supply chain as well as the management of the supply chain.

The second part deals with the principle of supply chain planning. We present the work of the scientific committee at the tactical planning level. For this purpose, we present the planning issues dealt with. The third section is dedicated to present our mathematical model and the resolution of the model based on machine learning algorithm.

1.1. Supply chain

The supply chain is a collaborative process that involves the transformation of raw material to final product in order to deliver at the end to the customer. The complete chain consists generally of four pillars _ Suppliers, manufacturer, distributors and customers. Therefore, logistics is essentially a planning orientation that help to take the decision in the strategic and tactical level for the flow of products and information through a business. [20] studied that the concept of supply chain management is expanding rapidly in industries in order to satisfy customers in effective profitable manners, [21] reported that, a Supply Chain is “a structured manufacturing process wherein raw materials are transformed into finished goods, then delivered to end customers”. [22] described the supply chain as "a general description of the integration of processes involving organizations to transform raw materials into finished products and transport them to the end user. [23], defined Supply Chain as “Life cycle processes comprising physical, information, financial, and knowledge flows whose purpose is to satisfy end-user requirements with products and services from multiple linked suppliers”.

2. Supply Chain Management

The notion of supply chain management introduced by [1], was the subject of multiple definitions proposed in the literature [23], asserts that SCM is the Design, maintenance, and operation of supply chain processes for satisfaction of end user needs. [24], reported that the logistics Management as " the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements". Illustrated in the form of a house that brings together the different parts of the logistics chain. Named the "Logistics Supply Chain Management House", which contains the different main players, to ensure an efficient supply chain, [25] stated that the main objective of supply chain management resides in The separation of supply chain activities between different companies that allows for specialization and economies of scale. Therefore, many important issues and problems must be solved for successful SC operation. The roof of this house determines the goal, which is competitiveness, which translates directly to customer satisfaction Figure 1. [26]. The components of this house must be improved and developed in an equitable way to ensure its stability, balance, robustness and sustainability. These pillars include advanced planning, which is a major component, requiring treatment. Hence, the interest of the work carried out in this respect.

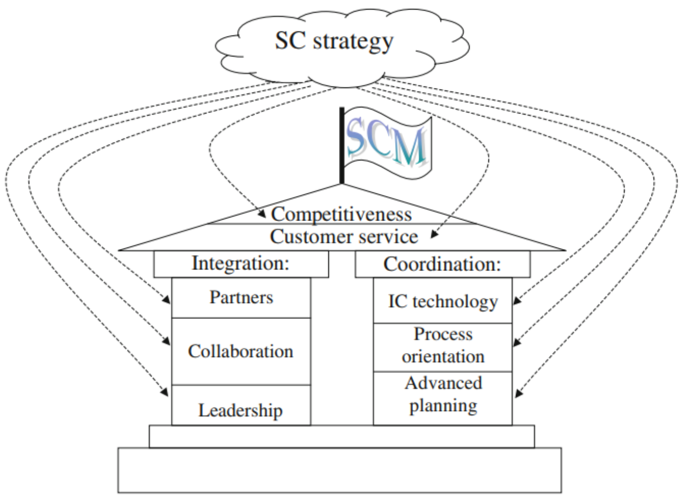

Fig. 1. The impact of a SC’s strategy on the building blocks of SCM [26].

3. Supply Chain: Decision Levels

The general definition of supply chain planning according to [27] consists of setting objectives and determining the actions to achieve them. The dimension of time is the key indicator for any Planning. That helps to make decisions in each level of management, therefore, the planning changes the form and parameters according to the level of management, and the horizon of the planning. Either short-term planning that focuses on the operational level or in the medium term. This is related to the tactical level in which [28] determined a hierarchical approach that breaks down into three levels as illustrate in the figure 2 below:

Fig. 2. The hierarchical levels of management

4. Supply Chain Planning.

The hierarchical approach (Figure 2) defines a decision framework in where each lower-level plan must fit. Pragmatically, planning involves constructing different scenarios in a given area, with objectives, resources and time. The longer the planning horizon minus the revision frequency is high. We have schematized in a matrix the levels of planning as well as the review of the decisions taken as shown in the figure 3 below:

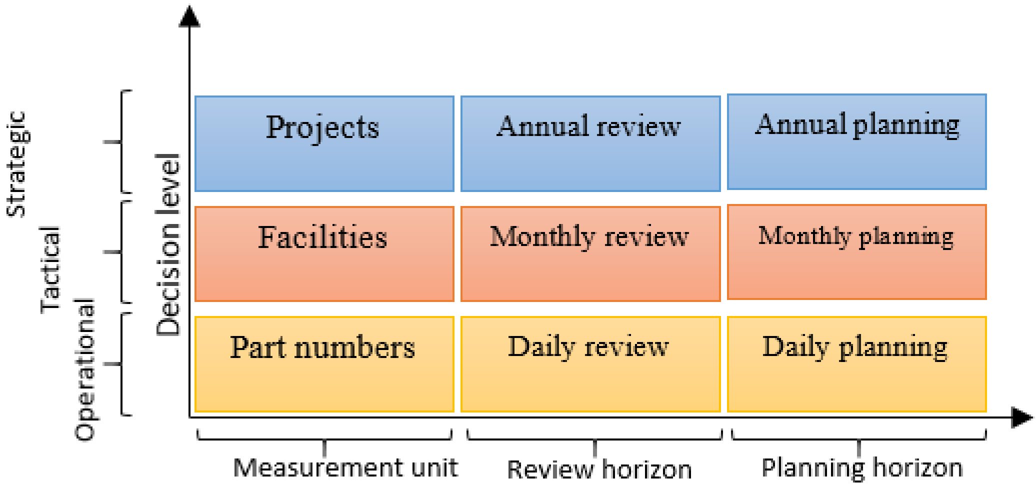

Fig. 3. Planning decision level matrix

a lot of criteria in supply chain was be the base of many researches, that they were worked indifferent type of problem, inbound flow, outbound or all the network of supply chain, and the dimension of this flow, one-site or multi-site, one level or multi-level. The type of the boom (Knock down product or assembly product), and the number of products (mono or multi product) as well as the Topological structure of the supply chain. The grouping of its elements provides us a structure which is relate to different forms, we found two topologies of networks descried by [29], [30], [31], [32], [33].Therefore, we combine those structure as a schematization illustrated in the figures 4, 5, 6 below:

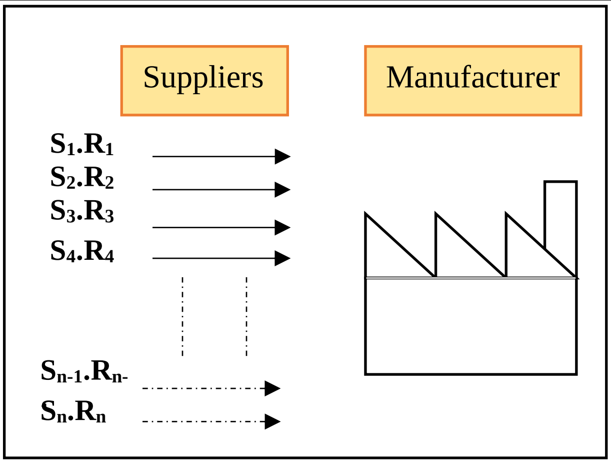

Fig. 4. Convergent structure

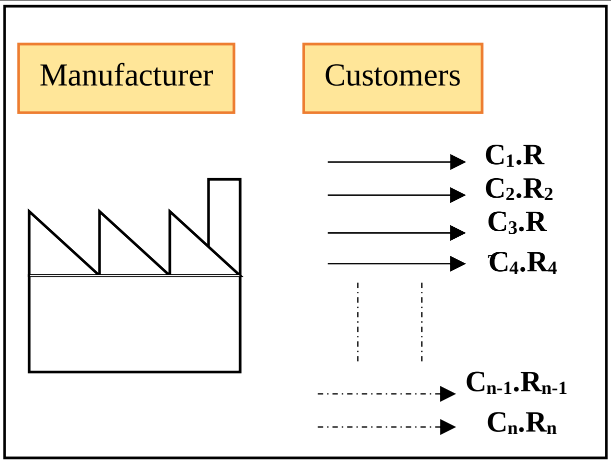

Fig. 5. Divergent structure

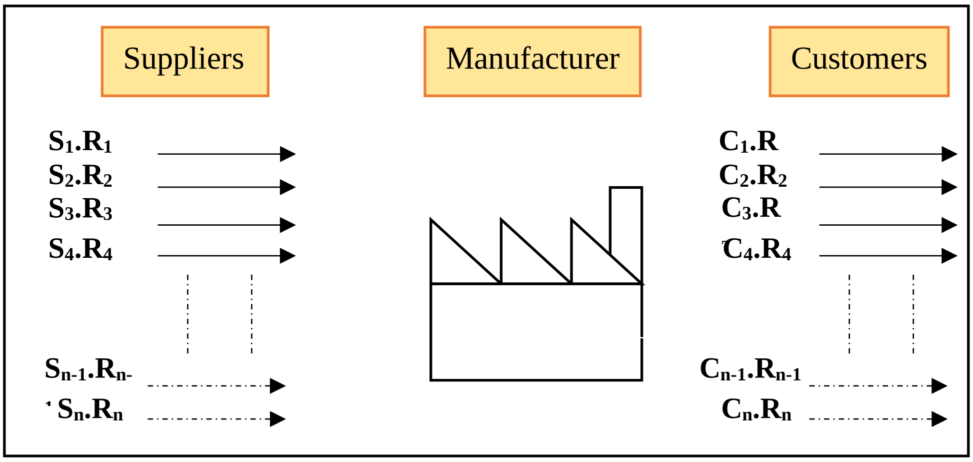

Fig. 4. Network structure

5. Uncertainty in The Logistics Chain

The word fuzzy started in 1965, the theory of fuzzy characterized with a variety of techniques and in many disciplines. [34], presented the theory of fuzzy sets and applied it into real case studied. This work provided a basis for the application of this method to solve problems relate to supply chain planning.

Therefore, the industry today has a serious problem relate to the low level of certain data, which impacts the entire logistics chain and makes the level of information flow, so the chain characterized with a very high level of uncertainty. However, the credibility of the decision is therefore less effective for the level of performance.

Therefore, the measure of the uncertainty and make a diagnostic of the weak links in the logistics chain seems to be the best way to perfecting the decision-making and increasing the level of planning performance. Nevertheless [35] conclude that decisions should be made based on a balanced assessment

[36] explained uncertainty in the supply chain as “the difference between the amount of information necessary to perform a task and the amount of information already available». Then we found the or done by authors in order to analyze the sources of uncertainty in a SC. [37]; [38]; [39]; [40] proposed a classification of those sources of into three categories (Supply, Demand, Manufacturing process). [41] Supplemented these sources and sorted them according to their approach category as illustrated in Figure 7.

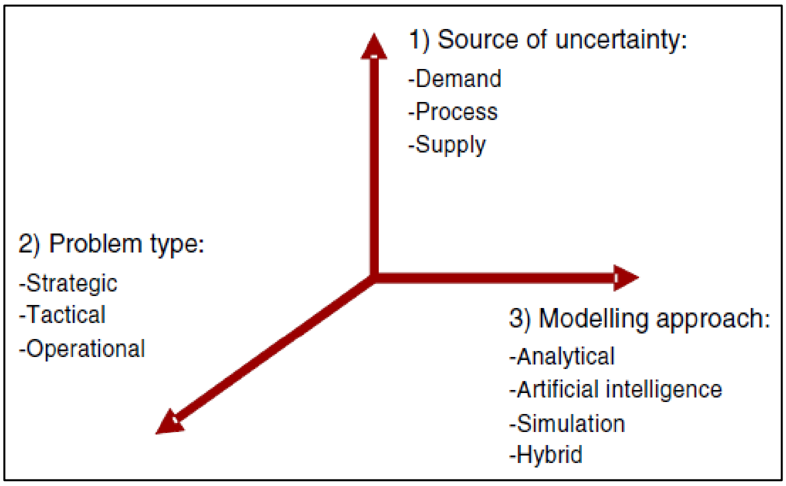

Fig. 5. The three taxonomy dimensions of the SC planning models [41]

Uncertainty of supply is caused by the variability caused by the way the supplier operates because of the delay in shipment order. The uncertainty in the process is the result of the unreliable production process due to resources. Finally, the uncertainty of demand, according to [38], is the most important of the three and is presented as a demand for volatility or as a requirement of inaccurate forecasts. [42] proposed a robust optimization planning for P-D (Production – Distribution) with uncertain parameters, thus, to minimize the costs. In the same way [43] proposed an optimization planning with uncertainty in demand. [44] developed a new fuzzy bi-objective mathematical model for the production-distribution problem in uncertainty for a four-tier logistics network design involving several suppliers, producers, distributors, customers and a set of transport modes. [45] applied a runaway horizon control method to a set of realistically sized large-scale supply chains under demand disturbances in an adaptive manner.

This uncertainty in a supply chain causes the risks, [46] investigates firms' adaptive strategies against disruptions in a supply chain network. Therefore, the work in each fact, help to minimize the costs. However [47] discussed an important indicator which is relate to deep uncertainty and the relation with closed loop supply chain management.

Therefore, the uncertainty in supply chain is not relate only to three sources, through the analyses of that, we add another important element that is decision in different horizon and levels, as we illustrate in the figure 8:

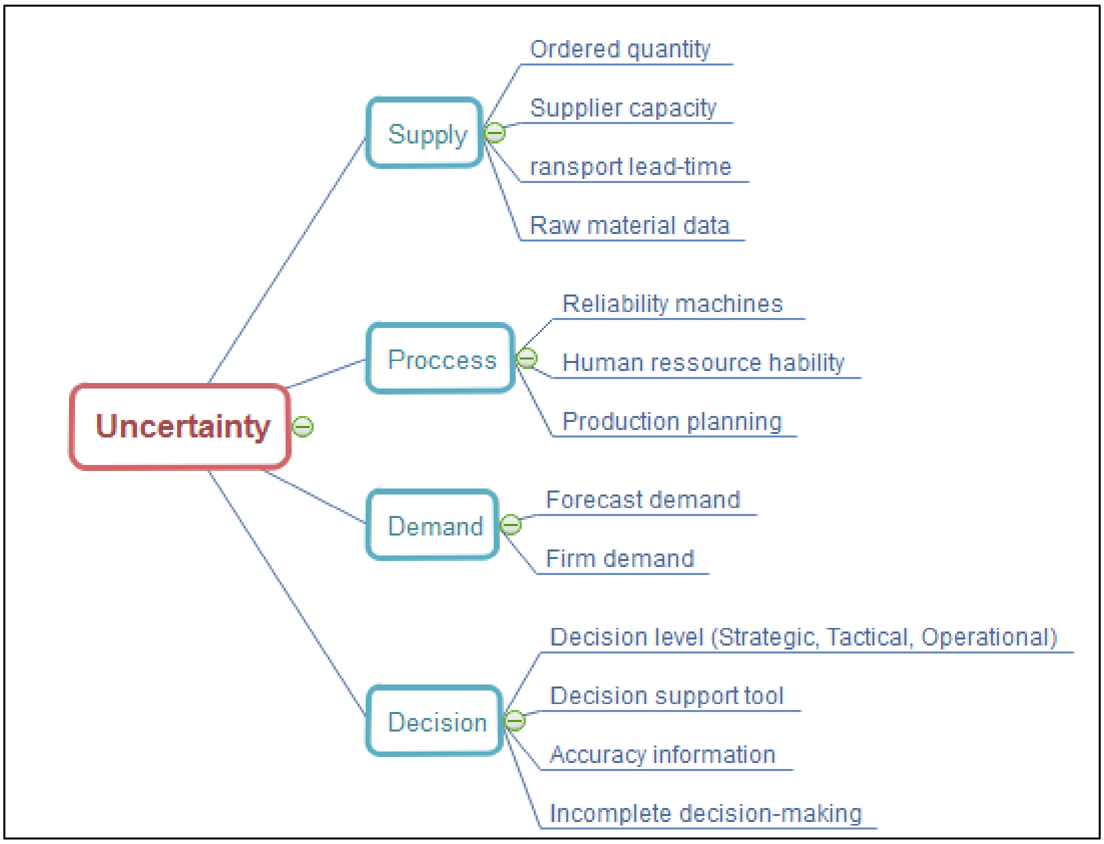

Fig. 6 . The taxonomy of uncertainty sources in supply chain

6. The Design of A Generic Model

6.1. Conceptual model

After presenting a review of the literature on the work done in the level of batch size determination and taking into account the dimension of uncertainties, it has been found that the studies carried out in the two tracks have Limitations in the determination of constraints and the choice of methods of resolution. [48] Developed generic models for the planning of mono-site and multi-site levels and then proposed a generic model of knowledge for the field of tactical planning, from which he obtained a generic mathematical model allowing answering the various problems such as the development of S&OP and Master Planning. However, we will adopt a technical approach based on the comparison between the different tools used to design a powerful and efficient model for the objective.

The work presented by [49] is more general, because their proposed model brings together the various crucial parameters, for the operation of the supply chain linked to production, distribution and transport, this by setting up a transport management schedule and satisfying requests from different consumers

However, based on the conceptual model of [15], we determine our own model that takes into account the uncertainty that can be a crucial actor in order to have an efficient planning. This will allow any researcher to draw his research voice according to the type of problem to be treated. In the figure 9 we show our model designed.

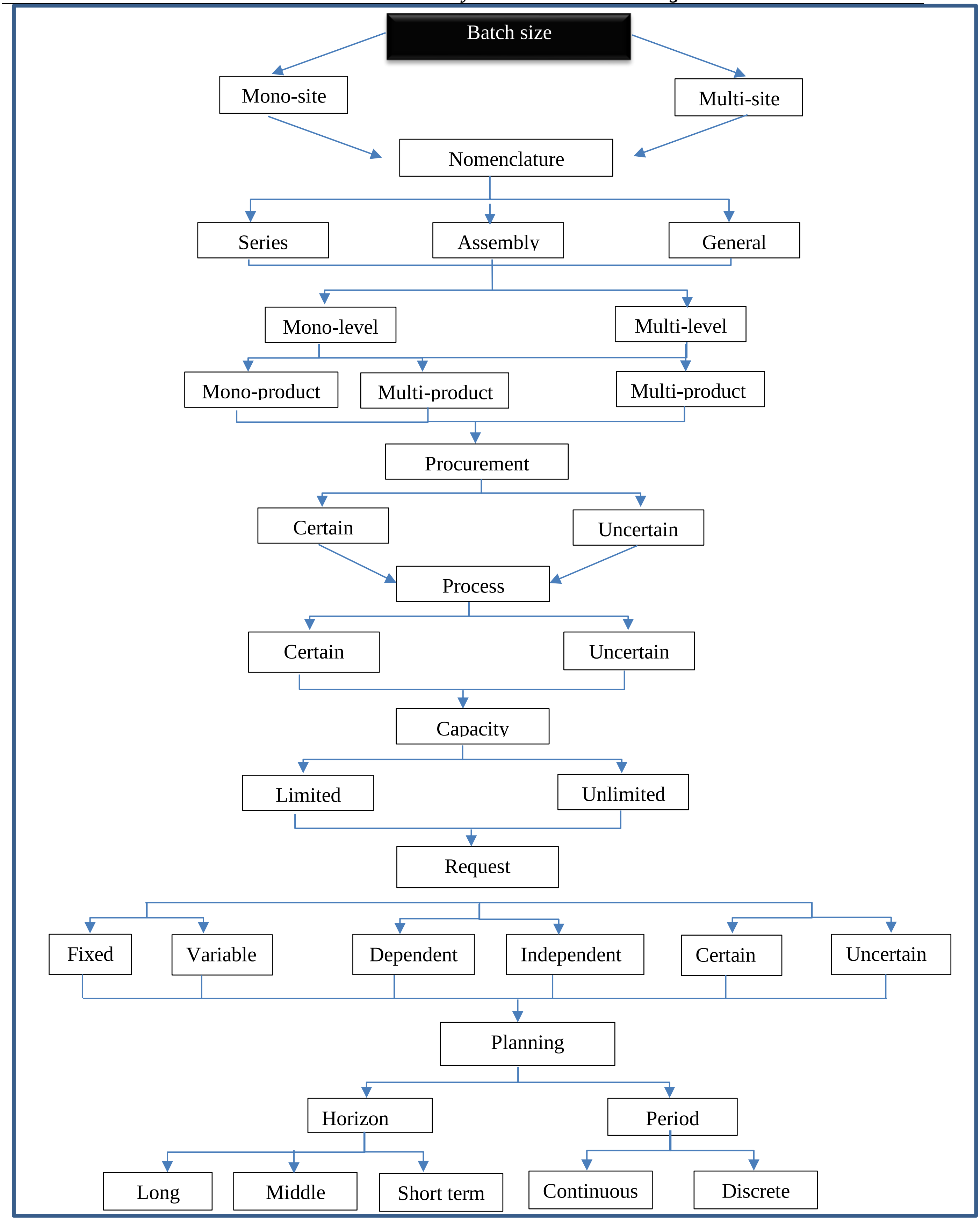

Fig. 7. Generic model

7. Mathematical Optimization Model

With a goal to know how to design and operate a system in the best way, under the given circumstances such as allocation of scarce resources, usually requires leveraging on quantitative methods in decision making. Mathematical optimization is one of the main approaches for deciding the best action for a given situation. It consists of maximizing or minimizing the real function by systematically choosing input values from an allowed set and computing the value of the objective function. Use cases for optimization are:

- **Product planning and inventory control:** planning the issue of orders while avoiding stock-out and exceeding capacity limitations
- **Routing decisions:** process of determining the most cost-effective route
- **Packing problems:** deciding the packing method without exceeding the capacity while minimizing the free space
- **Resource planning:** determining the amount of each item and resource needed
- **Scheduling:** such as scheduling the shifts of workers
- **Location problems:** placement of facilities to minimize transportation costs while ensuring the requested demand.

8. Mathematical Model

The work provided by researchers characterized by some limits, refer to the work (Michael C, 2008) who proposed a generic model. However, this model has been based on taking demand into account as a known parameter, and the transport constraint is not part of the model, as the failure to consider the uncertainty that characterizes certain constraints decreases the performance of the model presented. We propose to merge the two approaches, the approach of batch size determination, and the uncertainty measurement approach.

Our model takes into account all the limits found in the model defined consists of the uncertainty that characterizes certain parameters of the model. Therefore, in this article we present the objective function of our models with these parameters, in order to pave the way towards the determination of the constraints related to this model.

There are three components of linear programming:

1. **Decision variable:** variables that can be directly controlled by the decision-maker.
2. **Objective function:** the linear function that mathematically expresses the quantities to be maximized or minimized.
3. **Constraints:** mathematical expression of equalities or inequalities representing the restrictions on the decision variables.

8.1. Define Parameters:

- HC: unit holding cost
- PC: production capacity per month
- $I_{t=0}$: initial_inventory
- UPC_t : unit production cost in month t
- DQ_t: Demand quantity in period t
- $\delta \begin{cases} 1 \\ 0 \end{cases}$

8.2. Define Decision Variables:

The decision variables are the important elements that impact the performance of the supply chain therefore in our model we are choosing to work in:

- $\widetilde{RMC}$: Raw material cost.
- SQ: Supply quantity.
- $\widetilde{IC}$: Inventory cost at the end of period t.
- $\widetilde{CP}$: Production cost in period t which is not fix.
- $\widetilde{PQ}$: Production quantity in period t.
- RQ: Received quantity from suppliers
- OQ: Ordered quantity in period t
- X_t: Amount of production in period t
- TC: Transport Cost.
- TQ: Transport Quantity.

8.3. Define the objective function:

Our mathematical modal aim to minimize the total costs of the supply chain presented by supply, production and demand we add also another important cost which is relate the transport those indicators are considered as objective function.

$$MinZ = \sum_{t=0}^{n}\sum_{i=0}^{z}(\mathrm{HC}_t * \mathrm{SQ}_{it} * RMC_{it}) + \sum_{i}^{I}\sum_{s}^{S}\sum_{t}^{n}((TQ \times \widetilde{CT}) + (\Sigma\delta_{it} \times \widetilde{LC}_{it})) + \sum_{t=0}^{n}\sum_{i=0}^{z}\sum_{r=1}^{l}(\mathrm{UPC}_i * CP_{ir} * PQ_{itr}) \quad (1)$$

The objective function Eq (1) aims to minimize the total costs relate to holding cost and production cost that are characterized by the uncertainty aspect which makes their determination difficult because of the variability that characterizes the parameters of the supply chain and the inability to control the three financial, informational and physical flows.

9. Define the Constraints:

The constraints in our model relate to our objective function

9.1. Inventory constraints

$$IC = SQ * RMC \quad (2)$$
$$IC_t = IC_{t-1} + X_t - DQ_t \quad (3)$$

The inventory cost in our model is relate to procurement of raw material thus illustrate in two constraints Eq (2) aims to calculate the procurement cost.

Eq (3) indicates the balance of inventory in period t that is relate to demand and amount production in the same period.

9.2. Supply constraints

$$RQ_{i,t+1} \leq \mu \times \widetilde{SQ} \quad (4)$$
$$\widetilde{RQ}_{i,s,t+1} \ll OQ \quad (5)$$

Eq (4) we make the accent also about the constraints of maximum quantity Received from suppliers that should not exceed the maximum capacity allowed from suppliers, in order to respect the inventory level.

Eq (5) attempt to check the respect from supplier of the planning communicated to them and also to measure the variability in the received quantity.

9.3. Capacity production constraints:

$$\widetilde{X_t} = CP_{ir} * PQ_{itr} \quad (6)$$
$$\widetilde{X_t} \leq PC \quad (7)$$

Eq (6) Amount produced in period t is the relation between the cost and quantity produced. The production quantity should not exceed the maximum capacity.

9.4. Demand constraints:

$$QP \gg \widetilde{DQ} \quad (8)$$
$$\widetilde{DQ} \leq PC \quad (9)$$

Eq (8) the equation shows that the planned quantity must be higher than the demand in purpose to avoid fluctuation and variability in customer request.

Eq (9) this aim to remind client that they should not exceed our maximum capacity of production in purpose to avoid the shortage in production and also reduce the demand backward

10. Solving the Mathematical Program

To resolve this mathematical model, we are going to make an algorithm, this is the base of our new form of methods that I call MLOS (Multi-level Optimal Solution), this approach aims to take into account all the variability characterized some indicators (ordered quantity, demand…), and calculate the uncertainty, then provide the optimal solution in order to make a saving and make decisions in strategic and tactical levels. Therefore, I'm going to propose an optimal solution to resolve my mathematical model. Therefore, In this article, I will demonstrate a solution to optimize problem studied, leveraging on linear programming, and using PuLP library in Python and use CBC solver. Linear programming deals with the problem of optimizing a linear objective function aims to find a minimum cost subject to linear equality/inequality constraints on the decision variables. The figure 10 illustrate the followed steps, in order to implement the computer program aims to solve the mathematical model

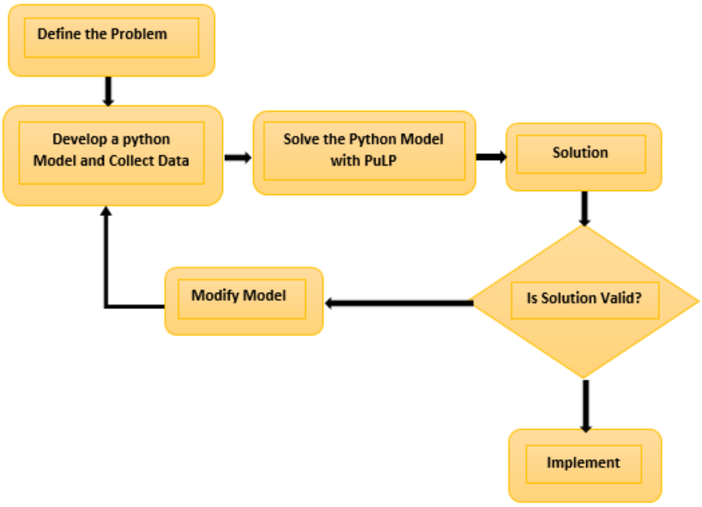

Fig. 8. Graph of optimization process

10.1. Process of resolve the mathematical model.

For relatively simple or well understood problems the mathematical model can often be solved to optimality. This is done using algorithm illustrate in the figure 11.

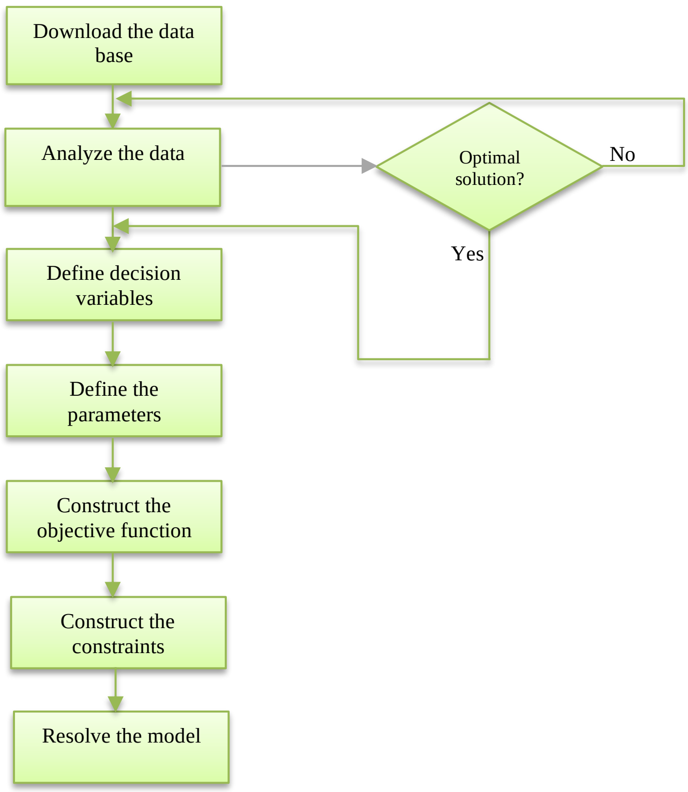

Fig. 9. Program operation algorithm in PYTHON

10.2. Comptational results and discussion

In this section we discuss the performance of MLOS on four results graph with the optimal cost for each variables in period t, used for optimal lunched cost that help us to assess the variability. The key of success of planification is to know how to manage the launched cost and have accuracy in the forecast in order to manage the uncertainty in the demand and improve the performance of production planning. In this model we were tried to take this indicator as a decision variale. Therefore we are successfully find an optimal cost of launched cost in period t, in pupose to schedule the monthly production plan of n products for a year. Then we were moved to manage the inventory, at first, we initialize the inventory with 500 units and the unit holding cost in the beginning and we execute the program aim to determine the optimal variable of inventory holding cost occurs at the end of each month. In the same time, we were focused in an optimal production cost that is relate to the optimal planning for each month through the obtained results we minimize shortage relate to demand uncertainty. The transport was the key performance indicator to assess the supplier efficiency and to determine the optimal transport cost of each volume and period.

Therefore, those results for each indicator enabled us to deduce the minimum cost for our objective function modeled “9,521,005.00”. Our output is generated also in Excel format

```
14:10:54,549  __main__:   INFO : Data is loaded!
14:10:54,592  __main__:   INFO : Model creation time in sec: 0.0250
14:10:54,595  __main__:   INFO : Writing the lp file!
14:10:54,598  __main__:   INFO : Optimization starts!
14:10:54,668  __main__:   INFO : The solution is optimal and the objective value is $9,521,005.00
```

This paper proposes a model MLOS to resolve problem of plannification in tactical level decision and also to handel the uncertainty in supply chain based on that we are try to propose a generic model for severeal problem in supply chain.in the figures 12,13,14,15 we illustrate the results as below:

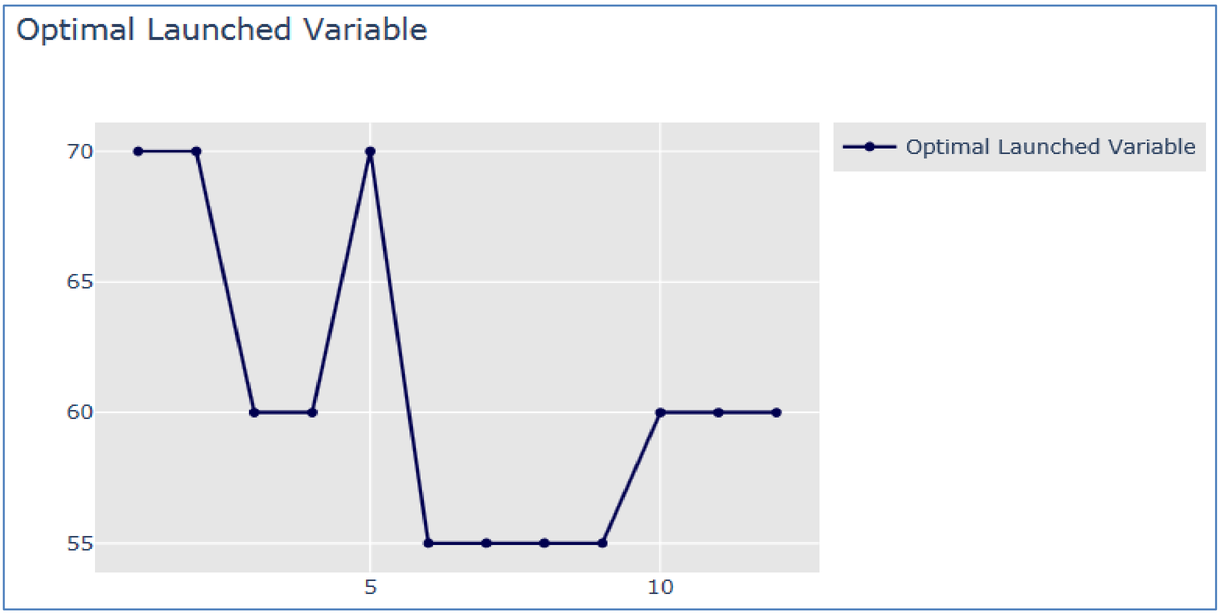

Fig. 10. Graph of optimal launched cost for a year

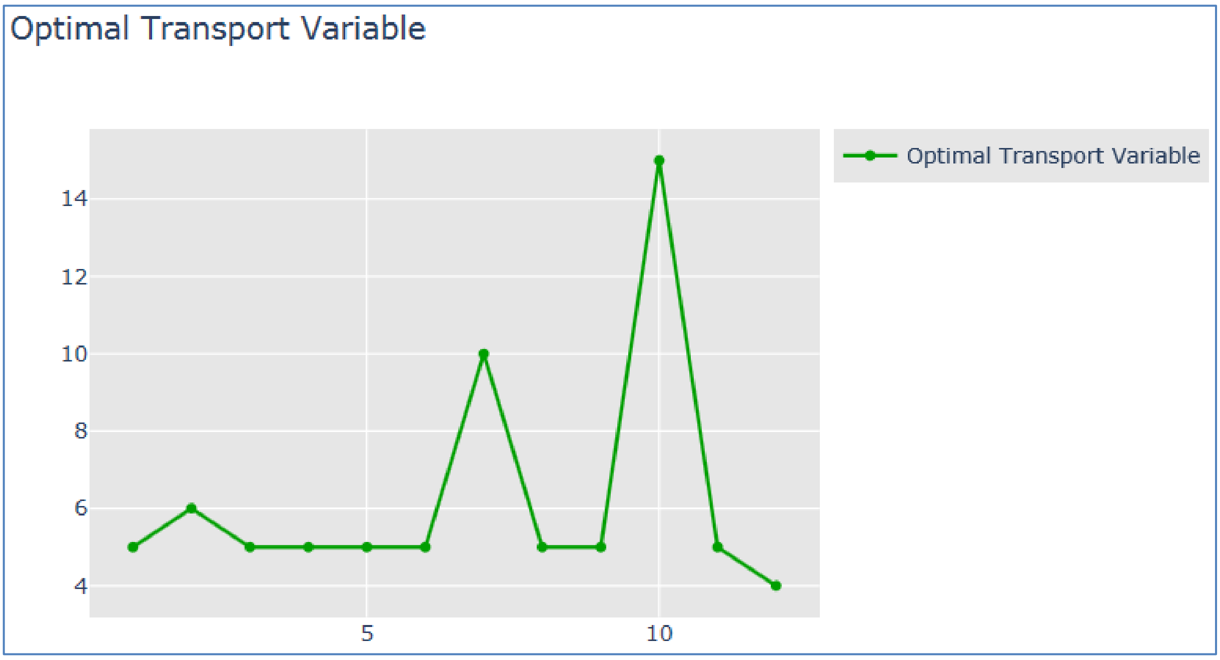

Fig. 11. Graph of optimal transport cost

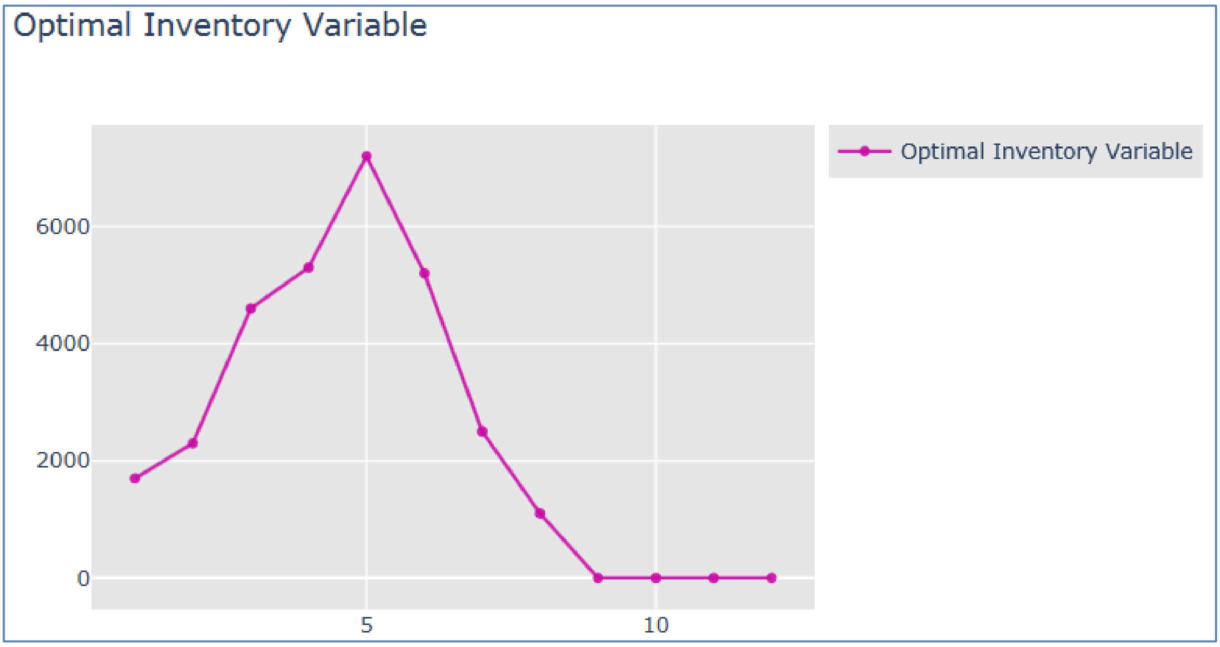

Fig. 12. Graph of optimal inventory cost

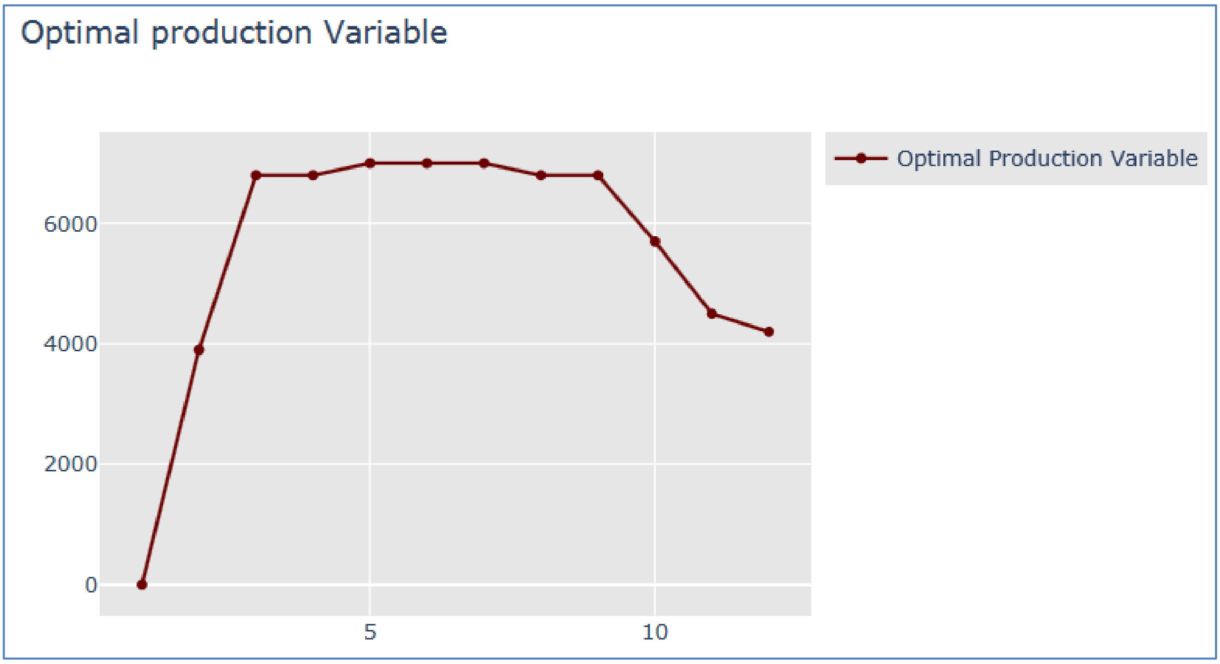

Fig. 13. Graph of optimal production cost

The illustrated results in the Graphs presented in the figures 12, 13, 14, and 15 show the optimal indicators for each month that can handle the variability characterized the demand, supply, and the process. Furthermore, those results permit to determine the optimal production planning for each month, with the minimum costs involved.

11. Conclusion

Tactical supply chain planning problems are complex and timely. The complexities and difficulties that characterize the algorithms used to solve the problems associated with this type of planning are a major challenge for researchers who try to take an objective look in their analyzes. In this article we have discussed a state of the art of work recorded in the field of planning. This approach allowed us to design a generic model that we translated as a mathematical model dependent on the character of uncertainty that characterizes the parameters of the model.

However, our next step will be dedicated to the determination of the optimization algorithm related to our problem, to go to the stage of resolution and simulation. Our next step will be another study with a simulation tool based on an object-oriented concept for fully graphical modeling lead to significant results.

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