# Automotive assembly industry's Supply chain in the delocalization context: A critical review And an algorithm approach for modeling at a tactical level

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## Abstract:

This article presents a methodology approach and a specific features that must be considered to design and formulate an optimization model for automotive industry's Supply chain in the delocalization context.

An extensive literature review of the important existing supply chain models in general and particularly in automotive industry is presented in this article.

The review objective is to see how the automotive supply chain design is approached with a mixed integer programming model. We focus on the identification of the relevant aspects included in the formulations and characteristics specific to the automotive sector study.

The models supply chain design discussed are then classified in a summary table according to aspects viewed to identify their lack of features and to verify how they support the delocalization problem.

Finally, we propound some guidelines, methodology approach to respect in supply chain modeling and identifying opportunities for further research.

## Keywords

Delocalization context, supply chain design, automotive sector study, Mixed integer programming.

## 1- Introduction:

Certainly the delocalization is a strategic decision currently being made by several MCNs (Multinationals) taking advantage of the globalization of markets, and it seen as the most effective way of reducing costs, in particular salary costs, and generating a comparative advantage to remain competitive in face of globalized competition.

Delocalization can be defined in the first instance as the transfer of the production units from developed country to low cost countries. In addition to reducing production costs, the delocalization decision is motivated by the measures taken by low-cost countries to motivate foreign investment by improving the attractiveness and the business environment by reducing costs and taxation, the creation of industrial free zones benefiting from export exemption rules.

Morocco is one of those low cost countries that have integrated measures into their industrial plan to improve the business environment and has become in the last decade a delocalization platform and the primary destination in the North African region for companies operating especially in automotive industry.

The arrival of the car manufacturer Renault had a catalyst effect that motivates the automotive suppliers delocalizing as the RENAULT ex-CEO Carlos Ghosn stated:" We are the ones who brought the suppliers and who restored the credibility of Morocco". We can distinguish here between two delocalization objectives: the first one consists of sourcing or manufacturing in low-cost countries and, the second consists of being close to emerging markets and / or consumption areas and to a potential industrial client. Morocco is considered a low-cost country, offering the best investment conditions for the automotive industry, namely reduced labor cost, tax exemptions and especially that car construction was already initiated by SOMACA Morocco Company. All that represents opportunities motivating Renaut Company to delocalize.

Nowhere existed strategies missing threats. Bruun and Mefford (1996) highlights that it has many examples of firms that have experienced great difficulties in establishing and operating manufacturing facilities in developing countries. Also, the industrial approach imposes that we only apply strategy insofar as they contribute to the development and sustainability of the company, and this, in the interest of its customers, shareholders and employees.

Indeed, delocalization induces some unpredictable problems and underestimated hidden costs, Hammami (2008) point out that some interviewed managers who have experienced delocalization gave some of such cost and injuries namely:

- Transportation, technology acquisition, and high stock levels were underestimated or not taken into account at the beginning.
- Decisions that are relevant when operating in developing countries such as the choice of adequate manufacturing technologies have not received the deserved attention.

We will only study in this work, the logistic aspects of delocalization. Indeed, our main objective is to identify special features of designing supply chains of automotive industry in the context of the delocalization of production activities in the North African area. whose countries are almost the same characteristics (Morocco, Tunisia, Algeria, and Egypt). The idea is to provide managers with a tool to keep the already relocated units competitive and to extend their strategy in emerging countries with sure steps. This proves the interest of this paper.

To achieve this objective, we will take as reference the work of Hammami (2008) that we consider to the best of our knowledge the one that identified all the characteristics of logistic chain in a delocalization context. This study proved that firms that delocalized without using optimization processes were surprised to realize that their gains were under initial estimations Therefore, the use of optimization approaches, which are generally based on mathematical models, is highly recommended in order to design supply chains Hammami (2008).

However, to properly assess the impact of the hidden cost on the productivity of an automotive constructor it is first necessary to aggregate all the costs from the raw material to the finished product delivered to the customer. To these expenses, it is necessary to add the possible problems of non-quality, the litigations, the ruptures (sales missed). Our local and regional teams know very well that to secure the future, we will have to be very exigent on our own performance, said Carlos Ghosn on the 11th edition of the World Policy Conference 2018.

In addition, the delocalization decision should not be taken on the basis of the parameters valid in a given period. For instance, the strong growth recorded by Asian countries whose labor cost is low, leads to a significant and constant increase in wages and the same goes for the other low cost countries of the North African region.

The remainder of this paper is organized as follows. In Section 2, based on (Hammami 2008) paper we determine the components that should be included in a supply chain design for automotive assembly industry. Section 3 is dedicated to a mathematic models classification. Indeed one choice the best works related to supply chain design in general and others specific to automotive industry in order to see how well existing models are adapted to our specific study (Automotive assembly in the delocalization context), and to set the parameters that must be included in our design approach. In Section 4, we propose a conceptual/Algorithmic approach that can help to construct an analytical supply chain design model of automotive industry in the context of delocalization. Finally, we give concluding remarks and future work directions.

## 2 -The characteristics of delocalization and required aspects in the automotive assembly case

### 2.1 Definition and motivation reasons of delocalization

In the main, the delocalization refers to change the facility location and create another in foreign country. One exists different definitions in the literature. These definitions do not distinguish between delocalization and other forms of international manufacturing like foreign direct investment (FDI) and outsourcing (Hammami (2008)), and not make clear the reason and motivation of delocalization.
The delocalization goals that motivate multinational's top management taking this strategic decision are reducing cost production and tax factors to increase the total revenue after tax, (or added value). Therefore, one accepts the following best definition proposed in Hammami (2008).

***"Delocalization is defined as the total or partial transfer, by a FDI, of a productive process whose production is initially destined to the same current markets with the objective of increasing the firm's added value***".

In reducing cost, the companies make an advantage comparative (Theory of David Ricardo) that remain them very competitive in the market. The delocalization is also induced by the creative destruction dynamism of the economy, introduced by Joseph Schumpeter, which precise that something new product kills another old, which explains the production transfer from industrialized countries to low cost countries.

### 2.2 Automotive delocalization strategies:

There are four distinct strategies of delocalization described in Hammami (2008): The centralized strategy, the decentralized purchasing strategy, the decentralized distribution strategy and the decentralized strategy. Delocalization manufacturing strategies differ essentially in the degree of autonomy given to delocalized units and in their missions. However, these units still largely depend on the company in all cases.

From our own professional experience in an automotive company installed in morocco and to our knowledge the decentralized strategy is adopted in automotive delocalize case. The delocalized units have relatively a big autonomy with respect to design, manufacturing, industrialization, and distribution while the supply chain integration refers to information sharing and decision-making processes within a company. However, Financial activities are still globally managed.

### 2.3 Automotive supply chain features in the delocalization context.

The Objective is to identify the important elements and relevant parameters that must be considered in modeling design for a supply chain's automotive industry in delocalization context, especially the three big parts: decision variables, costs factors and constraints (decision criteria).

One considers the last work made in this field and one base in Hammami (2008) paper to achieve our attempts. The characteristics of the delocalization problem are classified in five major aspects (Hammami2008):

1. Non-homogeneous location spaces.
2. International facility location.
3. High integration level.
4. Initial conditions impacts.
5. The product life cycle impact.

is limited to the tactical level, consequently we consider the three first aspects and we identify the features of automotive industry supply chain in the delocalization context with NORTH AFRICA area as a host country (Morocco case) according these three aspects.

#### 2.3.1 Non-homogeneous location spaces

As we are discussed above, the delocalization motivation is reducing cost production and the company's managers think for developing country as host facility to produce product that involving an important labor resource. It's clear they are a location spaces disparity between guest and host country in term of technology (technology issues), Industrial development (Supplier selection) and the cost and qualification of the labor(labor cost), so we have to think about these three parameters in supply chain modeling.

**Technology issues:** The car manufacturing company based in morocco like most outsourcing companies would like to take advantage of low labor costs in the host countries by implementing less automated and labor-intensive technologies. Then the selection technology is not significant since is known in advance, and the production process in the automotive industry is less automated more manual. Adopting a less automated technology as a strategic choice in advance does not mean neglecting the costs that it involve. Indeed, introducing and operating a new manufacturing technology in host developing countries induces labor qualification that includes a new training in the field for technical staff (Cost training), installation and after sales service (operation cost).

Mefford and Bruun (1998) states that delocalized plants are usually incapable of implementing a high-quality production system without foreign assistance. In result most MNCs implement such technologies at the first time in the origin plants. In our case study delocalized unit is not a new facility with a technology and manufacturing process never experienced in the origin countries, and the technology of automobile assembly is less automated.

As a host country morocco government like its similar in NORTH AFRICA area encourages foreign investment especially to create jobs and decrease the unemployment rate and boost the national industry and aims to provide more technology transfer, so the external constraints imposed by the authorities in host countries are neglected.

**Labor costs modeling:** As is mentioned above, the automotive delocalization movements are motivated by labor cost and tax reduction opportunities offered in Morocco and other factors like geostrategic position. This is the reason why it must appear in the optimization model. Labor costs are usually incorporated in a general production cost and Hammami (2008) highlights that this has a disadvantage of depriving decision makers of the possibility of evaluating several scenarios based on labor cost possible evolution and measuring their impacts on final decisions.

For the case of our study in the NORTH AFRICA area we must take into account judiciously the factor cost of labor and its evolution during the time. For instance in Morocco SMIG (Guaranteed minimum inter-professional salary) was 166 dollars in 1999 and 270 dollars in 2019, which means an evolution of more than 60% dirhams in 20 years, according to data from the central bank (Bank AL Maghreb).

Also according to the International Labor Organization, the minimum wage in Morocco is the highest in Africa. It is higher than that of some Arab countries such as Jordan, Algeria, Tunisia, or Egypt. It was even equal until 2016 to that of EU member countries like Bulgaria and Romania. Thus, the scenarios evaluating is necessary to estimate the impact on the final decision.

**Selection of low-cost suppliers:** The decision to relocate the automotive assembly in low cost country (Morocco) is not only motivated by the labor cost, but also by being close to suppliers to reduce the purchase cost, seeing that it constitutes a major part of the cost of production since the automobile manufacturing requires a huge number of assembly pieces, characterized by its diversity. Being close to suppliers also allows a shorter lead times and with lower transportation costs (Hammami (2008)).

However, these suppliers have in general neither the technological potential, nor the sufficient experience to supply MNCs with the required quantity and quality of products (e.g., Renault in Morocco). In the result the supplier's selection decision is hard to make and must be taken into account in modeling design.
The supplier of automotive industry must be classified in term of de type of the raw materials delivered (driving and safety parts requiring a higher level of quality and accessories parts) and their locations (local or outsider suppliers). Supplier integration fixed cost must be considered in addition to purchasing costs.
Finally, Hammami (2008) states that constraints related to supplier capacity and availability must not be neglected.

### 2.3.2 International facility location

The delocalization essentially means creation of facilities in different countries which involves new additional issues, like transportation and new legal rules.
In result, some factors induced by globalization should be noted. The essentially ones identified in the literature (Cohen et al (1989); Cohen and Lee (1989); Vidal and Goetschalckx (1997)) include transfer pricing, corporate income taxes, currency exchange rate, and constraints of local content rules and offset requirements (Hammami(2008)).
Automotive manufacturing units relocated to Morocco is attracted and motivated by the tax exemption applied by the government to acquire foreign investments (developing countries are considered tax havens).Since automotive assembly requires modules purchased from subsidiary manufacturers of the parent company with an agreed price called transfer price.
On the whole, the noteworthy international factors in automotive assembly that one could consider are transfer pricing and transportation issues.
**Transfer pricing:** When a subsidiary sells goods and services to a parent company, the cost of those goods paid by the parent company to the subsidiary is called the transfer price. The delocalized companies profit of the regulation's disparities between the origin countries and the host ones. Since the tax is relatively high in developed countries, the reduction in the transfer price implies the reduction of the taxes and consequently the profit after tax is decreasing while the same product is sold in developing country with a market price and tax rate reduced/or exempt. This is why more rigorous regulations are imposed in developed countries to avoid the arbitrary manipulation of transfer prices which deprives some countries of their proper tax revenues (Hammami (2008)), this is the case of the OECD requirements in terms of transfer price.
In the literature, one notes that the transfer price is considered in some papers as a decision variable (Benfssahi 2016) and as a cost factors in other ones (Vila and al 2006). As highlighted by Vidal and Goetschalckx(2001), the more restrictive the transfer price determination methods are, the lower is the interest of including transfer prices decision in supply chain design models.

**Transportation issues:** The delocalization essentially means creation of facilities in different countries and that involves increasing transportation issues (such time and costs of transport) more than others manufacturing strategies. As Hammami (2008) revealed in his article, given the inter-facilities transshipments of intermediate and final products are more intense in the case of delocalization, transportation and inventory in transit costs increase significantly (Hammami 2008). Hence, modification of supply chain design to adapt to a new situation and incorporating of such costs is unavoidable. Similarly in the case of the automotive industry in delocalization context, transport and inventory costs, delivery time or customer service constraints (impacted by transport time) are required for any supply chain modeling approach.

### 2.3.3 High integration level

**Intermediate products consideration**: The model must incorporate the decisions related to the flows of intermediate products and to the inter-facility transshipments in a multi-echelon supply chain configuration. As a consequence, bill of materials (BOMs) constraints should be considered. BOM constraints are fundamental when different parts, making a finished product, come from several countries in the world (Vidal and Goetschalckx,1997) and this is the case for the automotive industry

**Inventory policies interaction***:* Inventory decisions about at what stage of production and in what quantities inventory should be kept, as well as storage costs, should be considered into the model, especially in our industry case study.

## 3- Classification guidelines and Key components of supply chain models:

### 3.1- Key component of supply chain models:

### 3.1.1- General key components:

Identification of the key components of supply chain aims to frame the field of study and management which allows knowing on which parameters it is necessary to act for solving the problems related to the management of the supply chain. Min et al (2002) highlight that the components may differ from one company to another and presented a set of key components for supply chain in general as following:

a. **Supply chain decision variables:**

- ***Location*****:** This variable involves determining where plant warehouse must be located
- ***Allocation*** This variable determines which plant or warehouse should serve which customer and market
- **Network structuring:** determine which combination of supplier plants and warehouse should be utilized and involve the exact timing of expansion or elimination of facilities
- ***Number of facility and equipment*** determines which and how many plants warehouses are needed to meet the need of customers and determines also how many lift trucks are required for material handling.
- ***Number of stages:*** determine the number of stages that will comprise a supply chain
- ***Service sequence:*** it determines the delivery or pickup routes and schedules of vehicle serving customer or supplier
- ***Volume:*** determines the optimal purchasing volume production and shipping volume at each node of supply chain
- ***Inventory level:*** Determines the optimal amount of all type of inventory to be stored at each supply chain stage
- ***Size of workforce:*** Determines the number of truck drivers or order pickers needed for the system
- ***The extent of outsourcing:*** determines which and how many of supplier IT provider and the third-party providers should be used in long times

b. **Supply chain constraints**

Supply chain constraints are a condition that the decision of an optimization problem must satisfy. They represent also the limitations on the decision variables of a mathematic program. Min et al presented the most important of them:

- **Capacity** it includes *level of inventory, production, workforce, capital investment, outsourcing, IT adoption, Available space of inventory stocking and manufacturing*
- **Service compliance:** *Delivery time windows, manufacturing due date, maximum holding time for backorders, number of driving hours for truck drivers.*
- **The extent of demand.**

### 3.1.2- Key component of supply chain models in delocalization context:

As mentioned by Min et al the key components differs from company to another and in the same company which adopting different investment strategies. Thus, in delocalization context it is necessary to identify the specific components of supply chain included in the general components described above.

According to the characteristics of delocalization developed in chapter 1, the components such transfer pricing, Facility closing/Opening cost, Technologies selection, Exchange rate and BOM constraints must be considered. Hammami (2008) presented and classified the key components of supply chain delocalized under four axes as mentioned bellow:

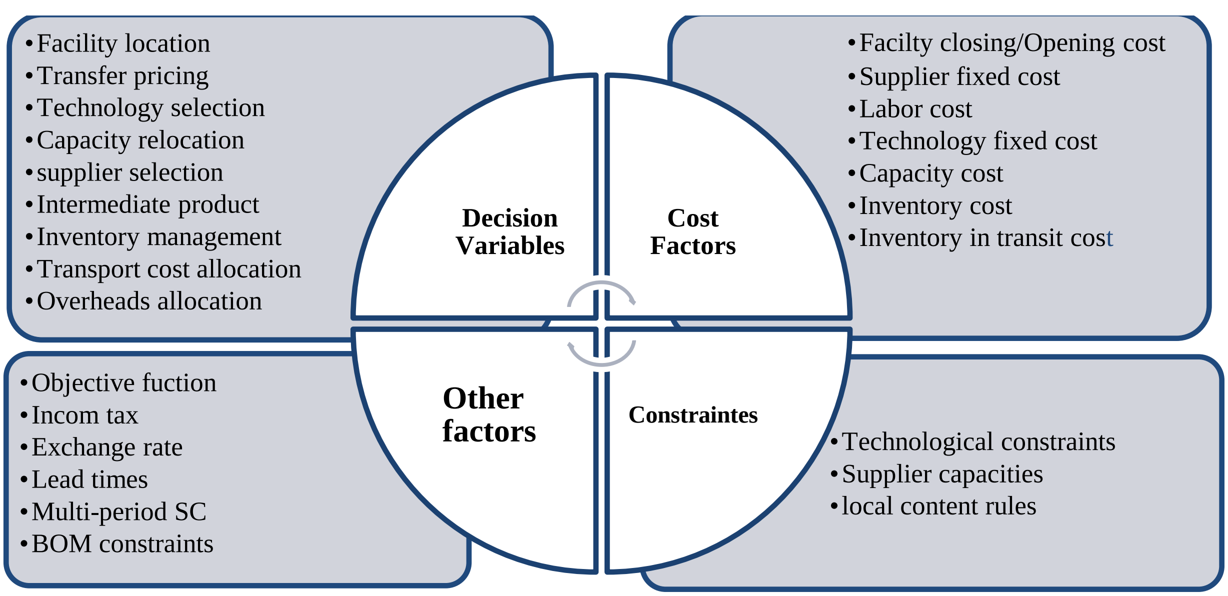


Figure 1: Key components of supply chain delocalized (Hammami 2008)

### 3.2- Guidelines of supply chain models:

Facing the several supply chain key components we will need to know how we can deal with it in supply chain modeling. Min et al (2002) point out that no model can capture all aspects of supply chain processes and a model builder defines the scope of the supply chain model in such a way that it is reflective of key dimensions yet not too complicated to solve. Chopra & Meindl (2001) and stephens (1989) proposed a guideline in which they classified all supply chain key components in three types based on three levels of decision hierarchy:

- **Competitive strategy:** *Strategic issues***:** Location/Allocation decision, demand planning, distribution channel planning, strategic alliance new product development outsourcing, supplier selection pricing
- **Tactical plans:** Inventory control, Production/Distribution coordination, Equipment selection, Layout design
- **Operational routines:** Vehicles routing scheduling, Workforce scheduling, Record keeping, Packaging

There are also various schemes to categorize supply chain model. Min el al (2002) classified supply chain model into four categories based on mathematical structure:

1. **Deterministic (non-probabilistic):** assume that all model parameters are known and fixed with certainty and are dichotomized as single and multiple objective models.
2. **Stochastic (Probabilistic):** take into account uncertain & random parameters and sub-classified into optimal control theoretic and dynamic programing models
3. **Hybrid:** include inventory-theoretic and simulation models that are capable of dealing with certainty and uncertainty involving model parameters.
4. **IT-driven:** it integrates and coordinates various phases of supply chain planning using application software to enhance visibility throughout supply chain: WM, ERP, GIS

In addition to the taxonomy proposed earlier Min el al (2002) also classified supply chain models according to their problems scope or application area. Such models deal with problems related to five functions of supply chain:

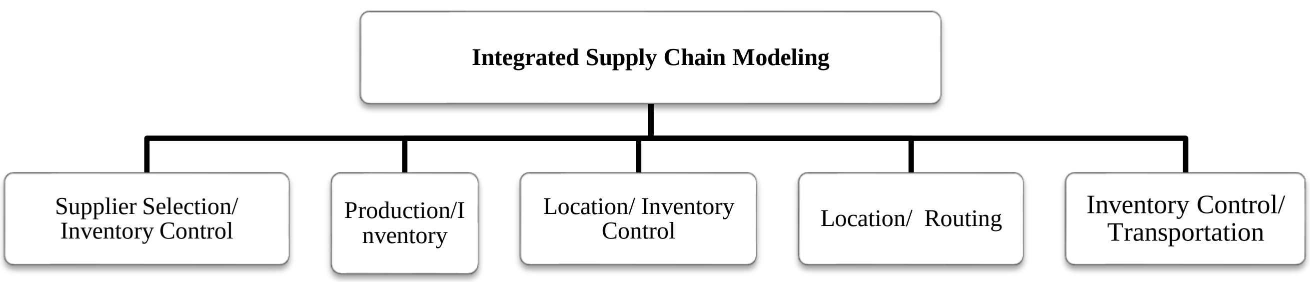


Figure3: Supply chain application area *(Adapted from Min el al (2002))*

## 4. Classification of existing models:

Our objective of the current literature review is not to seek a missing technical feature or gaps in supply chain model reviewed but rather to identify the methodologies to adopt and the steps to follow by a model-builder. Moreover, we verify how well existing models included the different keys components of supply chain in the delocalization context, especially we classified them according to the keys components refer to tactical level.

According to hammami(2008), the most adapted models to the delocalization problem are those of Arntzen et al. (1995){1}, Fandel and Stammen (2004{2}) and Vila et al. (2006){3}. Thus, we include them in our papers selection which includes also Cohen and lee{4} whose authors has published a multitude of papers on the subject. In addition, we study karbakal et al{5} which discussed automotive industry case, Hammami et al (2011){6}; Hammami et al (2013){7}and Benfssahi (2016){8} one of the last papers on the subject.

### {1} Artzen and al (1995):

Artzen and al (1995) present a Global Supply Chain Model (GSCM) as a large mixed-integer linear program for a specific sector that is a Digital Equipment Corporation. The minimizing objective function is a composite of “cost” and “time”, the cost factor includes: the variable and fixed cost of production, facility throughput costs, and taxes, inventory costs and net duty charges, while the time factor includes the production and in transit time. Both cost factors are respectively multiplied with $\alpha$ and $(1 - \alpha)$, while $\alpha$ is weight factor but is not defined. This objective function is under 17 constraints classified in four types such as: Production / Inventory /Shipping Constraints, System Configuration Constraints, Offset Trade and Local Content Constraints, Duty Drawback and Duty Relief Constraints. These duty constraints are exponential in the number of stages or generations of the global bill of materials.

GSCM minimizes cost or weighted cumulative production and distribution times or both subject to meeting estimated demand and restrictions on local content, offset trade, and joint capacity for multiple products, echelons, and time periods. In digital industry, the products component are manufactured by different facilities that why Artzen and al (1995) pointed out that the global bill of materials (GBOM) has been a valuable importance for expressing and implementing models of Multi-stage multi-location fabrication. A GBOM, help adding candidate suppliers by describing all intermediate products, and it must be tacked in to account in determining an inventory and fabrication capacity, consequently it's incorporated in GSCM constraints.

Artzen and al (1995) has use in her model 3 kinds of decision variables: 1) Production, inventory, and shipping variables; 2) System configuration variables; 3) Duty drawback and duty relief.

### {2} Vila et al (2006):

Vila and al (2006) proposes a mixed-integer programming model (MIP) to optimize the structure of the logistic network for lumber industry.
The MIP Objective function aims to Maximize the after-tax net revenues of the corporation in its reference currency.
According to Vila and al, in addition to facility location, other variables decision are included specifically layouts and capacity options to use during the planning horizon, the tactical decisions must be made on the quantity of products to manufacture, the seasonal stocks to accumulate and the internal flow of b products in the network. Therefore The MIP Objective function is established under 8 types of constraints namely: Supply market constraints, Seasonal capacity option usage constraints, Production activities flow equilibrium constraints, Storage activities inventory accounting constraints, Sales market constraints, Non-negativity constraints refer especially to binary variables of layout distribution center production distribution site options and capacity option options.

Vila et al (2006) accomplishes his model and determines all relevant parameters based in modeling in three steps: **Modeling the supply market; Modeling production-distribution facility layouts and capacity options** and **Modeling flows and inventories.**
The specific case study (lumber industry) implies that the supply conditions is a context dependent, then the supply contracts authority defining annual upper bounds on the supply of raw materials. Therefore, that conduct for inbound flows and sales market constraints.

Vila et al consider that the facility layout constraints must be included in the model to ensure that at most one layout is selected for each production-distribution. Since the activity is seasonal, the capacity selected can be shut down during some seasons, and the constraints are required to ensure that a capacity option can be used in a season only if it was in use.

Vila et al highlighted that any valid network optimization model must ensure the equilibrium between the flows of material entering an activity, its transformation or stocking in the activity and the flow of products exiting the activity. Moreover, the material flowing out of the production activity does not exceed the amounts produced; these require the modeling of flows in the network facilities and the consideration of conservation flow and inventory constraints.

The storage capacity is expressed in terms of a maximum throughput and not in terms of the storage space available. Vila defines the seasonal raw material relative to seasonal demand and insists that it should be kept with finished product inventories to help absorb supply and demand fluctuations. Indeed, the level of safety stocks and order cycle stocks generated by the network design must be taken into account. Also, for distribution centers, the storage capacity available depends on the installed storage technologies (storage capacity constraints). In result the mixed-integer program to solve includes 227 binary variables, 8234 continuous variables and 4206 constraints.

It remains to clarify that Vila defines the facilities total cost and revenue to describe the objective function. The expenses include especially the inflow transfer cost raw material cost, and inventory cost, on the other hand the revenue includes outflows to demand zone and to other sites.

### {3} Fandel et al

The efforts of Fandel et al focused on the so-called extended supply chain network, which is defined as the operational functions of development and recycling added to the processes of the traditional supply chain management of procurement, production, distribution and sales. Fandel et al developed a linear optimization model design that considers development and recycling costs, capacities and the process integration into an extended supply chain whose objective function is to maximize the sum, over the time periods, of the global after-tax profit in a standardized currency, and is subject to five kinds of constraint which include each one also a set of constraints : 1) development restrictions, 2) distribution restrictions, 3) retail and sales restrictions, 4) recycling restrictions, 5) bounds on decisions variables.
Even if Fandel et al has worked basically in extended functions of supply chain, namely development and recycling, their model design includes some relevant component keys of a global supply chain.

The model framework proposed consists in linkage the multi-period stochastic program and a single-period stochastic program sub-problem, in which the both material and cash flows are considered to generate a comprehensive analysis of the firm's global after-tax profit. However, no specific mathematical formulations and information about the size of the problems are given.


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### {4} Karabakal et al:

Karabakal et al aims to improve customer responsiveness and simultaneously reduce system costs in supply-chain analysis at Volkswagen of America by using an innovative combination of simulation and discrete optimization models of the flow of vehicles from plants to dealers. Both of customer service improvement and reduce system costs are functions of probabilistic (stochastic) and dynamic elements (Dynamic elements include the inventory-control policies at dealers and distribution centers and demand seasonality over the year. Stochastic elements include customer demand, customer choice, and transportation delays). Therefore, the objective function is to minimize the total combined costs of transportation and fixed-facility installation, and which is subject to the following constraints: Demand satisfaction; capacity facility limitations; Lead-times restriction; Maximum number limitation of distribution centers restriction.

Karabakal et al implemented the simulation model using the PROMODEL software [PROMO DEL Corporation 1995], and the MIP is coded using AMPL modeling language, and used CPLEX as its solver. However, the paper focused on outbound supply chain function in particular the distribution location and the transportation flow between plants to dealers.

### {5} Cohen and lee (1988):

The objective of this paper is to propose a model framework and an analytic procedure for evaluating the performance attributes of the production/distribution systems.
Cohen and lee (1988) developed a set of stochastic submodels including the optimization of material control operations, a serial production process, finished goods stockpile and a distribution process. These submodels are linked and related to each other using a set of variables under some assumptions were made in order to render the computations tractable and accessible. The authors treated each submodel independently, and thus the authors apply a heuristic procedure to obtain good operating policies by means of a mathematical program to minimize the sum of costs (production costs, goods stock-pile costs, expedited production costs...).

Additionally, the problems of facility location, capacity planning, and selection of technology are not considered in the submodels since they are assumed to be fixed.

### {6} Hammami el al (2011)

Hammami et al (2011) developed a mixed integer programming model for the supplier selection problem in an international context. The objective function of the proposed model is the minimization of the total cost which includes the pertinent costs that are incurred by the purchasing process in an international context. Namely: the purchasing cost, the transportation cost, the inventory cost, and the management cost.

The authors include, among the model constraints, the so-called minimum qualitative performance constraint. This constraint guarantees that each selected supplier must have a qualitative score that is larger than a minimum required level.
According to Hammami et al (2011), the qualitative score of supplier is a supplier performance indicator which depends on three factors: the initial score which is obtained by a multi-criteria approach such as the Analytical Hierarchical Process (AHP) (Satty 1980), the maximum score and the business volume allocated to this supplier. The qualitative score is also depending on the product and is a time-dependent in order to consider the possible improvement of supplier performance over the planning periods. However, the Analytical Hierarchical Process (AHP) is not clearly described and the different qualitative criteria that involve not presented. The authors consider in their model the relevant issues related to inventory and transportation such as: Transportation modes between suppliers' sites and buyers' sites characterized by a delivery frequency and a transportation capacity, the inventory levels that are incurred in the buyers' sites while including the constraints of inventory capacity. In particular, the safety stocks management in addition to the traditional decisions of supplier selection and order quantity allocation. Moreover, the model is developed as a multi-product, multi-buyer, and multi-period model. Hammami et al (2011 concludes experimentally that the higher the inventory capacity in buyers' sites is the lower the sensitivity of the purchased quantities to lead time uncertainty also the low-cost distant supplier should not be selected in some cases, especially when its delivery lead time is highly uncertain while the inventory capacity in buyer site is restricted.

Hammami et al (2011) highlight that the performing selected suppliers in an international context without considering transportation and inventory issues may then lead to inadequate decisions. The proposed model focuses mainly on the strategic decision of supplier selection in addition to the other tactical decisions. The authors have experimentally shown the relevance of including transportation and inventory management issues in the proposed model, and how supplier selection decisions in the international context are sensitive to such issues. As highlighted in Hammami et al (2011), other constraints can be added to the model such as order quantity, budget limitation, and number of selected suppliers and it would be interesting to work on an efficient heuristic approach that explores and uses the specific characteristics of the model.

### {7} Hammami(2013):

In this article presented a mixed integer programming model of multi-echelon supply chain including lead time and to analyze it impact on supply chain design decision and to prove the solvability of the model a computational study is conducted.
In this work the author adopted a modeling approach that gives a trade-off between: capturing the impacts of led time constraint on the supply chain decision and having a relatively low level of operational aspects since he focused on the strategic issues.

The objective function of this model consists of minimizing the total cost which including: The cost opening/operating facility, manufacturing cost, transportation cost and delivery cost of final product. Moreover, this objective function is subject, in particular, to supplier's capacity, Demand satisfaction and delivery lead time.
The author considered in the model the most relevant variables decision in delocalization context such as supplier's selection, the location of production facilities, the mission of each facility and the amount of inventories that must be held for every product.

### {8} Benfssahi(2018)

Through this article the author defined an analytical model of decision-making tool for delocalization taking into account the financial constraints. Besides, he evaluated the impact of financial policies and specially the transfer pricing policies on the amount of manufacturing capacity to relocate.
The transfer price defined as the value of goods and services exchanged between subsidiaries located abroad to maximize profits. Five methods approved by OECD classified in two types: Traditional methods based on transactions adapted to tangible goods and services and transactional methods based on profitability which includes Transactional Net Margin Method (TNMM) and Profit Split Method (PS) adequate for both tangible and intangible goods and services. Moreover, the model takes into account BEPS requirements including constraint of advanced price agreement (APA).
The objective function of the model is proposed to maximize to global profit after tax whose the expression is function to the transfer pricing. Thus, the objective function is evaluated and is subject to transfer pricing fixing methods constraints namely: constraint of using PS Method, constraint of using TMNM, constraint (APA).
A case study is conducted which proved in the result the impact of the method used for transfer pricing on: The decision of capacities transfer; the amount to be transferred; Profit of the company; the impacts of the OECD new constraints on the decision of delocalization.

Benfssahi (2018) focused on financials criteria impacts on total profit after tax especially the transfer pricing fixing methods, but it included some keys component characterizing the supply chain in delocalization context namely: intermediates products, management fixing cost, capacity relocation, exchange rate. Table 2 presents the results of study of selected papers and the important delocalization aspects and shows if they are considered by the selected papers.

Table 2: Delocalization aspects in the literature

| Delocalization aspects | {1} | {2} | {3} | {4} | {5} | {6} | {7} | {8} |
|---|---|---|---|---|---|---|---|---|
| **Objective function** | m | M | M | m | m | m | m | M |
| **Decision Variables** | | | | | | | | |
| Capacity relocation | | | | | X | | X | X |
| Supplier selection | | | X | | | X | X | |
| Intermediate product | X | X | X | | | | | X |
| Inventory management | X | X | X | X | X | | X | |
| Transport cost allocation | | | | X | X | | | |
| **Constraints** | | | | | | | | |
| Local content rules | | X | | | | | | |
| Supplier capacities | | | X | | | X | X | |
| customer demand satisfaction | | | X | X | X | | X | |
| BOM constraints | X | X | X | | | | | |
| **Cost factors** | | | | | | | | |
| Facility closing/Opening cost | X | | | | X | | X | |
| Supplier fixed cost | | | X | | | X | X | X |
| Labor cost | | | | | X | | X | |
| Technology fixed cost | X | | X | | | | | |
| Capacity cost | | X | | | X | | X | |
| Inventory cost& transport cost | X | X | X | X | X | X | X | X |
| **Financial factors & other aspects** | | | | | | | | |
| Lead times | | | X | X | X | | X | |
| Multi-period SC | X | | | | | X | | X |
| Exchange rate | | | X | | | | X | X |
| Income tax | | | X | | | | X | X |

{1}Artzen et al; {2}Vila el al; {3}Fandel et al; {4}Karabakal et al ; {5}Cohen and Lee ; {6}Hammami et al(2011) ; {7}Hammami et al(2013) ; {8}Benfssahi(2016).(m:minimizing; M:Maximizing).

## 5- Conceptual modeling approach:

In order to obtain a mathematical model for supply chain design at tactical level that is adapted to the delocalization context, a model builder should follow a specific steps or an appropriate modeling algorithm that allows including the relevant key components: decisions variables, constraints and cost factors that are useful for the supply chain modeling and not capturing all aspects to not complicate the model solving. Although, we propose here the following algorithm approach which provides modeling guidelines and recommendations that can be helpful for a model builder:

1- **Identifying the set of potential suppliers:** The location facility is a strategical decision and in delocalization context and particularly in automotive assembly industry is relative to low-cost suppliers proximity. It is necessary to identify the set of potential suppliers and distinguish between local and external ones in order to determines the relative costs and constraints.
2- **Study of final product & market:** The study of final product & market aims to identify the characteristics of customer demand and the potential markets in order to determine all parameters impacting customer satisfaction (Delivery lead time in particular).

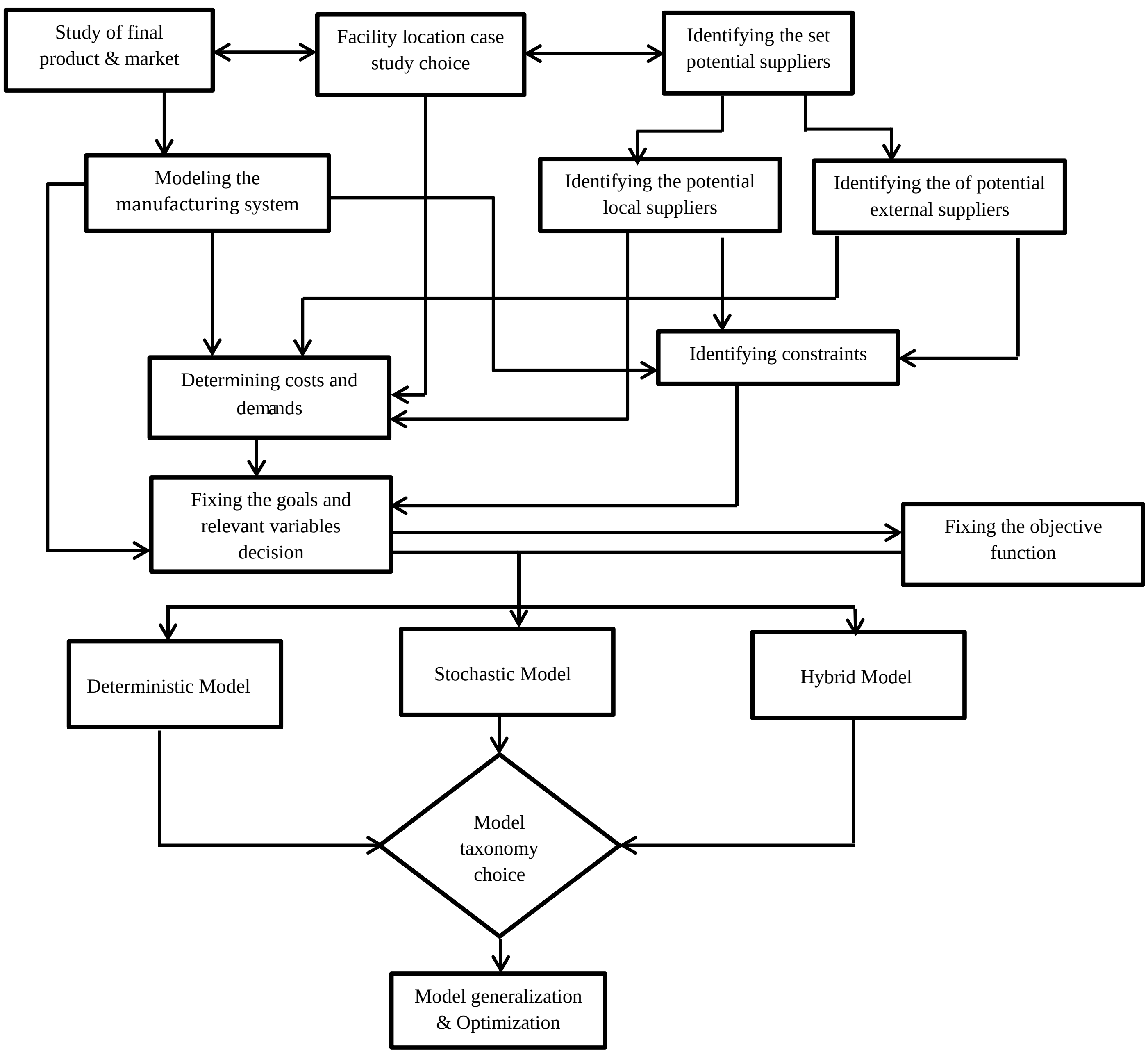


Figure 4: An algorithm approach for modeling supply chains at a tactical level in the delocalization context.

3- **Modeling the manufacturing system:** At a tactical level of the delocalization problem, a complete description of the manufacturing system (processes, technologies, products, etc.) must be considered. The components description of all intermediate and final products is necessary to define material requirements constraints (BOM constraints). Hence, technological decisions that are of major importance in the delocalization context can be appropriately made, also the inventory requirement and the safety stock that are must be held at each stage of supply chain can be planned.

4- **Fixing the goals and relevant decision variables:** Identifying all costs and constraints at different stages of supply chain of automotive assembly industry, with a complete description of the manufacturing system permits determining some shortcomings and fixing goals to reach, and the decision variables to consider in supply chain model.

5- **Fixing the objective function and Model taxonomy choice:** The optimization of supply chain design leads us to define the objective function under all constraints previously described, also we have to make decision about the taxonomy model that will be adopted and choose between deterministic stochastic and hybrid models.

## 6- Conclusion

In this paper, we are interested on the design of a car assembly industry supply chains in the delocalization context. Our objective was the proposition of a conceptual modeling approach at a tactical level and provides a model builder with guidelines.

According to the characteristics of the delocalization phenomena described in Hammami (2008), we identified those characteristics adapted to automotive assembly industry. In light of this preliminary step, we identified the most relevant keys dimensions that should be incorporated in an automotive assembly supply chain design model that is adapted to the delocalization problem at a tactical level. Most factors highlighted were: BOM constraints, transportation, inventory cost and labor costs evolution.

We selected the papers according three criteria: the last published in the subject, famous specialist author on supply chain, the most relevant paper identified in the literature review in particular in Hammami (2008), and classified them according to four dimensions (decisions, cost factors, constraints and other supply chain aspects), which regroup the delocalization features in tactical level. The results resumed in Table 3 which confirm that Hammami (2013) paper is the best one including the most relevant delocalization features, indeed it focused in their impact on the lead time. We can also take notice the inventory management allocation is not issues have not received an adequate attention as well as the labor cost evolution, Inventory cost, transport cost and BOM constraints.

Based on the literature review and on our own professional experience, we can assure that inventory allocation management cost and the transport cost are the success keys of delocalization that must have more focus in the future supply chain modeling design, particularly in delocalization context. Furthermore, the pandemic due to covid19 confirmed the importance position of transport and inventory management in supply chain especially that the china role in the global economy is increasing, and it was the first country impacted by the pandemic crisis. We then proposed an algorithm approach for modeling supply chains at a tactical level in the delocalization context that can help a model builder to construct an analytical model for designing the supply chain in the delocalization context.

Hence, there is a real need to provide new tools that can help decision makers to optimize and taking appropriate decisions about inventory management and transport while facing delocalization projects.

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