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A Proposed Budgeting Planning Model for Bimodal Transportation in a Phosphate Supply Chain

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Abstract*: *To better understand supply chain behavior and to evaluate its performance, it is necessary to start a modeling process. For this purpose, various tools and approaches are used. Among these tools, the analytical models can be used. With this background, the purpose of this study is proposition of a generic model for the transportation budgeting planning problems in multi-sites, multi-products, multi-depots and multi-periods context. The main contribution of this paper is to develop an integrated budgeting planning model (Mixed Integer Programming) applied in a phosphate supply chain. The purpose of the developed model is to define the optimum transportation budget of products routed in the various entities of the studied supply chain, considering various constraints (Capacity of facilities, availability of product and transportation vehicles, customers demand…) in order to plan and define the optimum products quantities and the optimize the costs to feed stocks and satisfy customers.

Keywords: bimodal transport, modelling, planning model, platform logistics, supply chain.

I. INTRODUCTION

In an increasingly competitive environment, companies must satisfy customer demands, maintain and improve concurrently their profitability using Supply Chain Management.

Today, understanding supply chains is a key resource that can contribute significantly to solve this delicate equation. To achieve this understanding, it must proceed by modelling the supply chain [1].

Since its inception in the early 1990s [2-4] the search work on supply chain analysis, modeling and optimization has multiplied [5-7]. Then the modeling of supply chains activities considering physical, informational and financial flows were treated as separate problems and the modeling approaches developed were implemented in independent environments. These models neglect the consequences of financial flows to optimizing these activities on the one hand. In the other hand the use of these type of models has been advocated in several types of industries: the computer industry [8], the detergent industry [9], the health industry [10], The pharmaceutical industry [11], the paper industry [12], the petroleum refinement industry [13] and the textile industry [14]. At the end of this review, there is an absence of a reference model that formalizes this type of problems.

The purpose of this study is to establish an analytical planning model of a company operating in the phosphate industry. Specifically, the modelling of logistics flows in a reel supply chain composed on production sites and a logistics platform in order to improve the planning and management of daily traffic flows. Also, to minimize the transportation cost of goods considering all the constraints (the capacity of stocks, cadence of production, the capacity of the transportation equipment and finally the customers demand…). In this study, the tactical and operational decision-making levels are considered, since the strategic level concerns decisions that affect the physical organization of the logistics chain.

This paper is organized in three paragraphs as follows. Paragraph 1 presents the basic terminology and a supply chain modelling approaches review. Paragraph 2 describes the development of the integrated budgeting model applied in a case study of supply chain. The last paragraph exposes the results and discussions.

II. ESSENTIAL TERMS

To better organize the structure of this paper and better comprehend and focus in the purpose of this work, it is necessary to define an essential term as follows.

Logistics: The definition of logistics takes more precise meaning depending on the context in which it is deployed. Indeed, is accepted that logistics is a set of techniques for managing and optimizing flows of raw materials, components and semi-products in the case of supplier-customers exchanges [15].

Supply chain: The supply chain refers to series of processes involved in the production and distribution of goods. It represents the steps that should be taken to bring a product to from suppliers to the consumer [16].

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Logistic platform: The logistic platform is a temporary storage and transit area, where products are deposited temporary before being redirected to other destinations [17].

III. SUPPLY CHAIN PLANNING MODELS REVIEW

Modelling is a set of methods that offers the ability to study and understand the structure and the operating principle of a system.

Considering a broad spectrum of the supply chain concept, there are various classification of modelling approaches used to describe and analyze the supply chains. Several reviews of the literature reflect the interest of this research area [18]-[24]. Labarthe [20] present in his work, the main classification with the main modelling approaches divided in three principal approaches: the analytical approach, the simulation approach and organizational Approach.

This paper focus generally in developing a *Mixed Integer Programming* analytical model for planning problems in a supply chain. This model belongs to analytical approach.

In this kind of approaches, the modeling is done by a mathematical equation describing and reflect the functioning of the supply chain using two approaches: the control theory or the operational research.

The work related to planning models applied in different areas is wide, several works can be found in [8]-[14];[25]-[33]. Many literature reviews confirm the interest in this research area [34].

IV. RESEARCH METHODOLOGY

To accomplish the purposes of this study in an efficient way, a structured methodology is followed, based on the work of [35]-[37]. This methodology can be summarized as followed (See Figure 1):

- Problem formulating: Define the objectives and the perimeter of the study and clarify the functioning of the system.
- Data collecting: Specify the parameters of the model and collect the information necessary for the functioning of the system.
- Model developing: propose the main objective function and the various constraint.
- Model checking and validating: determine if the developed model reflect precisely the real system.
- Executing the models: analyze, take back the results and evaluate their impacts on the performances of the systems.

As presented in figure 1, these steps can be iterative. This process continues until the model is considered to be sufficiently valid.

V. MODEL DEVELOPMENT

The system studied is a supply chain [38]-[40] composed of logistics platform and a chemical complex:

The logistic platform is designed for exporting fertilizers and phosphoric acid also importing Sulphur from different world destinations. This platform in a sea port is far 13 km from production sites.

The production sites are designed to produce the phosphoric acid, fertilizers also transformation of Sulphur.

The following Figure 2 show the structure of the studied supply chain also the repartition of physical flows.

A. Indices set

TP: Series of the transportation provider tp ∊ TP;
Itm: Series of the routed items, itm ∊ ITM;
T : Number of time t in the planning period t ∊ T;
D : Series of the days in the planning period j ∊ J;
U : Series of the supply chain units, u=prt for facilities in port, u=ps for facilities in production sites u ∊ U.

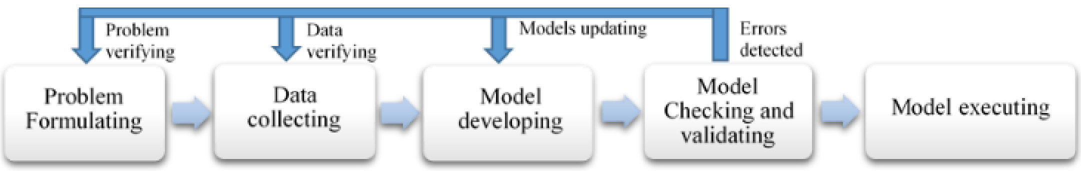

Fig. 1.Search methodology

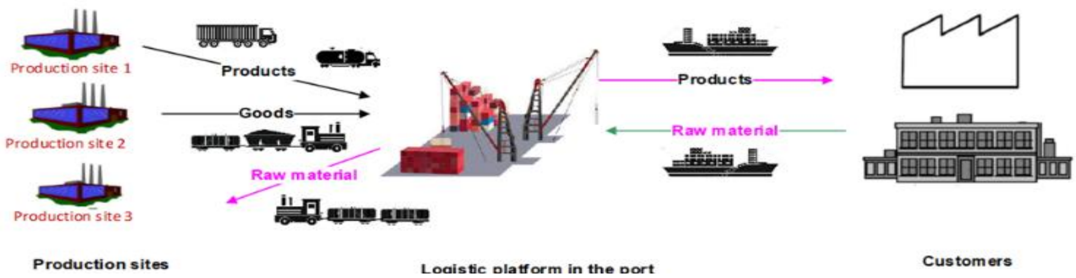

Fig. 2. Studied supply chain

A. Parameters

$ST_{u,\text{itm}}^{d,t}$: Stock of the item itm in the unit u during the day d in the planning period t.

$QTP_{u,\text{itm}}^{d,t}$: Production of the item itm in the unit u during the day d in the planning period t

$QTD_{u,\text{itm}}^{d,t}$: Demand of the item itm in the unit u during the day d in the planning period t.

B. DATA

$DMax_{u,\text{itm}}^{t}$: Maximal demand of the item itm can be demanded in the unit u in the planning period t;

$STMax_{u,itm}$: Maximum capacity of items itm can be stocked in the unit u;

$SafST_{u,itm}$: Security stock of the item itm in the unit u;

$PRMax_{u,itm}$: Maximal quantities of item itm can be produced in the unit u;

$CapMax_{u,itm}$: Maximal quantities of item itm can be endured by the facilities in the unit u;

$NRMax_{Ca}$: Maximum of transportation can be made by truck in a day;

$NRMax_{Tr}$: Maximum of transportation can be made by trains in a day;

$QTMax_{Ca,Gd}$: The capacity of truck to transport the items itm;

$QTMax_{Tr,p}$: The capacity of train to transport the items itm;

LC^t : The Labor cost to transport items in period t;

MC^t : The Maintenance cost of the transportation equipment in period t;

$HCE^t_{Tr,itm}$: The Hiring cost of equipment used in routing of the item itm by trains during period t;

$HCE^t_{Ca,itm,tp}$: The Hiring cost of equipment used by transportation provider tp in routing of the items p by truck during period t;

M : A constant, M = "+ ∞".

C. Decision variables.

TC^t_{itm} : The transportation cost of the item itm transported in the period t;

$TC^{d,t}_{itm}$: The transportation cost of the item itm transported during day d in period t;

UTC $^t_{Tr,itm}$: The unit transportation cost by trains of the item itm in the period t;

UTC $^t_{Ca,itm,tp}$: The unit transportation cost by tracks of the item itm in the period t using the transport provider tp;

$QTrv^{d,t}_{Tr,itm}$: The items itm conveyed by trains in each trip;

$QTrv^{d,t}_{Ca,itm}$: The items itm transported by trucks in each trip;

$NTrv^{d,t}_{Tr}$: Total of trips made by trains in the day d of the planning period t;

$NTrv^{d,t}_{Ca}$: Total of trips made by trucks in the day d of the planning period t;

α_j : Binary variable to choose rooting by trucks.

D. The function objective

The purpose of the developed objective function (see formula 1) is minimizing the transportation cost between various entities of the supply chain studied in a specified planning period.

$$Min(z) = \sum_{t\in T} TC^t_p \quad (1)$$
$$= \sum_{t\in T}\sum_{d\in D}\sum_{itm\in ITM} NTrv^{d,t}_{Tr} \, .QTrv^{d,t}_{Tr,itm} . \mathrm{UTC}\,^t_{Tr,itm}$$
$$+ \sum_{t\in T}\sum_{d\in D}\sum_{itm\in ITM}\sum_{tp\in TP} NTrv^{d,t}_{Ca} \, .QTrv^{d,t}_{Ca,itm} \, . \mathrm{UTC}\,^t_{Ca,itm,tp} . (1-\alpha_j)$$

The formulations of the model constraints are as presented as follow:

- **Constraints related to costs of transportation**

The constraints (2) and (3) specify the transportation cost of one ton of product p using trains or tracks in period planning. This cost is equal to labor cost plus the maintenance cost and the transportation equipment rental cost.

$$\mathrm{UTC}\,^t_{Tr,itm} = LC^t + MC^t + HCE^t_{Tr,itm} \; ; \forall\, t \in T, itm \in ITM \quad (2)$$

$$\mathrm{UTC}\,^t_{Ca,itm,tp} = LC^t + MC^t + HCE^t_{Ca,itm,tp} \quad \forall\, t \in T, tp \in TP,\; itm \in ITM \quad (3)$$

- **Constraints *associated to the items transported***

Once the quantities of items in the stocks of the logistics platform not enough to serve the customer demand, the transportation of items is made in addition of trains by trucks. To do that, a binary variable α_j is used to choose between these two cases, it takes 0 $(\alpha_j = 0)$ if transport is done by trains and trucks and it takes 1 $(\alpha_j = 1)$ if transport is done only by trains.

The stock $ST^{d,t}_{prt,itm}$ in port is an indicator to start or stop transportation by trucks, if this stock is less than security stock $SafST_{prt,itm}$, then α = 1 consequently the part of rooting by trucks in the formula 1 is equal to zero. These conditions are presented in the constraints (4), (5) and (6) as follow.

$$ST^{d,t}_{prt,itm} - SafST_{prt,itm} \le M.\alpha_j \quad \forall\, t \in T, d \in D, itm \in ITM \quad (4)$$
$$ST^{d,t}_{prt,itm} - SafST_{prt,itm} > 0 \;\; \forall\, t \in T,\; d \in D, itm \in P \quad (5)$$
$$ST^{d,t}_{prt,itm} \le SMax_{prt,itm} \quad \forall\, t \in T,\; d \in D, itm \in P \quad (6)$$

The purpose of the following constraint (7) is defining the quantity of products transported in each planning period:

$$QT^{d,t}_{itm} = \sum_{t\in T}\sum_{d\in D}\sum_{itm\in ITM} NTrv^{d,t}_{Tr} \, .QTrv^{d,t}_{Tr,itm} + \sum_{t\in T}\sum_{d\in D}\sum_{itm\in ITM} NTrv^{d,t}_{Ca} \, .QTrv^{d,t}_{Ca,itm} \, .(1-\alpha_j)$$
$$\forall\, t \in T, j \in J, p \in P, Gd \in P \quad (7)$$

- **Constraints associated to storage of items**

To assure the continuity of items in the supply chain, it is required to guarantee the availability of items in the warehouses of different entities in order to serve and satisfy customers demands. This condition is formulated as follow:

Constraint (8) approves the availability of products are in warehouses of the various entities e.

$$SafST_{u,itm} < ST^{d,t}_{u,itm} \le STMax_{u,itm} \quad \forall\, t \in T,\; d \in D,\; u \in U, itm \in ITM \quad (8)$$

Constraint (9) stipulate total of items itm in warehouses $ST^{d,t}_{u,itm}$ of unit u. It is equal to total of items stored in the unit u in the day d-1 plus the items produced or transported in the day d, less the items transported or demanded by clients.

$$ST^{d,t}_{u,itm} = ST^{d-1,t}_{e,itm} + QTP^{d,t}_{u,itm} - QTR^{d,t}_{u,itm} \quad \forall\, t \in T,\; d \in D,\; u \in U, itm \in ITM \quad (9)$$

- **Constraints associated to the production and customer demands**

The transported items $QTP_{u,itm}^{d,t}$ shouldn't surpass the maximal quantities of item itm can be produced in the unit u $PRMax_{u,itm}$. (see the constraint 10).

$$QTP_{u,itm}^{d,t} \leq PRMax_{u,itm} \qquad \forall\, t \in T, d \in D, u \in U, itm \in ITM \quad (10)$$

The customers demand $QTR_{u,itm}^{d,t}$ shouldn't surpass the maximal quantities of item itm can be endured by the facilities in the unit u (see the constraint 11).

$$QTR_{u,itm}^{d,t} \leq CapMax_{u,itm} \qquad \forall\, t \in T,\ d \in D,\ u \in U, itm \in ITM \quad (11)$$

- **The constraints related to the transport**

The items $QTrv_{Tr,itm}$ conveyed by trains in each travel shouldn't surpass the capacity of train to transport the items (see the constraint 12).

$$QTrv_{Tr,itm}^{d,t} \leq QTMax_{Tr,itm} \qquad \forall\, t \in T,\ d \in D,\ u \in U, itm \in ITM \quad (12)$$

Total of trips completed by trains in the day d of the planning period t, shouldn't surpass the maximum of transportation can be made by trains in a day (see the constraint 13).

$$NTrv_{Tr}^{d,t} \leq NRMax_{Tr} \qquad \forall\, t \in T,\ d \in D,\ u \in U, itm \in ITM \quad (14)$$

Similar conditions constraints are considered using transportation by trucks (see the constraints 15 and 16).

$$NTrv_{Ca}^{d,t} \leq NRMax_{Ca} \qquad \forall\, t \in T,\ d \in D \quad (15)$$

$$QTrv_{Ca,itm}^{d,t} \leq QTMax_{Ca,itm} \qquad \forall\, t \in T,\ d \in D,\ u \in U, itm \in ITM \quad (16)$$

VI. CONCLUSION

In this study, a basic search is conducted to develop a planning model specifically an integrated budgeting planning model, with the purpose to minimize the transportation cost between different units of the studied supply. To do that, a literature review on supply chain modelling approaches is directed also a review of a related works. This study is applied on a reel case study of a phosphate supply chain.

In this paper, a structed methodology is followed and the result is a model that defined the transportation cost of various products. It is a global model, that defined the specific models for each product during each planning period. This model is a Mixed Integer Programming belongs to the NP complete problems.

Actually, the last phase in the research methodology are started which is implementing and validating of the code in a solver software.

In the future work, we suggest to develop a specific budgeting model for each unit in the studied supply chain and to link this model to a specific simulation models.

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