# "WHAT TO" APPROACH FOR THE OPTIMIZATION OF A LOGISTICS PLATFORM

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## ABSTRACT

The paper proposes a "what to" approach in order to optimize the receiving activities in a logistics platform operating in the food sector.

The aim is the minimization of the receiving makespan, the time between the arrival and the exit of the inbound trucks at the node.

The approach is based on a dynamic, stochastic, discrete-event micro-simulation model, that is properly specified, calibrated and validated.

The simulation model allows the evaluation of the efficiency and functionality of the receiving activities. It can be applied to existing logistics platforms or to logistics systems in project phase, by offering managers summary indicators to support decisions related to planning receiving activities at different levels.

Finally, a test application is proposed showing the optimal configurations of the system through the adjustment of the layout characteristics and the resources employed to serve inbound trucks.

Keywords: Logistics platform, micro-simulation model, optimization.

## 1. INTRODUCTION

A logistics platform, like a warehouse, "is a facility, which provides the services about material storage and management to a manufacturing firm or customer". Its efficiency depends on many factors and is important because costs affect the production or distribution accounts and ultimately fall on the consumer.

The paper proposes a "what to" approach in order to optimize the receiving activities in a logistics platform operating in the food sector.

The aim is the minimization of the time inbound trucks spend at node. A discrete event, stochastic, dynamic micro-simulation model was specified and calibrated to solve the problem and it was implemented by using WITNESS software.

The simulation model allows to evaluate the efficiency and functionality of the receiving area of logistics platforms, already existing or to be built, by offering managers summary indicators to support decisions related to the planning of receiving activities at different levels (strategic, tactical and operational).

Through "what to" procedures, the model provides the analysis of the receiving area performance in relation to the node working conditions and the managerial policy adopted by the terminal operators. The proposed model is a useful decision support tool for operators of existing logistics platforms, since it enables them to make operational evaluations (space organization, resources utilization, etc.) that can direct the planning of tactical and strategic actions. Furthermore, in the case of platforms still to be built, the proposed simulation model allows to test scenarios and to make informed choices about the provision of space and resources and about the management approach to be taken in planning phase.

After a brief review of the studies about inbound vehicles scheduling, the description and the mathematical formulation of a model is proposed in order to optimize receiving activities in the logistics platform.

Finally, the paper proposes a test of the above-mentioned model to a logistics platform operating in the north of Italy.

## 2. LITTERATURE REVIEW

The trucks scheduling problem takes into account temporal constraints and determines where and when trucks should be processed. In literature sector, this problem is faced in different ways in relation to the presence of temporary storage during the goods transfer from inbound doors to outbound doors.

Tsui and Chang (1992) study the problem without considering temporary storage of incoming goods, the objective is to minimize the distance traveled by handling means in warehouse. They use a traditional formulation for the problem (bi-linear programming) and Branch & Bound algorithm for resolution. The model is a reference point in the litterature sector, in fact many authors propose a integration or adaptation of it (Bermudez et al., 2001; Rong Zhu et al., 2009; Cohen and Karen, 2009; Guignard et al., 2012).

Also Boysen et al. (2010), in the case of direct goods transfer without temporary storage, propose a procedure to schedule inbound and outbound trucks. The used approach is dynamic and the problem is resolved by using heuristic methods. The objective is to minimize the total time spent at node.

Instead Chen and Lee (2009) develop a polynomial approximation algorithm and a branch-and-bound algorithm to minimize the makespan for products going through a crossdocking facility without temporary storage. In particular, the authors propose to sequence the unload/upload and degroupage/groupage operations for the inbound/outbound goods to minimize the makespan. They formulate this problem as a two-machine flow shop problem.

Yu and Egbelu (2008) study the scheduling issue of inbound and outbound trucks in a crossdocking systems with temporary storage. They try to find the scheduling sequence for both inbound and outbound trucks to minimize the total operation time when a storage buffer to hold items temporarily is located at the shipping stock. Boloori Arabani et al. (2011) deal with the same problem and propose an implementation of a genetic algorithm for the resolution.

Other researches concern the study of the trucks scheduling through the simulation, for instance McWilliams et al. (2008) cover a specific trucks scheduling problem at a parcel hub. They propose a simulation-based scheduling approach with an embedded genetic algorithm.

The trucks scheduling problem is related to vehicle routing problem and internal resources scheduling problem. In fact, the arrival times of the inbound trucks are determined by the route travelled on the network. The arrival time is an important parameter influencing the assignment of the inbound trucks to the unloading doors. In addition, the assignment of the trucks to the doors determines the handling activities inside the platform, in other words, the distance that the workers and the handling means have to travel to transfer the goods from inbound doors to outbound doors.

In function of last consideration, the paper proposes the resolution of trucks scheduling problem by using a simulation approach. The supply variables are clearly considered in the problem formulation. They characterize a logistics platform and influence the system performance and the service level offered to clients, therefore the efficiency and the speed with which the inbound trucks are served. The objective is to minimize the inbound trucks makespan through the optimization of the infrastructural and superstructural resources of a platform, without defining the best sequence of inbound trucks.

## 3. MATHEMATICAL MODEL FORMULATION

The aim of the proposed model is to optimize the receiving activities by minimizing the total time spent by the trucks at the node, from their arrival to their departure.

The receiving area of a logistics platform has a gatehouse; one or several docks equipped with doors for unloading operations and for the reloading of rejected goods; an area where the inbound goods are subject to the qualitative and quantitative checks and, then, are sorted into the storage area. Generally, the docks of a logistics platform correspond to specific warehouse zones and are used to receive only certain types of goods so that the following operations of handling and storage of inbound goods can be simplified.

The receiving process concerns the activities carried out to handle inbound trucks and involves the receiving area and the corresponding operational areas. In detail, once the conformity of the amount and type of goods transported by a truck is checked, following the order of arrival, the gatehouse assigns a dock and a serial number to the inbound vehicle. Generally, the dock is assigned according to the type of goods, in order to optimize the following unloading and storage operations, while the serial number is assigned on the basis of the arrival time and registration at the gatehouse. Thus, the truck remains waiting for the service and, when one of the doors of the assigned dock becomes available, it is let in. Then, the unloading operations start and, finally, they are followed by check operations (Transport Document: TD). It is important to notice that the qualitative and quantitative check is carried out by priority, i.e. if the inbound goods are not immediately required in the warehouse, the check is postponed. When checking operations end, if goods are deemed suitable, they are stored, otherwise they are reloaded on the truck, which leaves the door at the end of all operations.

In relation to the operational and functional characteristics of the receiving area of a logistics platform, the optimization problem of the makespan of inbound trucks ($T_I$) can be formulated as follows:

$$Min\ T_I \tag{1}$$

Subject to:

$$\begin{cases} x_{ij} - 1 \le y_{ik} - y_{jk} \le 1 - x_{ij} \\ i, j = 1, \ldots, n+1 \quad i \ne j \quad k = 1, \ldots, m_k \end{cases} \tag{2}$$

$$0 < \sum_{k=1}^{K} m_k \le N \tag{3}$$

$$0 < \sum_{k=1}^{K} a_k^{unload} \le A^{unload} \tag{4}$$

$$0 < \sum_{k=1}^{K} a_k^{c} \le A^{c} \tag{5}$$

$$x_{ij} \in \{1,0\} \quad \forall i, j = 1, \ldots, n \tag{6}$$

$$y_{ik} \in \{1,0\} \quad \forall i = 1, \ldots, n \quad k = 1, \ldots, m_k \tag{7}$$

where:

- $x_{ij}$ binary variable equal to 1 if the truck *i* and truck *j* carry the same type of goods, 0 otherwise;
- $y_{ik}$ binary variable equal to 1 if the truck *i* carries the goods that will be unloaded at dock *k*, 0 otherwise;
- *n* total number of inbound trucks;
- $m_k$ number of doors operating at the *k*-th dock;
- *K* total number of operating docks;
- *N* total number of operating doors;

- $a_i^{unload}$ number of workers for goods unloading at *i*-th dock;
- $A^{unload}$ total number of workers for goods unloading;
- $a_i^c$ number of workers for goods checking at *i*-th dock;
- $A^c$ total number of workers for goods checking.

Constraint (2) requires that the trucks carrying the same type of goods are served at the same dock.

Constraint (3) considers the node layout and imposes that the numbers of operating doors in every docks does not exceed the total number of doors available at the logistics platform. Constraints (4) and (5) are budget constraints related to human and superstructural resources that are necessary for the functionality of the receiving area. In particular, constraint (4) ensures that the workers or the handling vehicles dedicated to unloading activities at each dock do not exceed the number of workers/vehicles available for unloading operation. Similarly, constraint (5) requires that the resources employed in checking activities at each dock do not exceed the number of workers available for this activity. Finally, constraints (6) and (7) ensure that $x_{ij}$ and $y_{ik}$ are binary variables.

Specifically, the receiving makespan can be defined through the following function:

$$T_I = T_W + T_{Service} \tag{8}$$

where $T_W$ is the waiting time of the trucks at the collect point and $T_{Service}$ is the service time.

The service time is the sum of three elements: the time necessary for unloading operations ($T_{unload}$), the time spent to perform the first qualitative and quantitative checks on incoming goods ($T_c$), the time spent on docking/undocking operations at the door and the time lost waiting for the go-ahead by the logistics platform management ($T_{extra}$):

$$T_{Service} = T_{unload} + T_c + T_{door} + T_{extra} \tag{9}$$

Generally, $T_{door}$ is negligible and it can be considered as included in the last term, thus the following is the simplified form:

$$T_{Service} = T_{unload} + T_c + T_{extra} \tag{10}$$

## 4. SOLVING APPROACH

The problem described above was solved by using a simulation approach.

In particular, a discrete-event, stochastic, dynamic micro-simulation model was specified, calibrated, validated and implemented through the WITNESS software.

The phases of the model specification and calibration were based on a statistic procedure for the evaluation of the time/cost variables. The methodological approach is schematized in Figure 1.

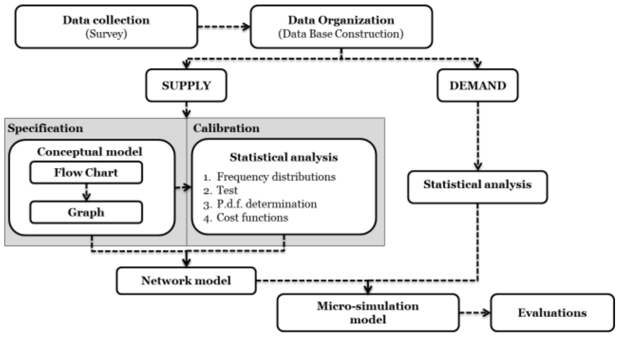


Figure 1: Methodological approach (Gattuso and Cassone, 2012)

### 4.1. Micro-simulation model

The model specification consisted in the definition of the conceptual model and in the identification of the system variables (Gattuso and Cassone, 2012).

The conceptual model was built by consecutive steps, through gradually increasing the details of representation, defining first the flow chart of nodes and then their graph. The system variables considered are the time variables that define the makespan of inbound trucks.

The calibration of the micro-simulation model consisted in identifying the distribution of the system variables and in evaluating the corresponding characteristic parameters.

The calibration of the simulation model was based on the statistical analysis of the data collected through direct surveys at existing logistics platform.

Table 1 specifies the average and the standard deviation for each system variables.

Table 1: Statistics related to system variables

| Variable | Goods type/ Dock | Average (min) | Standard dev. (min) |
|---|---|---|---|
| $T_w$ | *Cross* | 72,61 | 51,15 |
| | $k_B$ | 65,11 | 53,97 |
| | $k_C$ | 66,78 | 59,64 |
| | $k_D$ | 73,71 | 64,11 |
| | $k_E$ | 76,78 | 62,69 |
| $T_{unload}$ | *Cross* | 6,91 | 2,34 |
| | $k_B$ | 10,78 | 4,51 |
| | $k_C$ | 10,71 | 4,65 |
| | $k_D$ | 11,68 | 4,54 |
| | $k_E$ | 11,50 | 4,63 |
| $T_c$ | *Cross* | 10,15 | 7,83 |
| | $k_B$ | 32,77 | 19,63 |
| | $k_C$ | 33,09 | 23,04 |
| | $k_D$ | 33,58 | 17,66 |
| | $k_E$ | 45,69 | 31,05 |
| $T_{extra}$ | *Cross* | 34,36 | 28,04 |
| | $k_B$ | 37,69 | 36,27 |
| | $k_C$ | 38,24 | 37,12 |
| | $k_D$ | 40,26 | 33,36 |
| | $k_E$ | 57,63 | 61,61 |

$k_B$: detergents; paper products; hygiene and personal care products; $k_C$: beers, wines and liqueurs, plastic/glass drinks; high value perfumes; $k_D$: oil and vinegar; conserves; pasta, rice and similar products; $k_E$: water, milk, biscuits, bread and similar products; early childhood products; controlled temperatures and flammable goods.

Instead, Table 2 shows the calibration results referred to the type of goods or to operating docks (each dock is equipped to handle specific types of goods).

Table 2: Calibration results for each goods type

| Variable | Goods type/ Dock | Distribution | Parameters |
|---|---|---|---|
| $T_w$ | *Cross* | Beta ($\alpha$; $\beta$) $\alpha$: shape par. $\beta$: scale par. | (1,00; 3,00) |
| | $k_B$ | | (1,80; 7,50) |
| | $k_C$ | | (0,95; 3,50) |
| | $k_D$ | | (1,26; 6,60) |
| | $k_E$ | | (1,20; 3,90) |
| $T_{unload}$ | *Cross* | Poisson ($\mu$) | 6,91 |
| | $k_B$ | Weibull ($r$; $\beta$) $r$: shape par. $\lambda$: scale par. | (1,7; 12,08) |
| | $k_C$ | | (1,4; 11,66) |
| | $k_D$ | | (2,0; 13,78) |
| | $k_E$ | | (1,8; 12,93) |
| $T_c$ | *Cross* | Weibull ($r$; $\beta$) $r$: shape par. $\lambda$: scale par. | (1,1; 10,52) |
| | $k_B$ | | (1,8; 36,85) |
| | $k_C$ | | (1,6; 37,9) |
| | $k_D$ | | (1,7; 37,64) |
| | $k_E$ | | (1,6; 50,96) |
| $T_{extra}$ | *Cross* | Exponential($\theta$) | 0,0291 |
| | $k_B$ | | 0,0265 |
| | $k_C$ | | 0,0261 |
| | $k_D$ | | 0,0248 |
| | $k_E$ | | 0,0174 |

**4.2. Optimization Algorithm**

The optimization of the receiving activities in the logistics platform is developed by using the Adaptive Thermostatistical algorithm, also known as Simulated Annealing (SA). It is a research methodology fitting any no-convex optimization problem which is based on statistical mechanics. The SA originated as a simulation method of the tempering of solids (annealing).

In the annealing process, a solid is first brought to the fluid state by heating to high temperatures and then it is brought back to the solid or crystalline state, at low temperatures, controlling and gradually reducing the temperature. At high temperatures, atoms are in a highly disordered state in the system and, therefore, the energy is high. To give these atoms a highly ordered crystalline configuration (statistically), the system temperature should be lowered.

Fast reductions of the temperature can cause defects in the crystal lattice resulting in metastability, with cracks and fractures of the lattice (thermal stress). Annealing avoids this phenomenon by gradually cooling the system and leading to a globally optimal stable structure (Lacagnina, 2014).

The system is in thermal equilibrium at temperature $T$ if the probability $P(E_i)$ of a state having energy $E_i$ is governed by the Boltzmann distribution:

$$P(E_i) = \frac{\exp\left(-\frac{E_i}{k_B \cdot T}\right)}{\sum_i \exp\left(-\frac{E_j}{k_B \cdot T}\right)} \tag{11}$$

where $k_B$ is the Boltzmann constant.

Note that, at high temperatures, all the energy states are probably possible, while, at low temperatures, the system is definitely in the states of lowest energy.

For optimization problems, the SA works as follows: at high temperatures, the algorithm behaves more or less like a random search. The search jumps from one point to another in the solution space by identifying the characteristics and thus the directions or areas where it is more likely to find the global optimum. At low temperatures, the SA is similar to the methods of steepest descent. Solutions are in the area of the most promising domain. This means that the analyst should decide to implement the method with a large number of parameters allowing greater freedom of choice and therefore high applicability. However, there is a price to pay: the calibration of a large number of parameters causes an initial hard work to make the method converge. A key advantage of SA is that the analyst can adopt it for not well-known optimization problems.

The simulation of the annealing process applied to optimization problems requires several preparatory steps. First, in the optimization problem, the similarities with the physical concepts have to be identified: energy becomes the cost function; the configuration of particles becomes the configuration of the parameters (decision variables) of the problem; the search for a minimum energy state becomes the search for a solution minimizing the cost function; temperature becomes a control parameter. Hence, an appropriate annealing scheme has to be chosen, which consists in the adjustment of the parameters on which the optimization process depends. That means the temperature decay law and the time duration required to reach thermal equilibrium at each temperature have to be defined. Finally, a perturbation method of the system has to be introduced to explore the search space by generating new configurations.

Metropolis et al. (1953) developed an algorithm to simulate the behaviour of a set of atoms in thermal equilibrium at a particular temperature. The essential feature of this algorithm is that it generates a set of configurations, for each temperature $T$, whose energies can be represented by the Boltzmann distribution. The algorithm starts from a given initial atoms configuration in a system with energy $E_0$. Then, successive configurations are generated through small random perturbations of the current configuration. The difference between the energy of the current configuration and that of the new configuration (candidate configuration) allows accepting or rejecting the new configuration. The energies of the accepted system configurations have to follow a Boltzmann distribution if the thermal equilibrium is reached.

Metropolis algorithm always accepts a candidate solution if its energy $E_j$ is lower than that of the current configuration $E_i$. On the other hand, if the energy $E_j$ of the candidate configuration is higher than that of the current configuration, then the candidate is accepted with the following probability:

$$P(\Delta E) = \exp\left(-\frac{\Delta E}{k_B \cdot T}\right) \tag{12}$$

where $\Delta E = E_j - E_i$.

For an optimization problem, the SA algorithm can be summarized as follows:

1. An initial configuration or solution $x_0$ is given with energy or value of the objective function $E_0$. Select an initial value for the temperature $T_0$.
2. Perform the following steps for each temperature stage:
   Generate a new valid configuration through a small random perturbation of the current configuration. Evaluate the energy difference $\Delta E$ between the two configurations;
   If $\Delta E \leq 0$, the objective function of the new configuration has a value lower than that of the current configuration. Accept the new solution and change the current one. If $\Delta E > 0$, the objective function of the new configuration has a value higher than that of the current configuration. Accept this solution with a probability $P(\Delta E)=exp(-\Delta E/k_B{\cdot}T)$ and update the current configuration if it is necessary;
   If the thermal equilibrium is not reached, return to Step 2.A. Otherwise, go to Step 3.
3. If the annealing process is incomplete, reduce the temperature and return to 2.

## 5. APPLICATION

A test application is proposed to optimize the efficiency of the receiving area of a logistics platform.

The considered platform is located in the north of Italy and operates in the food sector. Table 4 shows both the layout characteristics of the receiving area and the resources employed to serve inbound trucks.

In order to simplify the following activities of storage, picking and composition of the outbound loads, inbound trucks are sorted at docks in relation to transported goods.

For this reason, the efficiency analysis of the receiving area was carried out considering the operating dock (or the type of goods).

Table 4 and table 5 respectively show the values of reference variables and the values of the objective function in the current system configuration.

The results of the considered optimization problem are shown in table 6.

The analysis of the optimization results shows an clear reduction in the makespan of inbound trucks due to the reorganization of the docks and to the redistribution of the human resources at each dock.

The reorganization of docks implies 28 doors (compared to 34 current doors), 10 workers for the unloading activities and 9 workers for the checking activities (1 unit less than at present).

In particular, the optimal configuration of the dock 1 has 9 doors (5 more than current state), 5 workers for unload activities (3 more than current configuration) and 2 workers for checking activities, so the makespan is cut by 27.69%. The optimal configuration of dock 2 is very similar to current state: 8 doors for goods unloading (1 door less than the 9 doors of current state) and 3 workers (1 worker less for goods unloading), this means a reduction in the makespan of about 3.89%.

Table 4: Reference variables in the current system configuration

| Reference variable | Description | Value |
|---|---|---|
| $n$ | Total number of inbound trucks | 130 |
| $m_1$ | Number of doors operating at dock 1 | 4 |
| $m_2$ | Number of doors operating at dock 2 | 9 |
| $m_3$ | Number of doors operating at dock 3 | 3 |
| $m_4$ | Number of doors operating at dock 4 | 9 |
| $m_5$ | Number of doors operating at dock 5 | 9 |
| $K$ | Total number of operating docks | 5 |
| $N$ | Total number of operating doors | 34 |
| $a_i^{unload}$ $i=1,2,..,5$ | Number of workers for goods unloading at $i$-th dock | 2 |
| $A^{unload}$ | Total number of workers for goods unloading | 10 |
| $ai^c$ $i=1,2,..,5$ | Number of workers for goods checking at $i$-th dock | 2 |
| $A^c$ | Total number of workers for goods checking | 10 |

Table 5: Objective function value in the current system configuration

| Dock | $T_I$ (min) |
|---|---|
| 1 - cross activities | 407,13 |
| 2 - treatment of $k_B$ goods type | 420,78 |
| 3 - treatment of $k_C$ goods type | 141,63 |
| 4 - treatment of $k_D$ goods type | 394,32 |
| 5 - treatment of $k_E$ goods type | 439,18 |

Instead, for dock 3 the optimal configuration requires a minimum use of resources (1 door, 1 worker for goods unloading, 1 worker for goods checking) and the makespan is cut by 60.66%.

The optimization results require significant changes in the configuration of dock 4. In fact, it has 2 doors for goods unloading (7 less than current state), 1 worker for goods unloading (1 less than current condition), 2 workers for goods checking (equal current state). The makespan is cut by 19.93%.

Table 6: Optimization results

| Dock | $T_I$ (min) | $m$ | $a^{unload}$ | $a^c$ |
|---|---|---|---|---|
| 1 | 294,38 | 9 | 5 | 2 |
| 2 | 404,43 | 8 | 1 | 2 |
| 3 | 55,723 | 1 | 1 | 1 |
| 4 | 315,74 | 2 | 1 | 2 |
| 5 | 343,78 | 8 | 2 | 2 |
| TOTAL AMMOUNT | | 28 | 10 | 9 |

Finally, the optimal configuration of dock 5 is similar to current state (8 doors, 2 workers for unloading, 2 workers for checking) with a makespan reduction of about 21.72%.

The simulation results recommend a reorganization of the receiving area in order to increase functionality and performances.

## 6. CONCLUSIONS

The logistics platform is a fundamental component of the supply chain; it is the link between the producers and the consumers and, in general, it accounts for 15-20% of the logistic costs. It plays a double role in the logistics network: it is both a “container” of goods in stock and a “transformer” of inbound flows into outbound flows.

Therefore, there is the tendency to improve productivity and to reduce the total supply chain cost.

The paper proposes a “what to” approach to optimize the activities and functionality of the receiving area in a logistics platform operating in the food sector.

The optimization has the aim to minimize the time spent by inbound trucks at the node through the formulation of a discrete event, stochastic, dynamic micro-simulation model implemented by using the WITNESS software.

The proposed model is a useful decision support tool for operators of existing logistic platforms, since it allows the analysis of the real functionality/efficiency of the receiving area. The aim is to obtain some useful indicators to establish if the current organization of space and distribution of resources are the best possible, or if a reorganization is necessary to offer a better service level to the inbound trucks.

The model allows ex-ante performing evaluations on the receiving area efficiency for the platforms to be built, so that the operators can define the physical structure of the node and identify the resources necessary for the receiving activities by using suitable efficiency indicators.

The proposed optimization procedure has good transferability to similar contexts (cross-docking, urban distribution centres, etc.).

Future developments of research will integrate the proposed model in order to carry out the efficiency analysis of the whole platform. In addition, a few elements considering ITS technologies used to perform the internal activities of the node will be studied.

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