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A MODELLING FRAMEWORK FOR PROCUREMENT OF A RETAIL DISTRIBUTION SYSTEM WITH ECONOMIC AND ENVIRONMENTAL GOALS

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ABSTRACT: *Reducing procurement costs as well as controlling greenhouse gas (GHG) emissions is becoming a major concern for the retail industry. In order to support a retail company to optimize its procurement policy and coordination with its suppliers at the tactical planning level, we propose a multi-periodic, multi-product modeling framework for a three-level distribution system encompassing the suppliers, intermediate platforms and distribution centers. Different procurement and transport policies may be undertaken between the entities, such as direct shipment from the suppliers to the distribution centers or shipment through intermediate platforms. We have designed a generic MIP (Mixed Integer Programming) model with two objective functions to be considered (total shipment and storage cost, or CO2 emissions from transport). Solutions will be obtained using realistic data provided by a major French retail company.*

KEYWORDS: *Supply chain, Sustainable development, Transport network, Optimization, Retail industry.*

1 INTRODUCTION

Transport is an essential component of the management of physical flows in supply chains, interfering from the sourcing of raw materials to the product distribution and to end customers. It also plays a key role in the delivery of products or other materials for systems with open or closed loop. Improving the efficiency of transport is a major issue in the supply chain management.

However, for many years, the performance of supply chains and transportation networks has been studied only in economic terms, especially with the objectives of cost minimization or profit maximization in a given context. Taking into account the uncertainty and the quality of service have been introduced gradually.

Nowadays, distribution activities are increasingly facing the challenges of sustainable development. Global supply chains now span long distances and require significant use of fossil fuels to deliver goods to consumers (Venkat, 2003). Indeed, the transport sector is a major source of greenhouse gas (GHG) emissions. International studies highlight the need to find alternatives to reduce carbon footprint and other impacts from transportation systems. Impacts from freight transportation systems have increased; by 2050 global emissions from vehicle use might be 2.5 to 3 times as large as they were in 2000 (Transport Outlook, 2011). Furthermore, (Piecyk and McKinnon, 2010) studied three scenarios illustrating the trend of road freight carbon footprint. According to their study, the carbon footprint of road freight sector will increase to 30.0 million tones of CO_2 in 2020 (56% above the present level), if no action is implemented to limit the phenomenon.

Therefore, actions must be taken to reduce the environmental impacts of these systems. Most of the studies highlight the need to reduce environmental impacts from road transport and to move toward more environmentally friendly transport systems.

Some actions have been taken relatively for sustainable development for freight transport and for city logistics. Among solutions, there is the need to use alternative transportation modes by promoting multimodal transportation systems (Sawadogo and Anciaux, 2011) in order to reduce their environmental and societal impacts. Multimodality combined with a pooling system has been studied by (Pan *et al.*, 2010) in order to reduce distribution cost and CO_2 emissions. Other alternatives for reducing emissions from distribution systems are by alternative fuels, eco-driving …

In this paper we address the problem of the tactical planning of procurement and transport activities for the multiproduct distribution system of a retail supply chain with economic and environmental goals. In order to do so, we propose a generic modeling framework for a three-level system covering suppliers, intermediate platforms warehouses or distribution centers. We have designed a generic model for multi-periodic planning of transport and storage activities allowing different transport policies

and transportation modes. This model considers the total transport and logistics costs, and CO_2 emissions from transport in products distribution for a retail supply chain. It aims at investigating different distribution and transport policies on the basis of their economic and environmental impacts. We will also investigate the ecological impact of a given economic strategy. The ultimate goal is to provide to decision makers new distribution canals and new distribution policies with less environmental impacts while reducing the distribution cost.

The paper is organized as follow: section 2 contains a literature review about of sustainable development issues in distribution systems. Section 3 is devoted to describing our modeling approach and section 4 is about the perspectives for solving this model. Section 5 contains our conclusions and the expected extensions of our approach.

2 SUSTAINABLE DEVELOPMENT FOR TRANSPORTATION NETWORKS DESIGN AND OPTIMIZATION

Traditionally, studies about supply chain management have been focused on supply chain design and planning mainly based on the economic issues (cost, time, quality of service...). A literature review on these models has been proposed by (Mula *et al.*, 2010); they have presented a review of mathematical programming models for supply chains, considering both production and transport activities including supply chain structure, decision levels and modeling approaches. Regarding the transport planning, (Crainic and Laporte, 1997) identified the main problems related to freight transport planning as well as relevant operations research existing methods and models. More recent methodological advances in the transport planning area are presented in the book edited by (Barnhart and Laporte, 2007); the chapter presented by (Crainic and Kim, 2007) addresses the relevant methodological questions relative to the planning of transport operations at the national and regional levels, also addressing multimodal transportation planning.

It is well-known that economic productivity remains the major concern of companies. Nevertheless, environmental issues, particularly greenhouse gas emissions reduction and energy consumption reduction are increasingly at the heart of their policies. This is partly due to legislative obligations (Kyoto protocol 1997, European commission regulations…), and partly due to the brand image that companies want to put forward.

So, the current state and trend of environmental degradation implies a need for change in consumer and manufacturing practices. There must be a fundamental change in the management of operations and distribution systems. We are seeing a move towards sustainability pointing out the need for integrating the three constituent parts (social, economic and environment) of sustainable development into supply chain management.

Green supply chain is defined as the integration of environmental issues into the supply chain management, going from the sourcing to distribution of the product to customer, including reverse logistics. Some literature reviews about green supply chain management can be found in (Sarkis *et al.*, 2011), (Beamon, 1999), (Srivastava, 2007). The impacts identified in these studies are greenhouse gas emissions (CO_2, NO_x...), the wastes, the noise emitted, and the degradation of ozone layer among others.

Sustainable Supply Chain incorporates the principle of green supply chain (Seuring and Müller, 2008) by integrating social and economic components of sustainable development. In the literature, many studies are presented about supply chains performance analysis and optimization considering the sustainable development constituent parts. Most of these studies focus on reducing the carbon footprint of distribution systems.

Up to now, social issues of distribution systems have been studied through corporate social responsibility (CSR) by implementing logistic social responsibility (LSR). (Ciliberti *et al.*, 2008) presented a taxonomy of LSR practices underlying five areas, namely purchasing, social responsibility, sustainable transportation, sustainable packaging, sustainable warehousing, and reverse logistics.

In their recent paper, (Chardine-Baumann and Botta-Genoulaz, 2011) proposed a framework for sustainable performance assessment in a supply chain. They proposed three models; the first one analyses the sustainable performance of a supply chain considering economic, social and environment criteria. The second model point out the relationships between some supply chain management practices and a supply chain performance matrix. The third one is an analytical assessment model based on the Supply Chain Sustainable Performance (SCSP) matrix, which permits to determine the sustainable performance profile of a supply chain.

Some models for computing the environmental and social impacts of transportation systems can be found in (Janic, 2007). (Bektaş and Laporte, 2011) clearly show the possible diverging interests between minimizing the cost (particularly drivers cost), traveled distance and CO_2 emissions. They use an objective function that incorporates in particular the fuel costs, and the CO_2 emissions cost. But according to (Kohn and Brodin, 2007), there are many cases where even the operational or tactical decisions are inconsistent with the strategic objectives; they demonstrate that it is possible to improve simultaneously costs, service and environmental impact.

Regarding the reduction of carbon footprint in distribution systems, there are two main trends in the literature.

The first one considers the optimization and reduction of the environmental costs; for example, (Forkenbrock, 1999) proposed an evaluation model for computing internal and external costs of intermodal transport on one side and road transport on the other side, considering factors such as demand, capacity and vehicles filling rate as well as frequencies and apply it to a European transport case. His modeling concerns accidents cost, GHG emissions cost, and cost due to noise and public works (such as road building or maintenance).

The second trend aims at computing the real amount of CO_2 emitted at each phase of the distribution process. To this end, many studies have been conducted to compute emissions factors for transportation systems according to the transportation mode used; see for example Artemis (Joumard *et al*, 2007), or INFRAS-HBEFA (Rexeis *et al*., 2009). According to these studies, the total emissions depend on the emission factor and the activity data as follows:

Emissions = "activity data" x "emission factor"

Activity data means the amount of energy burned. The emission factor is the amount of CO_2 generated by each activity data, for example, tons of CO_2 per tons of good transported.

(DEFRA, 2005) proposes conversion tables between the quantity of fuel used and the quantity of emissions of CO_2. Several units are used in order to measure the GHG or CO_2 emissions: Carbon equivalent, CO_2 equivalent of GHG or CO_2 emissions only. Some European projects have been devoted to the estimation and modeling of GHG emissions from transport: MEET (Hickmann *et al*., 1999), COST (Joumard *et al*., 1999) and (INFRAS, 2008).

There are some commercial softwares calculating the CO2 emissions of a distribution network based on these emission factors, but these evaluations are often made a priori or a posteriori, knowing all characteristics and flows of supply chain and transport system. On the contrary, our approach aims at optimizing the supply chain and transport systems characteristics and the vehicles and goods flows in order to reduce costs and CO2 emissions in a decision making process.

In the retail industry, the global emissions from transportation must encounter the emissions along the whole distribution process (from the supplier to the stores). In recent years, retailers have been implementing techniques for reducing environmental impacts at each level of their activity. These techniques involve pooling where different suppliers share the same distribution center; see for example (Pan *et al.*, 2010). Other actions have been taken to optimize the loading factor of each transportation mode used, by using different loading units, and conveying different products in the same load unit; this contributes for example to reducing the number of trucks used. Some retailers implemented actions as using inland waterways for their transportation, using transportation modes with lower noise level or implementing green purchasing.

In conclusions of this state of art one can observe that a significant amount of work has already been devoted to green supply chain management in two directions: evaluation of the economic and environmental impacts of activities, or the development of optimization models for decision making. In the distribution and retail sector, noticeable work with the optimization approach has been devoted to the consideration of cooperation among suppliers through pooling of resources in order to achieve a better productivity and reduce the environmental impacts of transport.

In our work, we develop a different approach focused on the redefinition of the procurement supply chain of a given distributor. We will focus on the environmental impacts abatement of the distribution system including transportation and the related procurement operations (cross-docking, storage). We will consider only the emissions of CO_2 and the overall cost. The major challenge in this study is to strike a balance between environmental performance and maintenance of acceptable delivery, responsiveness, quality and costs.

3 PROBLEM DESCRIPTION AND FORMULATION

In our modeling framework, we consider the distribution of products in a retail supply chain. The studied network consists of four possible entities (figure 1):

- The supplier facility or warehouse
- The retailer platform
- The distribution center
- The stores

In this network, a set of platforms receive products from suppliers and then, the products are transported from platforms to each distribution center according to a minimum known demand from the stores. In this paper, we will consider the products flows from suppliers to the platforms, and the distribution centers. The optimization of distribution of products from the distribution centers to the retail stores is out of the scope of our work.

We assume that the shipment of products from the suppliers' warehouses to the platforms allows less than truck load transportation, while full truck load transportation between the platforms and distribution centers is imposed as a general policy in order to increase efficiency. Multimodal transportation is allowed for the transportation from platforms to distribution centers, which can be done either by road or by train.

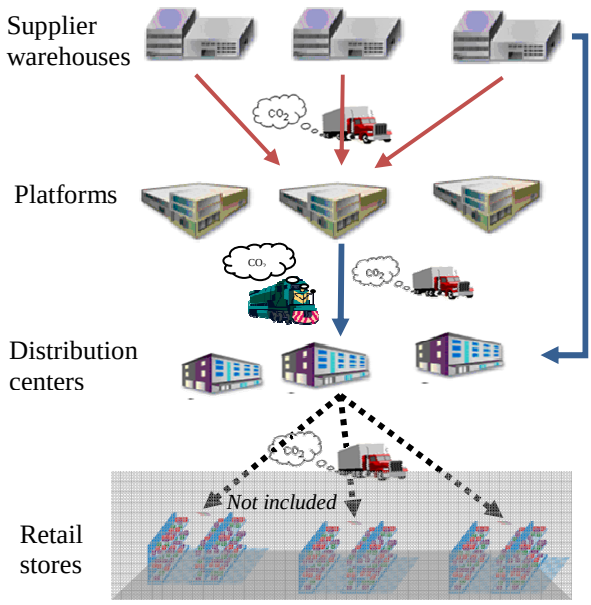

Figure 1: Generic supply chain for retail activity

Our modeling approach will allow the testing of different alternative scenarios.

3.1 Hypothesis

Figure 2 represents the generic distribution network underlying our modeling approach as described above.

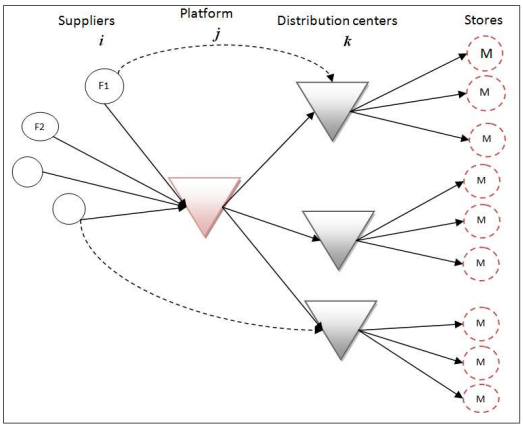

Figure 2: Generic distribution network

- We consider the tactical planning of procurements and transport activities over a number T of time periods t (typically T covers several weekly time periods).
- Several suppliers may offer the same product
- A given supplier may provides several products
- Products are shipped onto pallets
- Depending on the transportation links, two transportation modes may be considered: road and rail. Road transportation may use LTL (Less than Truck Load) or FTL (Full Truck Load) vehicles, while rail transportation is restricted to a minimum load.
- Transportation costs will distinguish costs applied to full load means of transport and costs applied to pallets shipped by LTL mode.
- Retail stores are allocated to a specific distribution center.

Due to the last hypothesis, the aggregated demand from the stores constitutes the demand of the corresponding distribution center. So, the minimum demand of product p from the distribution center k at the period t is δ_k^{pt}.

3.2 Notations

Sets:

J Set of platforms

J_k Set of platforms delivering the distribution center k

J_i Set of platforms delivered by supplier i

I Set of suppliers

I_j Set of suppliers allocated to platform j;

$$I = \bigcup_j I_j$$

P Set of products

P_i Set of products delivered by supplier i

K Set of distribution centers

T Set of time periods

V Set of transportation mode (truck/train)

$V1$ Set of less than truck load (LTL) transportation modes

$V2$ Set of full truck load (FTL) transportation modes

$V3$ Set of rail transportation mode

$V1_i$ Set of $V1$ transportation modes used from any entity i

$V2_i$ Set of $V2$ transportation modes used from any entity i

$V3_i$ Set of $V3$ transportation modes used from any entity i

V_i Type transportation modes used from any entity i

Parameters

ct^v Transportation cost for a pallet by the mean of transport v

c_f^v Transportation cost for a full load means of transport v

$cdoc_j$ Cross-docking cost for a pallet at platform j

cm_k Handling cost for a pallet of product p at distribution center k

ch_k^p Holding cost for a pallet of product p at distribution center k

d_{ij} Travel distance between two entities i and j

Cap_v Capacity in pallets of means of transport v

$CapS_k$ Storage capacity in pallets in the distribution center k

$CapC_j$ Cross-docking capacity in pallets in the platform j

Cap_i^p Capacity of supplier i for product p

Cap_{min}^v Minimal allowed shipment by transportation mean v

$S0_k^p$ Initial inventory of product p in the distribution center k at period $t = 0$

ST_k^p Ending inventory of product p in the distribution center k at period $t = T$

δ_k^{pt} Aggregated demand for product p of all the stores allocated to distribution center k at period t

Variables

S_k^{pt} Inventory of product p at the end of period t in the distribution center k

X_{ij}^{vpt} The number of pallets of product p transported from i to j using the means of transport v at period t

V_{ij}^{vt} The number of full load means of transport v used between the entities i and j at the period t

R_{ij}^{vpt} The number of residual pallets in the less than truck load means of transport v

Y_{ij}^t Binary variable equal to 1 if there is a less than load truck between i and j, 0 otherwise

3.3 Emissions factor calculation

The emissions factor aims to compute the amount of CO_2 emitted by any transportation mode. The factor that we used depends on the number of pallets transported, the traveled distance and the truck loading factor.

This emissions factor retained is based on the MEET report (Hickman *et al*, 1999) and (Pan *et al*., 2011) with the following hypothesis: for road transportation, the vehicles are Heavy Duty Vehicles of 38 t, the average speed is 80 km/h, a road gradient of 0% is considered; the capacity of the trucks varies from 20 to 50 pallets depending on the product transported. We obtain the following formula:

$$E_{g/km}(\alpha) = 772 + 324\,\alpha \qquad (1)$$

where α is the loading factor with $\alpha = \in [0,1]$.
Depending on the loading factor, we can compute two emission factors: one for the full load trucks E_{full}^v and one for empty trucks E_{empty}^v. So, given these assumptions for road transportation:

$E_{full}^v = 1{,}096$ kg/km

$E_{empty}^v = 0{,}772$ kg/km

Considering these emissions factors, the travel distance and the truck load in terms of number of pallets, the amount of CO_2 emitted is calculated by:

$$\varepsilon(d,c,x) = d.\left(\frac{E_{full} - E_{empty}}{c}\right).x + E_{empty}\left\lceil \frac{x}{c} \right\rceil$$

With d=distance, c=transport capacity in pallets, x=number of pallets transported.

For rail transportation, the train considered here is an electric "short train"; the gross weight of short trains has been estimated to be around 500 - 600t, the average speed considered is 100km/h and the total capacity in pallets is 36 in each railcar with 13 railcars per train. Given these hypothesis, the emission factor for rail transport is:

$$E_{g/km}(x) = 0.498 + 0.0014\,x \qquad (2)$$

where x is the number of pallets transported.

The emissions factors retained are:
$E_{empty}^v = 0{,}498$ kg/km

$E_{full}^v = 1{,}16$ kg/km, considering a train with 13 railcars.

3.4 Model formulation

Two objective functions have been implemented into the generic model.

Objective 1: Cost minimization
The first objective is to minimize the total transportation cost for the overall network. This cost function takes into account the overall cost of the network; it involves the transportation cost between any suppliers and the platforms, the cross-docking cost in the platforms, the transportation cost between the platforms and the distribution centers.
The generic cost function has five components and is given by F1:

$$F1 = \sum_{t \in T} (CT1 + CT2 + CT3 + CP + CD) \qquad (3)$$

Where:

- $CT1$ is the transportation cost between suppliers and platforms:

$$CT1 = \sum_{j \in J} \sum_{i \in I_j} \sum_{v \in V_i} \sum_{p \in P_i} d_{ij}\left(ct^v R_{ij}^{vpt} + c_f^v V_{ij}^{vt}\right) \qquad (4)$$

- $CT2$ is the transportation cost between platforms and distribution centers:

$$CT2 = \sum_{j \in J} \sum_{k \in K} \sum_{v \in V_j} \sum_{p \in P} d_{jk}\, c_f^v V_{jk}^{vt} \qquad (5)$$

- $CT3$ is the transportation cost between suppliers and distribution centers:

$$CT3 = \sum_{k\in K}\sum_{i\in I}\sum_{v\in V_i}\sum_{p\in P_i} d_{ik}\left(ct^v R_{ik}^{vpt} + c_f^v V_{ik}^{vt}\right) \quad (6)$$

- CP is the cross-docking cost at platforms

$$CP = \sum_{j\in J}\sum_{i\in I_j}\sum_{v\in V_i}\sum_{p\in P_i} cdoc_j X_{ij}^{vpt} \quad (7)$$

- CD is the operations costs at distribution centers

$$CD = \sum_{k\in K}\sum_{i\in I\cup J_k}\sum_{v\in V_i}\sum_{p\in P} X_{ik}^{vpt} cm_k + \sum_{k\in K}\sum_{p\in P} ch_k^p S_k^{pt} \quad (8)$$

The operations costs here represent the products handling cost including all the flow of products entering the distribution centers and the holding cost.

Objective 2: CO_2 minimization

Objective function F2 computes the amount of CO_2 emitted for the transportation between suppliers and platforms or distribution centers, and from platforms to distribution centers, using the expressions developed in section 3.3.

$$F2 = \sum_{t\in T}(EC1 + EC2 + EC3) \quad (9)$$

Where,

- $EC1$ is the amount of CO_2 due to transportation between suppliers and platforms:

$$EC1 = \sum_{j\in J}\sum_{i\in I_j}\sum_{v\in V_i}\left(d_{ij}\left[X_{ij}^{vpt}\left(\frac{E_{full}^v - E_{empty}^v}{Cap_v}\right) + E_{empty}^v\left(V_{ij}^{vt} + Y_{ij}^t\right)\right]\right) \quad (10)$$

- $EC2$ is the amount of CO_2 due to transportation between platforms and distribution centers:

$$EC2 = \sum_{j\in J}\sum_{k\in J_k}\sum_{v\in V_j} d_{jk} X_{ik}^{vpt} E_{full}^v \quad (11)$$

- $EC3$ is the amount of CO_2 due to transportation between suppliers and distribution centers:

$$EC3 = \sum_{i\in I}\sum_{k\in K}\sum_{v\in V_i}\left(d_{ik}\left[X_{ik}^{vpt}\left(\frac{E_{full}^v - E_{empty}^v}{Cap_v}\right) + E_{empty}^v\left(V_{ik}^{vt} + Y_{ij}^t\right)\right]\right) \quad (12)$$

Constraints

$$S_k^{pt-1} + \sum_{i\in I\cup J_k}\sum_{v\in V_i} X_{ik}^{vpt} \geq \delta_k^{pt} \quad \forall\, k,p,t \quad (13)$$

$$\sum_{i\in I}\sum_{v\in V_i} X_{ij}^{vpt} = \sum_{k\in K}\sum_{v\in V_j} X_{jk}^{vpt} \quad \forall\, j,p,t \quad (14)$$

$$\sum_{j\in J_i\cup K}\sum_{v\in V_i} X_{ij}^{vpt} \leq Cap_i^{pt} \quad \forall\, i,p,t \quad (15)$$

$$\sum_{i\in I_j}\sum_{p\in P}\sum_{v\in V_j} X_{ij}^{vpt} \leq CapC_j^t \quad \forall\, j,t \quad (16)$$

$$\sum_{p\in P} S_k^{pt} \leq CapS_k^t \quad \forall\, k,t \quad (17)$$

$$S_k^{p0} = S0_k^p \quad \forall k,p \quad (18)$$

$$S_k^{pT} = ST_k^p \quad \forall k,p \quad (19)$$

$$S_k^{pt-1} + \sum_{i\in I\cup J_k}\sum_{v\in V_i} X_{ik}^{vpt} - \delta_k^{pt} = S_k^{pt} \quad \forall k,p,t \quad (20)$$

$$\sum_{p\in P} X_{ij}^{vpt} = Cap_v V_{ij}^{vt} + R_{ij}^{vt} \quad \forall i\in I, j\in J_i\cup K, t, v\in V1_i \quad (21)$$

$$\sum_{p\in P} X_{ij}^{vpt} = Cap_v V_{ij}^{vt} \quad \forall i\in I, j\in J_i\cup K, t, v\in V2_i \quad (22)$$

$$\sum_{p\in P} X_{jk}^{vpt} = Cap_v V_{jk}^{vt} \quad \forall k,t,j\in J_k, v\in V2_j \quad (23)$$

$$\sum_{p\in P} X_{jk}^{vpt} = Cap_v V_{jk}^{vt} + R_{jk}^{vt} \quad \forall k,t,j\in J_k, v\in V3_j \quad (24)$$

$$R_{ij}^{vt} < Cap_v \quad \forall i,j,t,v\in V_i \quad (25)$$

$$R_{jk}^{vt} \leq Cap_v V_{jk}^{vt} \quad \forall v\in V3, j,k,t \quad (26)$$

Constraint (13) is the retail stores demand satisfaction constraint which includes the quantity of products supplied to each distribution center k and the total inventory at distribution center k. Constraint (14) is the flow conservation constraint at each platform. Constraints (15), (16) and (17) are the capacity constraints at respectively the supplier warehouse, the platform and the distribution center. Constraint (18) and (19) are resp. the inventory at period 0 and the inventory at the last period in distribution center k for each product p. Constraint (20) is the inventory equilibrium constraint at distribution center k. Constraints (21) and (24) are the transportation mode capacity constraints when moving from the supplier plant to the platform and respectively when moving from platform to distribution center. Constraints (22) and (23) are about the full truck or the train capacity constraints when moving from the platform and the distribution centers, where the number of non-fill loads is equal to zero. Constraint (25) insures that the number of residual

pallets is less than the means of transport v capacity. Constraint (26) insures the avoidance of non-filled trains.

3.5 Distribution scenarios analysis

The generic model presented above can be solved according to different scenarios corresponding to possible logistic policies that a retail company may want to evaluate considering their costs and CO2 emissions impacts. We propose to study three complementary scenarios.

Scenario 1:
In this scenario, suppliers may either deliver their products to platforms or directly to the distribution centers.
This scenario corresponds to solving the full generic model (figure 2).

Scenario 2:
All the suppliers will ship their products directly to the distribution centers. Cross-docking platforms are not considered for shipment consolidation to the distribution centers (figure 3). Furthermore, the rail mode is no more considered.

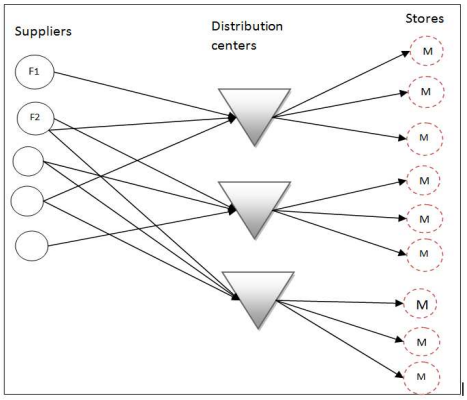

Figure 3: Distribution network for scenario 2

The overall cost associated to this network corresponds to the transportation cost from the suppliers to the distribution centers and the storage cost at the distribution centers.

The cost function (1) becomes:

$$F1 = \sum_{t \in T} (CT3 + CD) \tag{27}$$

The CO2 emissions are only relative to the transportation between the suppliers and the distribution centers. The emission function (8) becomes:

$$F2 = \sum_{t \in T} EC3 \tag{28}$$

Where $CT3$ and CD are defined as in 3.3 equations (4) and (6). $EC3$ is defined as in 3.4, equation (11). For this scenario, the objective functions are subjected to constraints (13), (17), (18), (19), (20), (21) and (25).

Scenario 3:
All suppliers deliver their products through platforms. This scenario allows the consolidation of all the products from the suppliers into the platforms (figure 4). The resulting increased fret to be transported between the platforms and the distribution centers benefits of the FTL advantages and railroad transport may be considered.

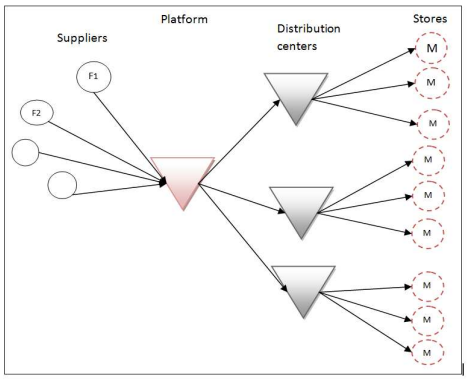

Figure 4: Distribution network for scenario 3

For this scenario, the total cost includes the transportation cost from supplier's plants to the platforms, the cross-docking cost associated to the platforms, the transportation cost from the platforms to distribution centers and the total operations costs at each distribution center.

The cost function (1) becomes:

$$F1 = \sum_{t \in T} (CT1 + CT2 + CP + CD) \tag{29}$$

The amount of CO_2 emitted (8) becomes therefore:

$$F2 = \sum_{t \in T} EC1 + EC2 \tag{30}$$

Where $CT1$, $CT2$, CP and CD are defined as in 3.3. $EC1$ and $EC2$ are defined as in 3.4. The objective functions are subjected to constraints (14), (15), (16), (21), (22), (23), (24), (25) and (26).

4 PROSPECTS FOR NUMER ICAL EXPERIMENTATIONS AND SOLVING

Having two objective functions leads us to implement techniques that can encompass both these objectives. This model is currently being implemented on the case of a major French retail company.

We are implementing several solving options. We can distinguish two strategies: an economic strategy and an environmental strategy.

For the economic strategy, the first option is to optimize the cost function and then evaluate the amount of CO_2 emissions resulting from the obtained solution. Then the amount of CO_2 obtained will be used to define constraints limiting the CO2 emissions and the cost the cost is therefore optimized again.

For the environmental strategy, the first step will to optimize the environmental function F2 and to evaluate the economic result of an environmental strategy. The procurement cost corresponding to the obtained solution will used as a constraint in a second step where CO_2 emissions will be optimized under cost constraints.

Another possibility is to use multiobjective optimization techniques and find a trade-off between the two objectives. A Pareto front will be then determined to analyze the compromise.

For solving the model according to the different scenarios, we will either use a commercial MILP solver or develop a specific heuristics. Depending on the problem size and its complexity, we may have to apply some relaxations or include some valid inequalities.

This model will be implemented on a case study based on a retail network in France, using data and supply chain network from a major French retail company.

We are currently implementing the model using the CPLEX solver. Depending on their complexity and problem sizes, the various scenarios exposed in section 3 will be solved either by CPLEX or will call for the development of specific heuristics.

5 CONCLUSION AND CURRENT WORK

In this paper we have proposed a modeling framework for the determination of best procurement strategies in the retail distribution sector. To that purpose we have developed a generic optimization model taking into account economic as well as environmental goals. Three different scenarios corresponding to possible procurement policies have been proposed. Solving the model aims at determining the best procurement strategy depending on their impact in terms of cost and CO2 emissions.

Several directions may be determined for future works.
The current model does not consider any requirement in terms of delivery frequencies from the suppliers, which favors the utilization of full load trucks. Including frequency requirements into the model will be more realistic. The model could be extended in order to allow the utilization of central warehouses as an alternative to the cross-docking platforms. In the economic function (F1) the LTL constant unitary cost for shipping pallets could be replaced by a more realistic term taking into account the size of the shipments. We also intend to include the emissions due to operations of the platforms and the distribution centers, in order for the emissions function (F2) to be more comprehensive. Finally, we could extend the network to include the retail stores. Delivery of products to the stores could be done directly from the corresponding distribution centers or using vehicle routing. In this case, we would consider developing vehicle routing models with backhauls. Backhauling would allow the collection of products from some nearby suppliers to avoid empty returns.
Preliminary results will be presented at the conference.

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