*Proceedings of the 24th International Conference on Harbor, Maritime and Multimodal Logistic Modeling & Simulation (HMS), 001*
19th International Multidisciplinary Modeling & Simulation Multiconference

2724-0339 © 2022 The Authors.
doi: 10.46354/i3m.2022.hms.001

# Advanced management in a logistics platform equipped with automated handling means

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## Abstract

A logistics platform represents a fundamental ring of the supply chain; it receives, stores and delivers goods trying to face the organizational problems of various type (economic, financial, technological, production, logistics, etc), experimenting with new organizational solutions aimed at making its production and logistics structure more efficiently. *Its efficiency depends on many factors and is important because costs affect the production or distribution accounts and ultimately fall on the consumer* (Gattuso et al., 2014a).

In a context more and more addressed to the search for solutions able to increase productivity and pursue sustainability, the paper aims to improve the performance of Logistics platform, and therefore of the Supply Chain, by using freight advanced handling systems of the latest generation. After an analysis of the logistics platform standard asset and the related handling means used for the goods movement, the attention is focused on a smart organizational and functional structure (fleet management) with automated handling vehicles. The paper aims to evaluate the impacts in terms of time in a scenario of partial and total automation of a system using a simulation approach.

**Keywords:** Logistics platform; automated handling units; intelligent systems; simulation

## 1. Introduction

In a scenario of increasingly intense competition, the managers of the logistics nodes try to experiment with new organizational solutions aimed at making their production structure and the logistics related to the management and transport of goods more efficient.

In recent years, strategies have been aimed at introducing intelligent systems that allow activities to be developed efficiently by eliminating time wasters, increasing safety, ensuring a higher level of sustainability (Gattuso et al., 2022).

A very interesting area concerns the automation of freight handling systems in a logistics platform. The main objective of the research is to analyse the impacts of Handling Units (HUs) characterised by different level of automation.

In the sector literature, there are several studies about intelligent applications in a logistics platform (Custodio and Machado, 2020). Some authors focus on optimization procedures, as resource allocation or goods picking, to improve the management performance of the logistics platform (Rahman and Rutz, 2015; Petrucci et al., 2010; Manzini et al., 2007). Researches are related to intelligent application on the freight and vehicles management (Oleari et al., 2014; Vivaldini et al., 2010; Amato et al., 2005).

The paper focus on the intelligent/automated vehicles that make possible to speed up the goods handling allowing a reduction in traditional labour.

They require continuous monitoring and intelligent management entrusted to specialized personnel. The use of automation technologies is also viewed positively from an energy and environmental sustainability point of view. Handling vehicles should be able to carry out operations without a driver, remotely controlled by traffic supervision operators. Automation requires specific navigation infrastructures; each automatic vehicle is subjected to continuous control in real time, thanks to the presence of a telecommunication network whose brain is located in a central control post.

The paper gives an updated framework of traditional and automated handling systems by comparing their operational/management characteristics in order to identify the best systems to use to optimize logistic activities in relation to the specific context and thus guarantee competitiveness, economic and environmental sustainability.

The work follows a simulation approach and an application on a logistical context is described. Specifically, the ordinary set-up of the systems considered will be compared, following a *what if* approach, with project scenarios that provide for the partial and total replacement of traditional vehicles with fully automatic. The goal is to evaluate the impact of the automated vehicles on the logistic platform, in terms of number of stored load units.

Specifically, the study concerns a simulation model, through the use of Flexsim software, which represents a real logistics platform located in Northern Italy. The model focuses on the receiving and the storage area and, through the building of different project scenarios, allows to compare the performance of different HUs. The simulation software represents an evaluation tool to direct sector managers towards better intelligent solutions than ordinary systems without directly experimenting in reality.

## 2. Handling Units

The HUs in a logistics platform influence the dimensional characteristics in terms of width of the corridors and height of the shelving. The HUs can be classified according to the mobility constraints: free systems, with flexible paths (i.e. industrial trucks); systems with fixed paths (i.e. conveyors, AGVs); systems linked to an assigned operating area (i.e. cranes, bridge cranes, robots). In relation to the operational phases, there are: continuous systems, in which the operations take place simultaneously; discontinuous systems, in which they occur in series. About the level of motorization, there are manual and motorized operations. There is also a classification based on the type of command, in particular, there are: systems with operator on board; with operator on ground; without operator; automatic systems. Finally, it is possible a subdivision of the systems according to the type of movement: with vertical lifting; with horizontal transport; with lifting and transport; systems with vibratory and rotary movement.

The description of the most used HUs in a logistics platform is described below considering the ordinary and automated means.

### 2.1. Ordinary Handling Units

Among the ordinary HUs it is possible to include Counterbalance forklift, Forklift with retractable mast, Narrow aisle forklift, Pallet truck.

The *counterbalance forklift* is a handling unit that has the forks at the front, through which the load is lifted (Fig. 1). These elements are fixed by means of a slide on two uprights, along which they can slide vertically, operated by a chain system or by hydraulic pistons. This HU requires corridors of at least 3.3 m for the goods loading/unloading, to allow the positioning of the mean perpendicular to the loading unit. The rear part of the bodywork is often suitably bevelled, to facilitate manoeuvring operations. The maximum height that can be reached by the forks is 8 m. In the electric forklifts, the mass is provided by the batteries and by the electric propulsion motors; the maximum idle travel speeds are in the order of 3 m/s; the maximum capacities are around 2,300 kg. In endothermic engine means, the rear part must be suitably "ballasted"; they reach speeds of up to 3 m/s with load and allow lifting up to 4,300 kg.

**Figure 1.** Counterbalance forklift (www.mecalux.it)

The *forklift truck with retractable mast* is a vehicle very similar to the counterbalance forklift with the particularity that, after having picked up the load, it positions the mast in such a way as to balance itself with the counterweight, i.e. with a maximum movement of 0.8 m. The greater stability that characterizes the forklift is due to the centre of gravity of the load that is always within the polygon circumscribed by the wheels. This vehicle is used to move the load at greater heights, up to 10 m; the capacities are around 3,000 kg, while the speeds are in the order of 3 m/s. To be able to carry out the loading/unloading operations, the aisles must have a width of at least 2.5 m.

*Narrow aisle forklift* has the forks that can be oriented in the three directions moving along a front slide (Fig. 2). The positioning of the trolley perpendicular to the load unit is not required. This HU is suitable for operating in small corridors, of the order of 1.4 m. Generally, it can move up to 2,000 kg and the forks reach up to 15 m. There are means with counterweight and with front support spoke types. The first ones allow to lift loads up to 9,000 kg up to 6 m, the means equipped with front support spokes can also be used for the storage of load units in double-depth racks and allow the lifting of loads up to 1,800 kg for 11 m in height.

**Figure 2.** Narrow aisle forklift (www.mecalux.it)

The *pallet trucks* are manual means with limited possibility of lifting, about 13 cm, which are therefore used for the horizontal transfer of pallets for frequent handling and reduced distances. This HU can be used only for transport on particularly smooth surfaces and with reduced slopes. They can be both manual and electrically motorized by means of batteries. Travel speeds are limited to a few meters per second for the motorized versions, with capacities of around 2,000-3,000 kg.

## 2.2. Automated Handling Units

Typical Automated HUs are Automated Guided Vehicle Automated Storage and Retrieval System, Vertical Lift Module, Stacker crane, Roller conveyor, Belt conveyor, Sorting system

The *Automated Guided Vehi*cles (AGVs) are widely used means that can transport raw materials, semi-finished or finished products, in the form of load units, without human presence, following predetermined path (Fig. 3). They adapt very well to production environments where demand is variable and the short life cycle of the products requires flexibility and adaptability of the material handling systems because they guarantee a rapid and efficient reorganization of material flows (*Ali and Khan, 2010*).

**Figure 3.** Examples of AGVs in warehouse

There are numerous technologies adopted to drive an AGV; the most common are:

- wire guide: a wire is placed under the floor surface and crossed by an electrical signal at a certain frequency. A pair of solenoids arranged on the HUs is able to detect the position of the wire and electronics control the steering;
- colored strip: realized by paints or colored ribbons; an optical system detects the position of the strip and controls the steering with a logic similar to that of the wire and magnetic guide;
- magnetic strip: a magnetic strip is placed under the floor and thanks to the different polarity of the strip it is possible to identify some positions;
- odometric guide: the movement takes as a reference reflector placed on poles along the path. Each AGV uses a laser which, hitting a reflector, is reflected and thus identifies the direction;
- GPS which allows to know the position of the AGV with high accuracy and then be able to guide it. It is a precise guide and does not need to identify paths through bands, making the vehicle able to travel different paths by acting on the control logic.

*Automated Storage and Retrieval Systems* (ASRS) consist of a stacker crane that can move on guides, along corridors, storing and/or picking up the products in the racks on both sides (Fig. 4). The horizontal and vertical movements are performed simultaneously.

**Figure 4.** Examples of ASRS

The storage structure can reach 40 m in height and can be single, double or multi-deep. The storage depth depends on the type of product and the technology. Multi-depth systems are mainly used for product storage where one of the purposes is to use as little space as possible. These systems can be classified in relation to the movement of depth:

- Rack push-back, where the crane stores the loads mechanically pushing them into the storage aisles. The system works according to the LIFO rule. A slight slope on the storage aisle uses gravity to ensure the load availability in front of its aisle.
- Conveyor-based system, in which there are conveyor systems with only two directions of movement. The operation is LIFO and the logic is very similar to push-back rack systems.
- Satellite-based system, in which a satellite connected to the crane is used to perform the movement deep into. To carry out a storage operation, the crane takes the load to be stored with a shuttle and goes to the storage aisle. Subsequently, the crane releases the shuttle which travels along the storage aisle to position the Load Units. The same logic also applies to withdrawal operations. An evolution of this technology is the Automated Vehicle Storage and Retrieval System.

*Vertical Lift Modules* (VLM) are vertical storage systems in which two columns of trays are mounted in a central lift, equipped with an insert (extractor) (Fig. 5). When a picking order arrives, the extractor identifies the trays in which the presence of the required item is stored and brings the tray to the specific position.

**Figure 5**. Example of VLM

The *stacker cranes* are sliding vehicles with a vertical column (or two) which in turn can move along the corridor; this frame is equipped with steel forks (Fig. 6). They require a corridor width of about 1.6 m; the reachable height is over 30 m.

**Figure 6**. Examples of Stacker cranes

*Roller conveyors* are motorized transport systems which do not accompany the load in its movement; they therefore remain fixed while the load unit moves (Fig. 7). The load handling on the roller conveyor takes place through motorized rollers that push forward by friction. Not all rollers are motorized, usually there is an alternation of motorized and idle rollers, depending on the size of the load unit to be transported. To have continuity in motion, each load unit has to always be simultaneously placed on at least two motorized rollers.

**Figure 7**. Examples of roller conveyors

The *belt conveyors* (Fig. 8) are systems used for the transport of materials units. They consist of a canvas or rubber belt, wound on two wheels, which moves by friction thanks to a driving wheel. The material, deposited on the belt in the loading area, is transferred towards the unloading. To contain the traction force to be transmitted for the movement of the belt, the driving wheel must be the wheel near the unloading area; on the non-driving wheel, on the other hand, screw or spring tensioning systems are mounted.

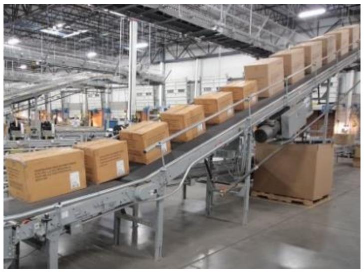

**Figure 8**. Examples of belt conveyors

The *sorting systems* make use of plates (Fig. 9), trays hooked to a central dragging chain, which transports the product along the output bays (sorting) and releases it at the destination chute (area, order, courier, etc.). The loading can be done directly by the operator on the plate or through one or more launch belts, which connect the worktables with the sorter by depositing the product on the tray thanks to a simple and reliable product/tray tracking system. The code (bar code) of the product positioned on the plate is automatically read and a supervision system manages the unloading and control with respect to the sorting plane.

**Figure 9**. Examples of sorting system

## 3. Scenario Design for logistics platform. Simulation and optimization procedures

The organizational problems of various kinds of a logistics platform are quite complex and timely decisions must be taken, since the delay results in loss of capital and damage to the system. It is rarely possible, convenient or legitimate to carry out experiments on the real system, even if this is the only way to have reliable answers. An alternative is to conduct experiments on a, more or less simplified, model that represents as faithfully as possible a real object or phenomenon. Models can be divided into physical models or abstract models; the latter ones can be divided into two categories.

The first class foresees the formalization of the problem in a mathematical form from which it is possible to obtain the solution to the problem; they use the principles of mathematical analysis, probability theory and statistics. A mathematical model is often constructed with the purpose of providing predictions about the future state of a phenomenon. Generally, the model describes the probable evolution of a phenomenon or a physical system on the basis of initial data (initial conditions) provided by the user (input), returning final data (output). The effectiveness of the model can then be measured by comparing the final data with the current observed result of the evolution of the phenomenon or system.

The second class consists of simulation models that allow to reproduce the behaviour of a real system and to evaluate the dynamic development of a series of events following the imposition of specific conditions. The simulation techniques make use of the principles of logic, mathematics and the possibilities of calculation offered by information technology.

The simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system (Shannon, 1975). Simulation is a tool which makes use of the computational potential offered by information technology; it is the transposition in logical-mathematical-procedural terms of a conceptual model of reality defined as the set of processes that take place in the observed system and whose whole allows to understand the operating logic of the system. The purposes of the simulation can be multiple: to answer the question "what happens if ..." (*what if approach*) or "how to do ..." (*what to approach*), compare two or more systems, optimize some parameters, identify the critical points of the system, predict its future behaviour, etc.

The advantages of simulation are linked to the fact that it allows to represent real systems, even complex ones, also taking into account the sources of uncertainty; and to reproduce the behaviour of a system in reference to situations that cannot be experienced directly. On the other hand, it provides information on the behaviour of the system, but does not give exact answers; the analysis of the output of a simulation could be complex and it could be difficult to identify which is the best configuration; the implementation of a simulation model could be laborious and furthermore high calculation times may be required to carry out a meaningful simulation.

The choice between analytical solution models and simulation models depends on the complexity of the model; if the abstract model created is simple enough, then it is possible to solve it by means of an analytical approach (differential equations, linear programming, queuing theory, etc.), alternatively it is necessary to resort to simulation techniques. The latter ones are more flexible, on the other they do not provide information on the choices to be made, and must therefore be used in conjunction with other analysis techniques.

The functional management analysis of a logistics system is often addressed using a simulation model following two different types of approach: what if; what to. Fig. 10 compares *what to* and *what if* approaches in the case of designing a transport network.

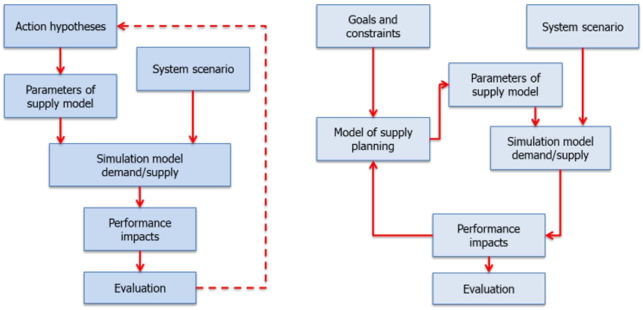

**Figure 10.** Approaches to the Scenario design on the transport systems (Elaboration from Cascetta, 2006)

## 3.1. *What if approach*

*What if* approach allows to evaluate the impact of a given action on the system in order to plan optimal strategies to achieve the objectives. In this type of application, called descriptive, mathematical models are used that aim to simulate the operation of a complex system, such as a freight interchange node, of which the supply system and the system of activities are exogenously defined.

*What if* analysis is a simulation with the goal to inspect the behaviour of a system under specified hypotheses called scenarios. In particular, it measures the variations of independent variables that characterize the system on a set of dependent variables. Therefore, formulating a scenario means building a hypothetical system that the analyst can interrogate to carry out a series of assessments.

*What if* analysis should not be confused with a forecast, as there is an important difference; in fact, the forecast is normally carried out by extrapolating the trends from the historical series stored in the information systems; *what if* analysis requires the simulation of complex phenomena whose effects cannot be determined simply as a projection of past data. On the other hand, the application of forecasting techniques is often required during the *what if* analysis.

## 3.2. *What to approach*

*What to* approach provides indications on how to intervene on the system to optimize determined objectives in compliance with fixed constraints. Through this type of application, during the design phase, it is possible to answer the question "what to do for"; the aim is to improve the results in order to increase the performance and efficiency of a system. Optimization is a process that selects the best system configuration. In general, according to this approach, the problem to be faced is expressed as an optimization problem (minimization or maximization) of an objective function, subject to constraints which can be expressed in the following form (1):

$$\begin{cases} \min f(x) \\ x \in X \subseteq R^n \end{cases} \qquad (1)$$

where *f(x)* is the objective function, *x* is the vector of the decision variables with *n* components and *X* is the subset of Euclidean space $R^n$ defined by the constraints.

The objective is to identify the vector *x* (the values to be assigned to the *n* decision variables) which, respecting the constraints, minimizes the value of the objective function.

The optimization methods can be differentiated in deterministic and stochastic. The deterministic optimization algorithms determine the local extreme of the objective function by making use of the optimum conditions which typically are the zeroing of the gradient and the definition of positivity of the Hessian matrix calculated at an equilibrium point of the objective function, be it maximum or minimum. Stochastic optimization methods are optimization algorithms that incorporate probabilistic, and therefore random, elements either in the problem data (the objective function, approximations, etc.) or in the algorithm (through random parametric values, random choices, etc.) or both.

## 4. Methodological approach

The proposed methodological approach uses a simulation model. The study process considers the following phases (Fig. 11):

1. analysis of the problem that consists in studying the problem by trying to identify the goals of the study, the essential components and the reference performance measures;
2. data collection about the system that has to be entered in an appropriate database through which it is possible to analyse them in order to obtain further information;
3. definition of the conceptual model. It consists in representing the main components of the system, their relationships and the activities carried out using graphic languages (e.g., flow diagrams, Petri nets, etc.). In particular, in a first phase the functional areas of the node and the relationships between them are represented through a flow chart; then the system is represented using the graph theory. Generally, this phase is part of the simulation model construction process and, in particular, the specification phase, in which the conceptual model is defined and reference variables are identified. After the specification, it is necessary to analyse the trend of the reference variables in order to define the frequency distributions and the theoretical probability density functions able to represent this real trend in the best possible way (calibration);
4. implementation of the model through the use of software in order to reproduce the dynamic behavior of the system over time by representing the components and interactions in terms of functional relationships;
5. pilot simulations that allow to carry out the validation of the model; they allow to establish whether the defined simulation model is an accurate representation of the system being analyzed in relation to the set objectives;
6. simulation design. Before the run, it is necessary to decide how to conduct the simulation. Simulation results often lead to more complex configurations. There are also statistical problems since the simulation does not produce exact values of the system performance measures; each simulation can be seen as a "statistical experiment" that generates statistical observations on the performance of the system. These observations are then used to define the best simulation characteristics;
7. implementation of the simulation and analysis of the results. The simulation output provides statistical estimates of a system's performance measures. Each measurement is related to a "confidence interval" in which it can vary. These results may immediately highlight a system configuration that is better than the others, but more often more than one configuration will be identified as being the best candidate. In this case, further investigation may be required to compare the configurations;
8. presentation of results through a report that summarizes the study carried out, how it has been conducted, including the necessary documentation.

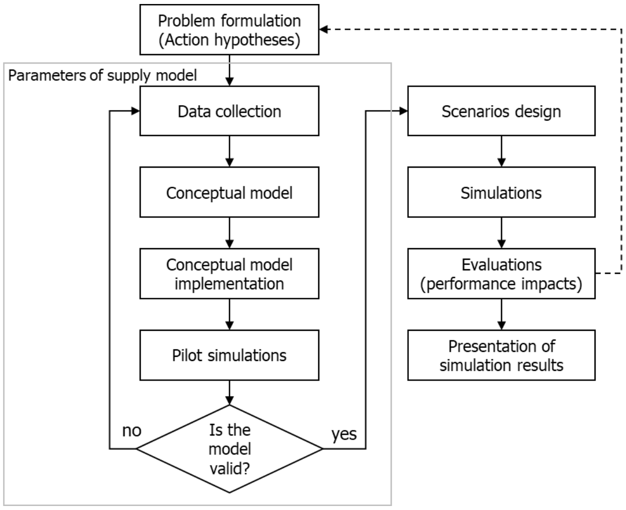

**Figure 11.** Process of a simulation study

In the proposed study, the simulation model has as its main objective to analyse the operation of a logistic platform in order to determine its performance in different system configurations (Scenarios). Specifically, the issues associated with the management/optimization of the fleet used for the handling of goods in the storage area are examined. The final objective is to reduce the time costs associated with the movements of goods in order to make the goods interchange node more competitive.

The model has been implemented through the use of FlexSim software.

## 5. Case study

The application is related to a logistics platform operating on Northern Italy (Cameri, Novara); it is configured as a logistics centre for food and household products distribution. Logistics activities take place six days/week from 5 am to 11 pm; the goods receiving time slot is 5 am-5 pm; the unloading operations continue until all the trucks arrived have all been served; the shipments start at 9 am and end at 10 pm.

The logistics platform covers a total area of about 55,000 sqm, divided into 5 main sectors (A, B, C, D, E). it is equipped with controlled temperature rooms for an area to accommodate fresh and flammable products. There are specific areas for maintenance and charging the batteries of internal HUs, technical rooms and an office room (Fig. 12). 175 employees work in the platform.

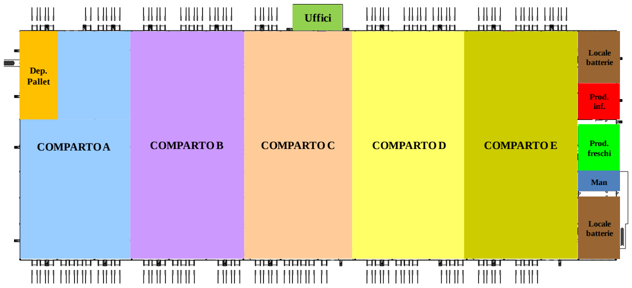

**Figure 12.** Layout of the logistics platform

Each sector of the platform is equipped with entrance/exit doors for loading/unloading truck operations for a total of 82 doors. The sector A is dedicated to the cross activity: the homogeneous pallets arriving at the platform are checked and returned within the day to the destination area (short storage). The other sectors are dedicated to carrying out storage and degroupage/groupage activities; the homogeneous pallets arriving at the platform are checked, stored and, if necessary, decomposed to pick up the packages that will form the uneven pallets exiting the node. Each sector corresponds to a specific product circuit. In each sector, there are dedicated areas for the freight handling, i.e., the area for the receiving goods and the qualitative and quantitative checks., the area for the composition of the outgoing loads, packaging and labelling.

The storage is traditional; it is equipped with double-sided shelves about 9 m high and divided into 6 compartments; the compartment at the base is dedicated to picking. Each shelve level can accommodate 3 pallets; each pallet cannot exceed the weight of 800 kg and the height of 1.30 m; the storage offers a capacity of 57,000 slots/pallets. The aisles between one shelve and another have an average width of 3.10 m and are crossed by zigzag handling vehicles.

The logistics platform is also equipped with a large area to allow trucks to stop waiting for service, the capacity of this area is about 150 trucks.

The HUs into the logistics platform, as well as the operations of lowering, raising and composition of loads are carried out with the aid of electric HUs of different types: Electric forklift with three wheels (EFG 110); Pallet truck (ERE 120); Electric forklift with four wheels (EFG 216); Forklift with retractable mast (ETM/EVT 216); Order picker (ECE 125).

The forklift with retractable mast is used for raising and lowering operations, i.e., for positioning the incoming pallets in the storage racks; the order pickers are used for the composition of the loads leaving the logistics platform; the pallet trucks are used to carry out the loading/unloading of trucks. The technical characteristics of HUs are specified in Tab. 1.

**Table 1.** Technical characteristics of HUs

| | EFG 110 | ERE 120 | EFG 216 | ETM/ EVT 216 | ECE 125 |
|---|---|---|---|---|---|
| Weight (kg) | 2,500 | 669 | 3,000 | 3,050 | 1,114 |
| Capacity (kg) | 1,500 | 2,000 | 1,600 | 1,600 | 2,500 |
| Width (mm) | 990 | - | 1,060 | 1,200 | 810 |
| Length*(mm) | 2,773 | 1,900 | 3,150 | 2,418 | 3,667 |
| Fork hoist. height (mm) | 4,500 | 122 | 6,000 | 9,200 | 125 |
| Travel speed °(km/h) | 12/12.5 | 7.5/8.5 | 16/16 | 14/14 | 9.5/12.5 |
| Hoisting speed °(m/s) | 0.3/0.5 | 0.1/0.1 | 0.5/0.6 | 0.4/0.7 | 0.1/0.1 |
| Lowering speed °(m/s) | 0.6/0.6 | 0.1/0.1 | 0.6/0.6 | 0.5/0.5 | 0.1/0.1 |
| Quantity | 5 | 25 | 5 | 20 | 65 |

* including forks; ° with/without load

### 5.1. *Model implementation*

The micro-simulation model has been implemented using the FlexSim software, a dynamic simulation tool, designed to allow the construction of interactive models of even complex production realities. The model implementation has been carried out by associating specific elements of FlexSim with the operational areas of the logistics platform and the activities/operations carried out.

The model has been implemented, starting from some previous authors works (Gattuso et al., 2014a; Gattuso et al., 2014b). All the input data in the model have been obtained by the authors through field surveys, in collaboration with the owner of logistics platform. The detected data have been systematized and organized in a database consisting of two parts; the first one contains all the "macro" information (dimensional and layout characteristics; over structural equipment; processes underlying the activities); the second one collects the information found during the "micro" survey referring to the five main node activities and related times.

The areas of interest are the receiving and the storage area; three models have been built in order to evaluate the performance of the system in the storage of goods considering different kind of HUs. The simulation scenarios have been configured by the authors in relation to sector experiences.

Scenario 0 reproduces the system in the current configuration, where the goods are stored using traditional HUs (Forklifts-FLs); there are 2 HUs for each receiving dock, for a total of 10 HUs. Scenario 1 has been built starting from the current state by replacing ordinary HUs with robots for storing goods, without alternating the number. Finally, scenario 2 considers different alternatives for the storage of goods; for docks A, B and C there is an AGV per dock, which moves the goods from the unloading door to a temporary buffer near the storage, which feeds an ASRS placed between two racks in each storage area; for docks D and E, for each dock, there is a robot that transports the goods from the unloading area to storage and an ASRS in series between two racks in each area.

The simulations have been carried out considering a platform operation of 720 minutes (5 am/5 pm) which is the receiving time of the trucks.

The trucks entering and the unloaded homogeneous load units (*pallets*) have been represented thanks to the use of *Source* and *Sink*, which allow the elements to enter the model and exit according to different rules, respectively. The trucks arriving at the platform, characterized by an *Inter-Arrival Time*, can be of five types in relation to the goods transported. This rule has been set in the model using the *Trigger on Creation* property.

The gatehouse that makes the vehicle document control, is schematized as a *Processor* with an average process time of 5 minutes and directs the arriving trucks to the dock suitable for unloading the type of goods transported.

The receiving docks are represented by 5 *Processors* whose process operating times are variable according to the previously defined statistical distributions. Each processor sends the trucks to the unloading doors represented by *Multiprocessor* in which three activities are defined: the control; the unloading; the ancillary times related to the positioning and approaching of the truck, waiting for checks and the possible loading of rejected pallets, and unloading operations.

To simulate the trucks unloading, a *Combiner* has been inserted on each dock, after the unloading doors, which associates the load on pallets for each truck and a *Separator* which directs the vehicles to the exit (*Sink*) and the pallets in a temporary storage area (queue) waiting to be moved inside the warehouse. These elements have zero process time as the unloading activities are already considered in each entry door.

Pallets temporarily stored near the doors are picked up and stored by 2 *Transporters* per dock managed by a *Dispatcher*. Storage is carried out with the aid of 2 *Racks* for each area of the warehouse sized according to the real data of the platform.

Fig. 13 shows the flow chart of the activities in logistics platform, referring to the activities that take place from the truck arrival to the goods storage, which are the logistics phases considered in the study

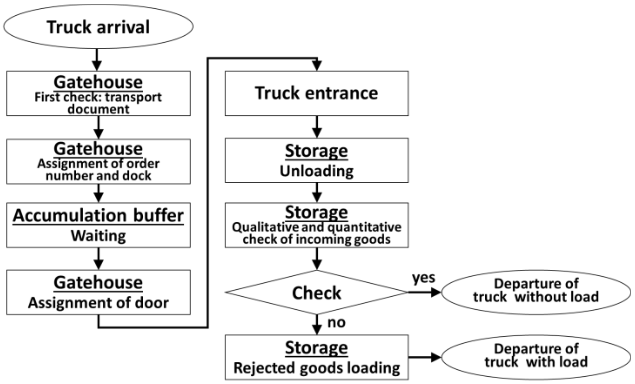

**Figure 13.** Sequence of activities in the receiving area

## 5.2. *Input data*

The application has been developed starting from a previously specified, calibrated and validated micro-simulation model (Gattuso et al., 2014a), that made possible to define some reference variables, identified in order to analyse the efficiency of the logistics platform to improve its performance and reduce the operational times of the node. The reference variables are the follows time costs: the trucks waiting time ($T_W$), the trucks service time ($T_S$), the trucks unloading time ($T_{unload}$).

To facilitate the interpretation of the logistics processes, the following variables have been also considered:

- the trucks number arriving at the node ($N_{TIR}$);
- the trucks Inter-Arrival Time (I);
- the unloaded pallets number per truck ($N_{UC}$).

The frequency distribution of each variable is shown in Tab. 2 (Gattuso et al., 2014a).

As regards the HUs for goods storage, in scenario 0 there are 2 forklifts for each dock, characterized by lift speed of 0.5 m/s and max speed of 12 km/h. Goods loading and unloading times of 30 s and 60 s respectively have been entered to take into account the docking/positioning manoeuvres of the platform and the identification of the unloading slot.

In scenario 1 and 2, the intelligent systems used have a maximum speed of 2 m/s and loading and unloading times of 10 seconds.

**Table 2.** Statistical distributions of the reference variables

| Variable | | Average (μ) | Standard dev. (σ) | Distribution/ Parameter |
|---|---|---|---|---|
| $N_{TIR}$ | 0:00-5:00 | 7 | 3 | P(λ=7) |
| | 5:00-17:00 | 112 | 20 | Geo(k=0.11) |
| | 17:00-21:00 | 1 | 2 | Geo(k=0.69) |
| | 21:00-24:00 | 8 | 6 | - |
| I (min) | 0:00-5:00 | 36.35 | 38.32 | Exp(θ= 0.028) |
| | 5:00-17:00 | 5.66 | 8.78 | - |
| | 17:00-21:00 | 55.00 | 48.60 | Exp(θ= 0.018) |
| | 21:00-24:00 | 8.98 | 13.95 | - |
| $T_W$ (min) | Dock A | 72.61 | 51.15 | B(α=1; β=3) |
| | Dock B | 65.14 | 53.97 | B(α=1.8; β=7.5) |
| | Dock C | 66.78 | 59.64 | Exp(θ= 0.015) |
| | Dock D | 73.71 | 64.14 | B(α=1.26; β=6.6) |
| | Dock E | 76.78 | 62.69 | B(α=1.20; β=3.9) |
| $T_S$ (min) | Dock A | 66.15 | 36.93 | Gam(k=0.068; λ=4.3) |
| | Dock B | 92.03 | 46.64 | Gam(k=0.042; λ=3.89 |
| | Dock C | 86.61 | 52.94 | Gam(k=0.031; λ=2.68 |
| | Dock D | 101.23 | 49.77 | Gam(k=0.041; λ=4.14 |
| | Dock E | 112.74 | 56.76 | Gam(k=0.033; λ=3.48 |
| $T_{unload}$ (min) | | 15,00 | 8.13 | G(μ=15; σ=8.13) |
| $N_{UC}$ | Dock A | 13 | 12 | Geo(k=0.076) |
| | Dock B | 30 | 18 | |
| | Dock C | 26 | 16 | |
| | Dock D | 27 | 15 | |
| | Dock E | 31 | 30 | |

P: Poisson; Geo: Geometric; Exp: Exponential; B: Beta; Gam: Gamma; G: Gauss

### 5.3. *Simulation results*

The scenarios implemented have been compared with reference to the storage operations and, in particular, to the ratio between the number of unloaded pallets and the number of pallets stored in the reference time window. It is important to understand how the efficiency of the logistics platform changes, replacing ordinary HUs with automatic ones. The results obtained from scenarios comparative assessments lead to evaluate the impacts of the intelligent systems on the productivity of a freight centre.

Specifically, by comparing the number of pallets unloaded, collected and stored in the three scenarios (Tab. 3), it emerges that intelligent systems significantly improve system performance. In fact, in scenario 0, 75.9% of the unloaded pallets are stored; in scenario 1, the storage is at 98.7%.

**Table 3.** Simulation results. Scenarios comparison

| | Scenario 0 | | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|---|---|
| Area | $N_{Udc}$ stock | % | $N_{Udc}$ stock | % | $N_{Udc}$ stock | % |
| A | 686 | 84.6 | 785 | 99.2 | 750 | 94.8 |
| B | 604 | 65.5 | 882 | 95.5 | 784 | 88.1 |
| C | 231 | 88.2 | 198 | 100.0 | 231 | 100.0 |
| D | 622 | 71.3 | 792 | 100.0 | 759 | 85.3 |
| E | 613 | 67.4 | 957 | 100.0 | 829 | 89.7 |
| Tot | 2,756 | 75.9 | 3,614 | 98.7 | 750 | 94.8 |
| Δ | | | +31.1 | | +21.7 | |

In scenario 1, the storage operations are performed with robotic systems able to carry out their activities autonomously/ automatically and more quickly thanks to computerized settings managed remotely by an intelligent control system. Scenario 2, better than the current configuration (+16.55 in storage units), does not represent the optimal setting in relation to the number of storage units; in fact, there is a lower storage percentage than in scenario 1 (-8.7%). On the other hand, scenario 2 is advantageous from the point of view of the number of vehicles considered; setting up automatic storage systems in the warehouse, the scenario considers 1 HU for each dock; half of the other scenarios.

Other considerations can be proposed in relation to the comparison of the operational level, or better of the idle time, of the HUs in the 3 scenarios (Fig. 14).

In scenario 0, the busy status of each HU is close to 90% in Docks A, B, D and E; this means that in order to store the unloaded pallets without generating slowdowns, and therefore without affecting the platform performance, the HUs are forced to carry out continuous activity. In dock C, on the other hand, the long waiting, checking and unloading times of the goods lead to high states of idle (up to 70%).

In scenario 1, the robots, thanks to the performance offered, involve low handling times; this means that the unloaded pallets are stored almost immediately. The HUs wait for the goods to be unloaded in order to carry out their duties. This is evident from the HUs status of idle is very high. This suggests that the use of this type of HU leads to reduce the HUs number to meet the needs of the platform, without compromising performance.

In scenario 2, although the number of stored pallets is lower than in scenario 1, the HUs idle time is lower than in scenario 1 (reduced number of HUs for handling, less downtime). It is deduced that the waiting of the pallets in the unloading area is not linked to the limits of the AGVs/robots that have an average level of activity close to 50%. This means that the waiting pallets have been downloaded at the end of the simulation period.

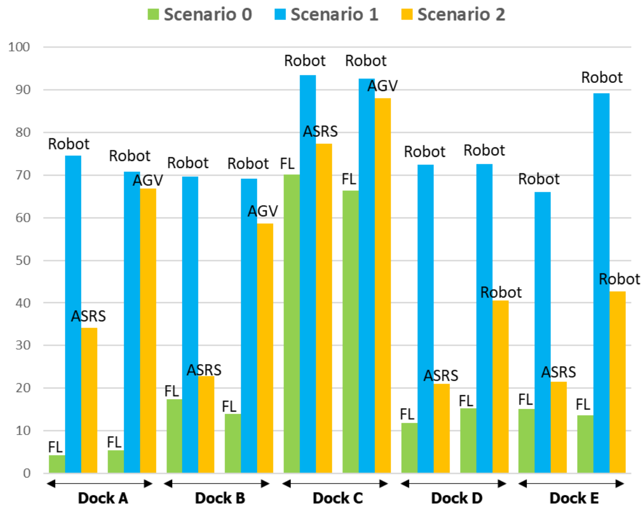

**Figure 14.** Idle status of HUs in the 3 scenarios

## 6. Conclusions

Automation is nowadays applied in an increasingly broad and transversal way to more sectors; it gave rise to important changes in the socio-economic field and led to changes in the social, economic, political and cultural system such as to mark the beginning of a new era ("intelligent society").

The automation has influenced the logistics sector too that is addressed to experiment new solutions to increase productivity and improve the quality of services in order to be competitive by contributing to economic growth and development.

The paper has provided a framework of the traditional and automated means used for the handling of goods in a logistics platform. A case study has been introduced with reference to a real platform on the North Italy. The main objective of the paper has been aimed at assessing the impacts on logistics performance in relation to the introduction of automation technologies by using *what if* approach with the aid of a simulation software.

The automated systems can improve system performance in terms of costs and efficiency. On the other hand, these systems involve large investment costs related to the purchase which are balanced by the elimination of other costs such as those related to labour (driver). Economic evaluations will be carried out to understand the advantages of automated systems.

The work has been limited to the analysis of a functional component of the logistics platform, therefore the simulation is partial. The interest of the authors is to proceed, with a similar approach, on the other functional areas in such a way as to have a global evaluation of the whole system. Future research developments will concern the evaluation of other system characteristics such as monetary costs and energy consumption and the use of the *what to* approach.

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