Negotiation models for logistic plarform planning and scheduling

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1 Introduction and problem description

This research work was initiated after an audit of a logistic platform belonging to a shoes distribution society. The final aim is to design a set of decision tools dedicated to smoothing the workload of the platform by using limited modifications of the arrival and departure dates concerning the suppliers and the customers deliveries, completed by additional workforce. Two millions of elementary articles (boxes of shoes) are crossing the platform each year with two seasonal peaks. We consider planning and scheduling levels, using for both levels Integer Linear Programming models, as generic as possible, but different for each level, where the unknown quantities correspond to box numbers and/or box volumes. We are concerned by three families of constraints : delay negotiations (essentially at the planning level), storage limitations (at both levels), social constraints associated with the human workforce activities (different at each levels and specific of the country laws). These generic models can be also used to compare various layout and work organisations of the platform, because the audit suggested that other organisation could decrease the number of times a pair of shoes is manipulated during its presence inside the platform.

Twice a year, spring and autumn, the platform receives products from its suppliers. A small part is kept in the reserve area for providing with restocking the chain stores, while the major part is immediately sent to the 90 stores. The quantities and the delivery dates are negotiated with the suppliers at planning level. The potential variations concerning delivery dates and quantities are strongly limited by the suppliers production and storage constraints and by the transport organization between the suppliers and the platform, which can be direct or through the Lyon auxiliary platform. On the other hand, the shoes distribution enterprise owns the stores and can manage completely the vehicle routing organization between the platform and its stores. In order to optimize the vehicle routing cost, optimized tours can be computed for subset of stores and dates and corresponding quantities of such tours can be slightly modified in order to smooth the platform workload and avoid if possible some extra workers at the platform. The workforce smoothing tool is necessary for the two annual peaks, whose duration is almost a month, corresponding to the main supplier delivery arrivals and customer delivery departures. During these two periods, excess overtimes and numerous temporary employees are necessary.

The literature associated with this work concerns the logistic platform optimization and the mean term flow management. On one hand, we found a lot of papers maximizing the throughput of platforms by designing the layout and/or choosing picking policies (Chen et al.,(2006); Bartholdi and Gue, (2004),...) but the stationarity of the phenomenon is always assumed and consequently negotiations with upstream and downstream partners to smooth the workload is useless. On the other hand, while numerous papers present Integer Linear Programming Models for designing medium term planning (Huragu et al., (2005)) in order to smooth the workload, very few are taking into account negotiation or cooperation with the partners (Dauzère-Pérès et Lasserre, (1999); Ouzizi, (2005)). We focus our research on two topics : how to model various types of negotiation with the upstream and downstream partners and how to model the social constraints associated to human resources depending on the parameter Δ associated to one time unit (one hour, one half day, one day or one week). We try to be as generic as possible with various types of stocking using assembly and/or disassembly bills of material, with various family of penalties linked to earliness and tardiness of deliveries relatively to ideal dates and with various workforce extension and costs.

We present here the most important families of variables and constraints of our ILP model. Due to the four pages limitation, we decided to focalize on the just in time negotiation constraints and costs/penalties and to simplify strongly the human resource limitations and costs.

2 Linear Programming Model : global description

The model contains numerous entities. For each of them, we provide the letter chosen for the most used index, followed by the mathematical symbol $\in$, followed by the identification symbol corresponding to the set of indices. The used entities are: time unit ($t \in NT$), multiple of Δ (Δ is much smaller at the scheduling level than at the planning level); storage areas ($z \in NZ$); worker caterories ($w \in NW$); products ($p \in NP$); upstream/supplier deliveries ($d_u \in NDU$); downstream/customer deliveries ($d_d \in NDD$); upstream and/or downstream deliveries ($d \in ND = NDU \cup NDD$); operations ($o \in NO$); activities, i.e. deliveries and/or operations, which both modify the stock contents ($a \in NA = NO \cup ND$).
We now present the main fixed parameters of the model gathered by main families, followed further by the variables description, the main families of constraints and criteria.

Stocks and products parameters

VZ_z, maximal volume capacity of the storage area z (for the storage areas, volumes are important, while for the transports, volumes and weights can be taken into account, but weights are more important); VP_p, volume of each box of product p; KP_p, weight of each box of product p; KL_d, KU_d, minimal and maximal capacity of the trucks that delivers d (some stores can be reached only with very small trucks authorized to access city centers); $TU_{o,p}$, unitary processing time corresponding to product p manipulated by operation o (operations inside a logistic platform are mostly unload, move, unpack, control, store, pick, group, prepare, load; almost all of them require a human worker); $SI_{p,z}$, initial stock of product p in the storage area z (quantities = number of boxes); QT_p, total amount of boxes of product p delivered in the considered season; $QLL_{d,p}$ and $QUL_{d,p}$, lower and upper bound for the number of boxes of product p inside the delivery d (0 and 0 if the product p is not concerned by the delivery d, twice the value ordered to the supplier if only the date of the delivery d can be negotiated and not the quantities) and a very important matrix needed for representing the routage of the products inside the platform and between the delivery arrivals/departures and the storage areas of the platform:
$LZE_{a,z}$, matrix defining if the activity a increases (or decreases) the stock z (0 if there is no relationship between a and the stock z, 1 if it increases with a, -1 if it decreases with a).

Earliness/tardiness parameters

The first series of parameters concern date modifications. TS_d desired delivery date for d (it is the ideal date for the vehicule tour); $EC\Delta_d$ and $TC\Delta_d$ earliness and tardiness cost associated with any deviation of Δ time unit relatively to the desired date of the delivery (any product arrival/departure inside the delivery being globally left or right shifted); $MAXE_d$ and $MAXT_d$ maximal number of time units tolerated in earliness/tardiness of delivery d (associated to arrival or departure of a truck tour); $MoveAuth_{d,t}$ matrix defining if delivery d is authorized during the period t (1 if yes and 0 otherwise, to restrict the period times during which deliveries can be accepted (hours, half days ... depending on the Δ value).

The second series of parameters concern the consequence of the date modifications on the cumulated delivered quantities and the quantity modifications inside the deliveries. Cumulated curves must be defined, which will be used either as imperative upper and lower bounds for computed cumulated delivered product quantities or as ideal cumulated curves, which permit to calculate penalty earliness and tardiness deviations. Contrarily to previous series of parameters, the associated penalty costs are not linked to transport cost, but to production costs upstream and downstream the platform.
$EUCC_{p,t}$ earliest upstream imperative cumulated curve ($EDCC_{p,t}$ if downstream); $LUCC_{p,t}$ latest upstream cumulated curve ($LDCC_{p,t}$ if downstream); $NUCC_{p,t}$ negotiated ideal upstream cumulated curve ($NDCC_{p,t}$ if downstream); MC_p, LC_p, cost associated to each unit of the early and late

surfaces between desired cumulated curves of product p and cumulated curves associated to planned deliveries as illustrated in figure 1 (fictitious penalties to balance deviation desagrement between ideal previously forecasted deliveries and new potential deliveries to be negotiated with the suppliers against decrease of workload costs).

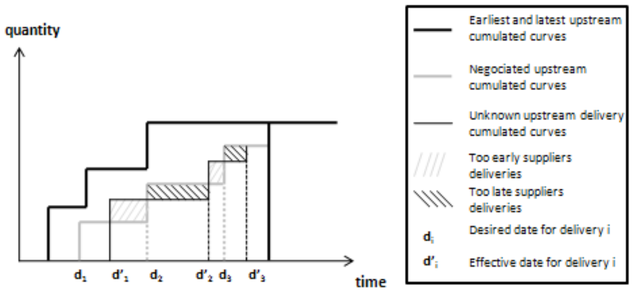

Figure1. Upstream Cumulated Curves for a product

Workforce (simplified) parameters

$nrh_{t,w}$ number of employees of category w working at period t; *MAXTW*Δ maximum working time inside a unit of time Δ; *CUch* unit cost (fictitious) of increase (or decrease) of the total workload deviation relatively to ideal workload in each period.

Stocks and production variables

$Q_{a,p,t}$ amount of product p processed by the activity a during period t; $S_{z,p,t}$ stock of product p in the storage area z at end of period t (we can only compute the stock levels at the end of periods, which induces small approximation in the storage limitation during the periods).

Workforce (simplified) variables

$TW_{w,o,p,t}$ total time of operations o realised by workers of category w to perform products p during the time period t; Ch_t workload of the platform during period t; $MaxCh_t$ overload above average (or ideal) workload during period t; $MinCh_t$ underload below average (or ideal) workload during period t.

Delivery date and quantity variables

$Move_{d,t}$ variable equal to 1 if delivery arrives in t, 0 otherwise (it is a classical way using binary variables to assign an entity to one and only one time index); T_d effective date of delivery d (deduced by the previous series of variables); DT_d, DE_d tardiness and earliness of delivery d relatively to its expected date; the following cumulated curves (and deviations between the desired and computed cumulated curves) are computing by using the previous sets of variables:
UDCC$_{p,t}$ unknown upstream delivery cumulated curve of product p; *DDCC*$_{p,t}$ unknown downstream delivery cumulated curve of product p; *NUE*$_{p,t}$, *NUT*$_{p,t}$, *NDE*$_{p,t}$ and *NDT*$_{p,t}$: for each period t, if the upstream (downstream) effective cumulated curve is greater or equal to the desired cumulated curve then NUE (NDE) represents too early suppliers (customers) deliveries else NUT (NDT) represents too late suppliers (customers) deliveries

Constraints and objective functions:

The families of constraints concern: flow conservation and capacity constraints, earliness tardiness computations and constraints, coherence between delivery dates and local/global quantities, cumulated quantity curves computations and constraints, workforce assignment, calendar constraints and workload computations. Several criteria can be aggregated; they concern sum of workload deviation penalties, sum of extra workers and overtime costs and various sums of earliness and tardiness penalties.

Constraints:

Flow conservation and capacity constraints

$\forall z, \forall p, \forall t$	$S_{z,p,0} = SI_{z,p}, S_{z,p,t} = S_{z,p,t-1} + \sum_{a \in NA} LZE_{a,z} \times Q_{a,p,t}$	(1,2)
$\forall z, \forall t$	$\sum_{p \in NP} S_{z,p,t} \times VP_p \leq VZ_z$	(3)
$\forall d$	$KL_d \leq \sum_{t \in NT} \sum_{p \in NP} Q_{d,p,t} \times VP_p \leq KU_d$	(4)

Earliness/tardiness computations and constraints

$\forall d$	$T_d \leq nt, DE_d \leq MAXE_d, DT_d \leq MAXT_d$	(5,6,7)
	$\sum_{t \in NT} Move_{d,t} = 1, T_d = \sum_{t \in NT} t \times Move_{d,t}$	(8,9)
	$DE_d \geq TS_d - T_d, DT_d \geq T_d - TS_d$	(10,11)
$\forall d, \forall t$	$Move_{d,t} \leq MoveAuth_{d,t}$	(12)

Coherence between delivery dates and local/global quantities

$\forall p, \forall d, \forall t$	$QLL_{d,p} \times Move_{d,t} \leq Q_{d,p,t} \leq QUL_{d,p} \times Move_{d,t}$	(13)
$\forall p$	$\sum_{d \in NDU} \sum_{t \in NT} Q_{d,p,t} = QT_p$	(14)

Cumulated quantity curves computations and constraints

$\forall p, \forall t$	$UDCC_{p,t} = \sum_{\tau=1}^{t} \sum_{d_u \in NDU} Q_{d_u,p,\tau}$	(15)
	$LUCC_{p,t} \leq UDCC_{p,t} \leq EUCC_{p,t}$	(16)
	$NUE_{p,t} \geq UDCC_{p,t} - NUCC_{p,t}$	(17)
	$NUT_{p,t} \geq NUCC_{p,t} - UDCC_{p,t}$	(18)

Workforce assignment, calendar constraints and workload computations

$\forall o, \forall t, \forall p$	$TU_{o,p} \times Q_{o,p,t} \leq \sum_{w \in NW} TW_{w,o,p,t}$	(19)
$\forall w, \forall t$	$\sum_{o \in NO} \sum_{p \in NP} TW_{w,o,p,t} \leq nrh_{w,t} \times MAXTW\Delta$	(20)
	$Ch_t = \sum_{w \in NW} \sum_{o \in NO} \sum_{p \in NP} TW_{w,o,p,t}$	(21)
	$MoyCh = \frac{1}{nt} \sum_{t \in NT} Ch_t$	(22)
	$MinCh_t \geq MoyCh - Ch_t, MaxCh_t \geq Ch_t - MoyCh$	(23,24)

Objective function:

Aggregation of workload, earliness/tardiness dates and quantities

Min $\alpha(\sum_t (MaxCh_t + MinCh_t) \times CUch) + \beta(\sum_{d \in ND}(DE_d \times EC\Delta_d) + (DT_d \times TC\Delta_d)) + \gamma \sum_{p \in NP} \sum_{t \in NT}((MC_p \times (NUE_{p,t} + NDE_{p,t}) + LC_p \times (NUT_{p,t} + NDT_{p,t})))$

A simplied version of this ILP model was implemented in CPLEX and tested on generated data corresponding to two propositions of the platform layout and work organization. This work will be pursued with the long term goal of building a complete generic hierarchical decision systems for smoothing the workload of logistic platforms.

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