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Its experimental applications in a freight interchange platform

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Abstract

The logistics and transportation sectors research new ways, new strategies and new technologies to improve the efficiency and the competitiveness, reducing the waste and increasing the services quality.

The ITS (Intelligent Transportation Systems) allow an efficient management of the logistics processes and represent useful tools for companies to produce new knowledge, new organizational models and new business cultures in order to carry out competitive advantage.

The paper aims to highlight the ITS contribution in the management of the freight interchange nodes. Four case studies are proposed, in which the current system is compared with some project scenarios involving ITS in the logistics activities.

The reference system is an agri-food platform and the study concerns the processes related to the inbound activities. The analysis has been carried out using a dynamic, stochastic, discrete-event micro-simulation model, conveniently specified and calibrated.

Keywords: Intelligent Transportation Systems, freight interchange platform, micro-simulation model, logistics, transportation sector

1. Introduction

In the literature, there are several studies about ITS/ICT (Intelligent Transportation System/Intelligent Communication System) applied to the logistics platforms like the warehouses. A framework of these studies has been proposed by Gattuso et al. (2014a) in the context of a paper related to the building of a stochastic, dynamic, discrete-event micro-simulation model for evaluating the impacts generated by ITS application in a logistics platform.

El Ouadaa et al. (2017) classify ICT in two dimensions: the corresponding business services and the related ICT deployment factors. ICT deployments are made up of hardware and software components. ICT business services are related to warehouse operations management; transportation management; anti-counterfeiting; anti-theft; quality monitoring.

Apiyo and Kiarie (2018) organize sector studies in relation to five ICT classes (independent variables): Bar coding, Radio Frequency Identification, Enterprise Resource

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Planning, Materials Resourcing Planning and Distribution Requirements, on which supply chain performance depends (dependent variable).

Liu et al. (2018) look at technologies useful to build smart warehouses under 4.0 vision, considering four topics about the data collection, the localization, the human resources activities and the multi-robot cooperation.

Other authors focus their research on specific technologies to improve the supply chain and logistics systems. Hamdy et al. (2018) suggest a WMS (Warehouse Management System) based on IoT (Internet of Things) to help the warehouse manager to control and monitor the activities in real time. Lee et al. (2017) propose an IoT-based WMS using computational intelligence techniques to achieve the vision of Industry 4.0. Yan et al. (2016) design a IoT system to support the agricultural products tracking and tracing in agricultural supply chain. Some web applications are proposed by Sahuri and Utomo (2016) that provide a web service to send information to help the small sized manufacturing company to improve their business and warehouse management. Patil et al. (2018) elaborate a web application to make the warehouse more efficient, able to manage multiple users, multiple warehouses, stock inward and outward. Jabbar et al. (2018) propose a web-oriented architecture to enable smart communication.

Many authors focus on RFID (Radio Frequency IDentification). Oner et al. (2017) design an RFID-based information system for a wool yarn industry for the purpose of managing both past and ongoing jobs, keeping track of the status of semi-finished products. Kirch et al. (2017) describe an intelligent approach for logistics in which RFID make possible to have the location and status of each element of the supply chain. Qin et al. (2017) deal with the inventory inaccuracy impact on bullwhip effect building different scenarios where RFID systems are applied. Adiono et al. (2017) propose a RFID based system to obtain the distance to the location of the purchased good. Pane et al. (2018) focus on the qualitative evaluation of RFID implementation on WMS.

In this context, the paper aims to evaluate the impacts of ITS applications in the inbound activities of a freight interchange node by using a micro-simulation model proposed by the authors. In particular four case studies were analysed. The specific applications have been carried out to understand the advantages deriving from the use of different intelligent systems in a freight interchange platform and to highlight how the introduction of these technologies can influence the global supply chain.

2. Micro-simulation model

The micro-simulation model helps the management of a freight interchange node and, in particular, allows to optimize the inbound activities. The model makes a representation of the system evolution in time and moreover provides the tools to evaluate the impacts of some potential actions on the system as the ITS applications.

The micro-simulation model has been developed in previous studies (Gattuso and Cassone, 2012). The model has been built, and in particular, it has been specified, calibrated and tested; the results of each phase have been proposed in a previous work (Gattuso et al., 2014a).

The specification consists in the definition of the reference conceptual model and in the individuation of the main system variables in relation to the specific aim of the study. The aim of the work is to optimize inbound activities in order to reduce the time that inbound trucks spent at node, the so-called *receiving makespan* (T_I), that is composed by the waiting time of trucks in the buffer (T_w) and the service time for each truck (T_S). The service time (T_S) can be formulated as:

$$T_S = T_{unload} + T_c + T_{extra}$$

It consists of the time for the freight unloading (T_{unload}), the early checking on inbound freight (T_c) and an accessorial time (T_{extra}) for the positioning and docking of trucks at the dock/door; the loading of the rejected pallet; the closing and the undocking of trucks and the waiting time before of the next checking activities.

3. Case studies

The case studies focus on ERP (Enterprise Resource Planning) and EDI (Electronic Data Interchange) for the optimization of the freight inbound activities; ICT for the management of the inbound trucks queue; RFID for the checking of the inbound freight; WDS (Workforce Deployment System) for the optimizing of the human and instrumental resources.

For each case study the technologies and the logistics activities (context) are defined; the advantages related to the ITS applications (objectives) are illustrated, the project scenarios (achievements) are described and finally the results are presented.

The analysis has been carried out referring to a logistics platform, operating at local/regional level in agri-food sector in the Northern Italy. The considered platform covers an area of about 55,000 sqm and is partitioned into 5 compartments (A-B-C-D-E) each of which is reserved to allocate a specific type of goods. The platform is operative six days a week, from 5:00 to 23:00; the time window for the reception is 5:00-17:00, instead the consignments to final clients take place from 9:00 to 22:00. The evaluations have been realized with reference to different scenarios in which the management of the trucks arrivals and the freights receiving activities are carried out through the use of ITS. The scenarios have been built from the current configuration using a “what if” approach.

3.1 Management of the inbound activities by use ERP and EDI

The combined use of ERP and EDI systems to logistics activities allows both the reduction of the waiting time for the users at the receiving area and the improvement of the system performance.

ERP system is an efficient tool to obtain, to elaborate and to send information along the inter-functional flow of the business activities, allowing a better management of the organizational innovation. In particular, this technology allows to plan the goods unloading from inbound trucks, in time windows, in relation to the needs of the storage area. It is possible thanks to intelligent exchange of information among the logistics system and the different suppliers. The system allows to reduce or remove the waiting time of inbound vehicle for the availability of a door to unload the goods.

The ERP system can be integrated with EDI technology, guaranteeing an improvement of logistics process thanks to a structured and organized management of the different operational functions. The main aim of the EDI is the connection computer-to-computer and the data direct elaboration, reducing or removing the human action; this requires a complete agreement among the connected organizations not only in relation to the systems and protocols for computers networks, but, above all, in relation to the structure and the messages contents so that they can be directly interpreted. This agreement involves technical, organizational and strategic aspects.

The integration between ERP and EDI allows to:

- optimize the trucks arrivals reducing the waiting time;

- coordinate orders, marketing, logistics, purchases, human resources;
- improve the speed of order transfer, the consignments and the invoicing;
- improve the quality of data reducing errors and inconsistency;
- reduce the costs related to orders forwarding and dead times.

An ERP system planning the goods unloading reducing or removing the waiting of truck at the gatehouse. Instead, the EDI informative system, through the complete computerizing of information, allows a reduction of times due to the checking of the transport documents, the processing of delivery documents and the elaboration of a sheet for the flawed or unsuitable goods.

The use of ERP and EDI systems for management the arrivals in a logistics platform allows to reduce both the extra time and the waiting time with consequent impacts on *receiving makespan* (T_I).

In the simulation 168 inbound trucks and a logistics working time of 720 minutes have been considered.

The use of an intelligent system for the management of the arrivals allows eliminating the inbound truck queue, because the vehicles arrive when they can be served.

The ERP/EDI integrated technology weighs on the performance of the logistics platform. In particular referring to the variable T_I (Figure 1) there is evident a sharp reduction in the project scenario (Scenario 1) as compared to the current state.

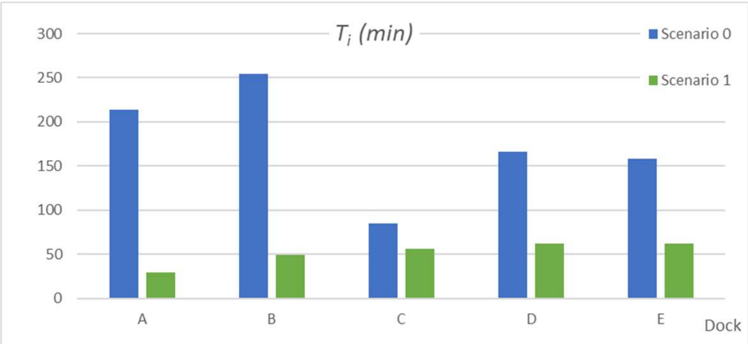

Figure 1: Values of T_I in the scenarios

The reduction of T_I is given by the decrease of their components (Figure 2). In particular a big variation of T_I is observed in the dock A and B because the waiting time, representing a significant rate of the receiving makespan in the current state, is equal to zero in the project scenario.

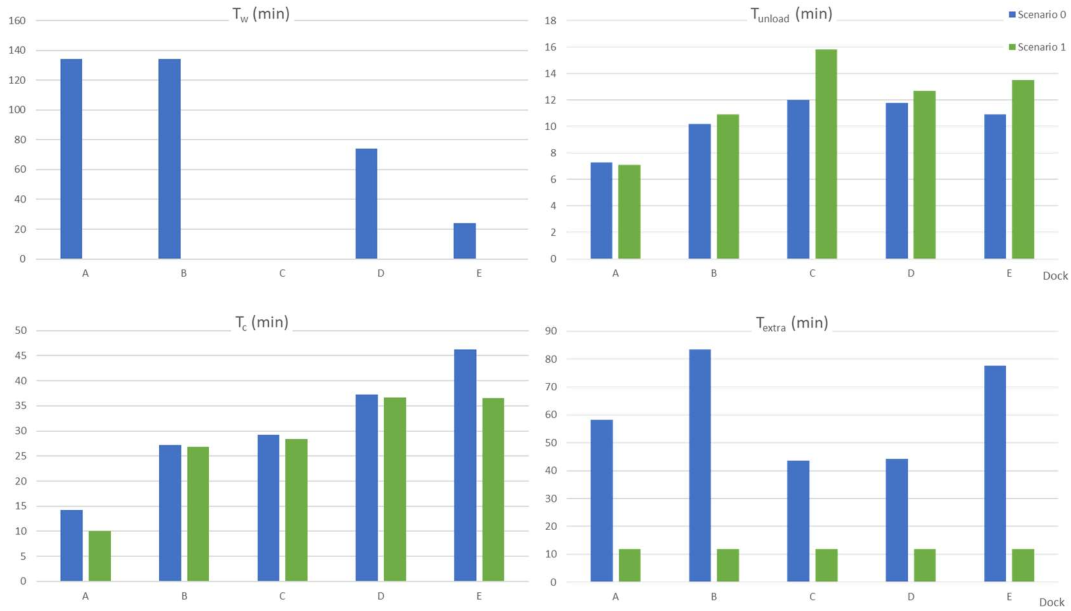

Figure 2: Values of the variables in the two reference scenarios

3.2 Intelligent management of the queue process by using ICT

This case study allows to examine the impacts resulting from the use of an intelligent system, composed of a management software and GPS devices, to organize the trucks arrival at a logistic platform so as to control the queue formation and to reduce the users waiting at the receiving area. The efficiency of a freight interchange platform can be evaluated in relation to the queue of trucks waiting the service.

A specific technological component, composed of a software and GPS devices, can be introduced to manage the queue, to streamline the arrivals and, consequently, to plan and manage the internal activities of the logistic platform.

Given the number of inbound trucks to serve on a working day and the goods type (k) transported by each vehicle, the software performs the scheduling of the inbound trucks assigning them in the time intervals in which the service is available, even depending on the priorities associated with the type of transported freights.

The software, thanks the information obtained from GPS devices, evaluates in real time the state of the service and the queue formation and, therefore, it knows the position of the vehicles directed to the platform. Where a queue occurs in the system and there is the inability to serve it in the time window programmed, the software makes a rescheduling of the inbound trucks. From the data provided by the GPS, the software detects the trucks further away from the platform or even those still at the origin of the trip, sending a message with which the driver is informed about the queue at the gatehouse and he is invited to postpone the arrival at platform to another time slot.

In the same way, it is possible to evaluate the impossibility of one or more trucks to arrive at destination for accidents during the trip. This implies that in the correspondent time interval the platform could be in a condition in which there are no trucks to serve. In this case, the software reveals the problem and makes a new scheduling of the trucks. The arrivals of some vehicles can be anticipated in order to guarantee a constant service in each time interval.

So, the intelligent system performs two types of operations: the management of the arrivals in relation to the current state of system service (Figure 3) and the scheduling of the inbound trucks in relation to the trucks positions in the network (Figure 4). Both operations are based on a preliminary phase that can be expressed in the following steps:

- inputs: the number of inbound trucks in a time window (N_{TIR}) and the type of goods (k) on each truck;
- the assignment of the priority levels to trucks in relation to the type of good transported;
- the partition of working day in time intervals ΔT_j (with j=$1, 2, \ldots, n$) and the assignment of trucks to ΔT_j;
- outputs: sequence of inbound trucks in the considered working day: $S^0_{TIR}=\{S^j_{TIR}\}$ with $j=1, 2, \ldots, n$.

The intelligent system has to guarantee that the inbound flow arrives at the platform during the working time and the flow does not exceed the service capacity.

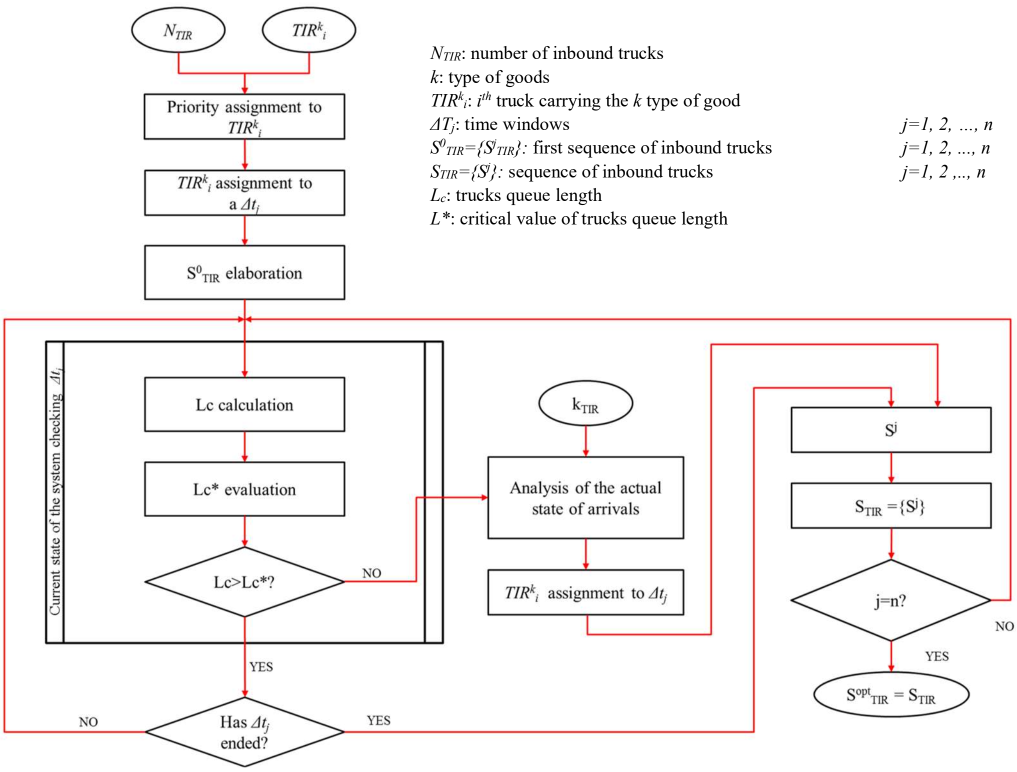

Figure 3: Flow chart of management operations of the truck's arrivals in current state

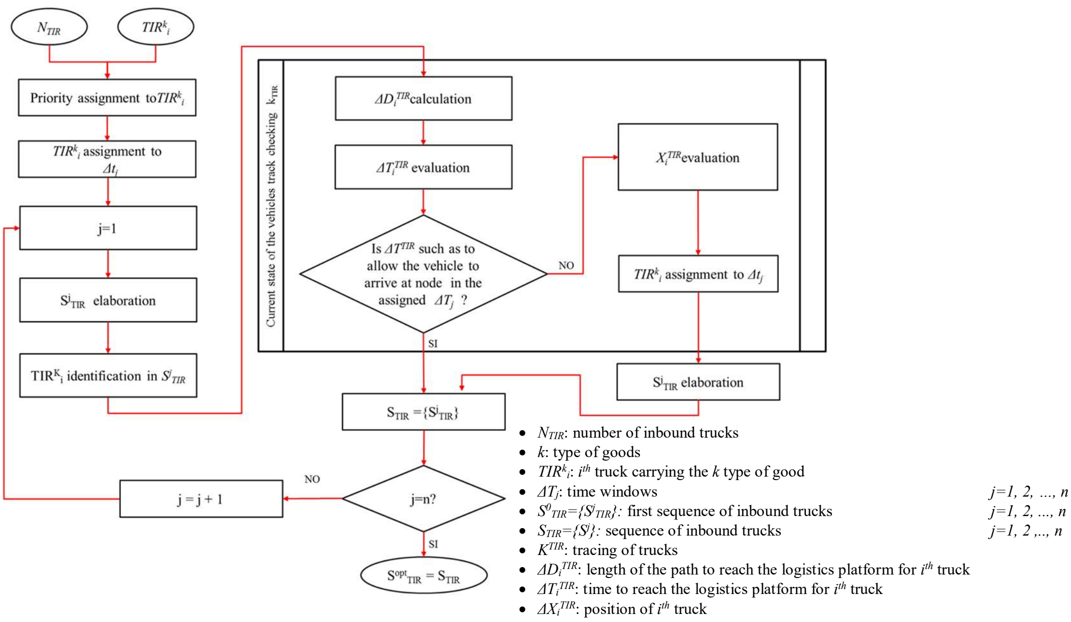

Figure 4: Flow chart of inbound trucks scheduling in relation to the network positions

The integration of the management system and the devices placed in the truck allows to control the queue formation in the receiving area, producing a reduction of the waiting time. Therefore, the proposed system allows the optimisation of the number of labours in the inbound activities according to the prediction of the arrivals.

In the project scenario, the proposed integrated management system makes sure that the trucks arrive only when they can be served, together with to a correct management of serving resources.

In the considered logistics platform, the organization of the arrivals is managed by the gatehouse, where the inbound trucks wait for the service. The service is provided simultaneously to ten vehicles, as there are 10 doors (s = 10) of the platform working in parallel.

The following hypothesis are assumed: a Poisson distribution of the arrivals with average rate of arrivals λ; the service times are independent and their distribution is an Exponential with parameter μ; the population has a limit value that is 154, the max number of inbound trucks in a day; the capacity to serve inbound trucks is equal to 9 vehicles/h; the queue discipline is PRI (the trucks are served in relation to priority levels). The queue problem can be summarised as *M/M/10/9/154/PRI.*

The simulation of the current state (Scenario 0) shows that the analysed system is saturated (utilization factor of the system ρ = 1.13>1).

Overall, it is possible to observe that all inbound trucks undergo an average delay of 2.8 h; the queue is disposed after two hours of scheduled time for the completion of the receiving activities; the average waiting time of the service is equal to 1.8 h; the maximum waiting time is 3.36 h; the maximum queue length is equal to 35 trucks.

The introduction of the integrated system for the management of the arrivals and the correct organization in real time of serving resources allows the control of the queue formation and the optimization of the available resources. For example, the Figure 5 compares the cumulative flows in the considered scenarios with reference to Dock D, where at current state there is a high level of saturation. The introduction of the proposed system can significantly reduce the time required to perform the receiving activities.

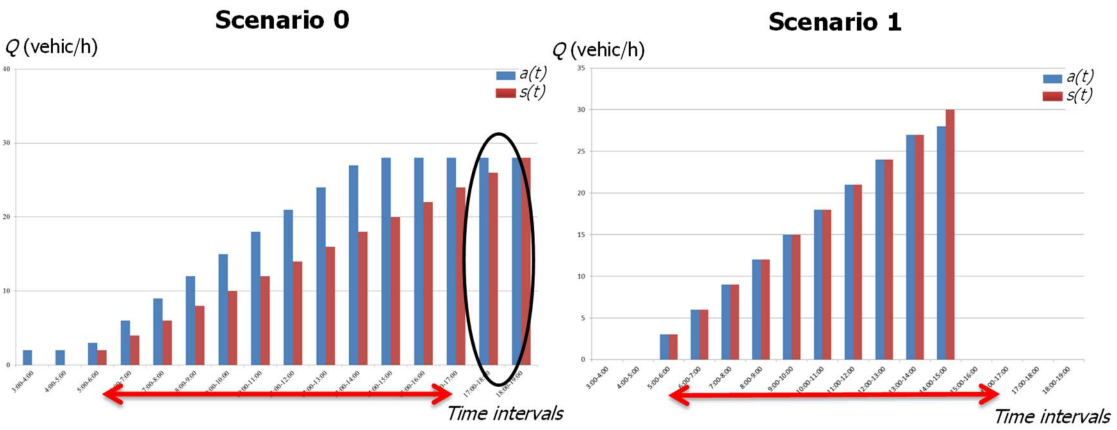

Figure 5: Comparison between Scenario 0 and 1 in terms of cumulative flows

3.3 RFID for the inbound goods checking

This application concerns the use of RFID in a logistics platform in order to reduce the goods checking times in inbound doors.

The checking activity not only affects the appearance of the goods (crushed or broken cartons, pallets noncompliant or damaged), the composition of the pallet and its height, but also a set of important information for logistics cycle as soon as the number of items in a pallet, the batch, the due date and the EAN code. The checking is very important, but involves a very long time, so the use of RFID allows to automate the operation.

The presence of RFID tags on inbound goods allows to check in automatic way, also in movement, the amount and the type of the receiving goods, using a reader able to obtain all the information from the codes contained on the goods and in the transport document. These activities can be carried out both by using RFID mobile terminal and RFID gates without human intervention.

The implementation of RFID system allows to:

- simplify the checking activities and the total/partial inventory;
- identify in a timely manner the nonstandard inbound goods;
- reduce the errors related to the management of hardcopy documents;
- avoid the erroneous allocation in the storage with temporary loss of goods;
- optimize and accelerate the routes improving the internal productive levels;
- improve the service level for customers.

The literature data suggest that the use of the mobile RFID readers allows a reduction of about 10-15% of the checking time through the speeding up and automating operations. The quality and quantity checking of the goods carried by fixed RFID readers, instead, involves times having zero value, the checking is made simultaneously with the unloading.

Taking account of this, with reference to an ordinary logistics platform (Scenario 0) two different project scenarios have been considered, in the first one (Scenario 1) there are RFID mobile readers for goods checking, in the second one (Scenario 2) the checking is carried out by RFID gates.

In the Scenario 1, the inbound goods are checked by using RFID mobile terminals, identifying the content of unloaded pallets at a distance. The technology allows to read simultaneously multiple tags without the need to open the packages to verify the content or look for the bar code. In Scenario 2, instead, the unloading goods cross the RFID gates identifying the pallet without requiring eye contact label. Each read cycle lasts less than three seconds and is able to simultaneously identify all the load and in hands-free mode. Controls, exceptions and variations are managed in real time.

The simulation results show that the RFID technology weighs on the logistics platform efficiency. In particular, referring to the variable T_I (Figure 6), it undergoes an evident reduction when the platform is equipped with RFID for the goods checking compared to the current state. The reasons giving the variation of T_I can be understand through the analysis of the variables that composed T_I (Figure 7).

In Scenario 1, the receiving makespan undergoes a little reduction in the dock A and B due to the decreasing of T_{extra}, instead in dock C T_I increases despite T_c takes a value equal to zero, but T_{unload} and T_{extra} increase compared to current state. In dock E, T_I value is similar to that taken in the Scenario 0. The comparison between current state and Scenario 2 allows to establish that the presence of RFID gates to check of inbound goods influence in a relevant way the system performance with a very considerable reduction of T_I.

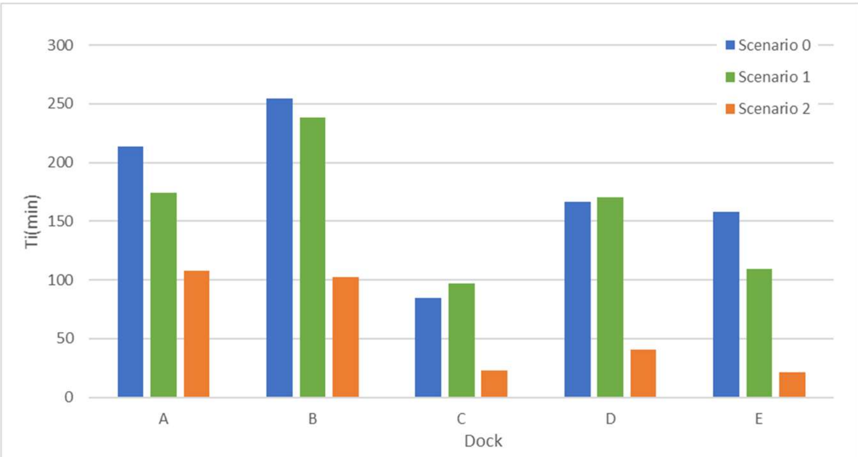

Figure 6: T_I for different scenarios

Another comparison can be made by reference to the saturation level of the system at the end of the operating time (720 minutes). The saturation can be expressed in terms of the queue length at the gatehouse defined as the number of vehicles awaiting service (N_q).

The introduction of RFID technology allows for reduced values of N_q (Table 1) due to the increase in speed of the service supply.

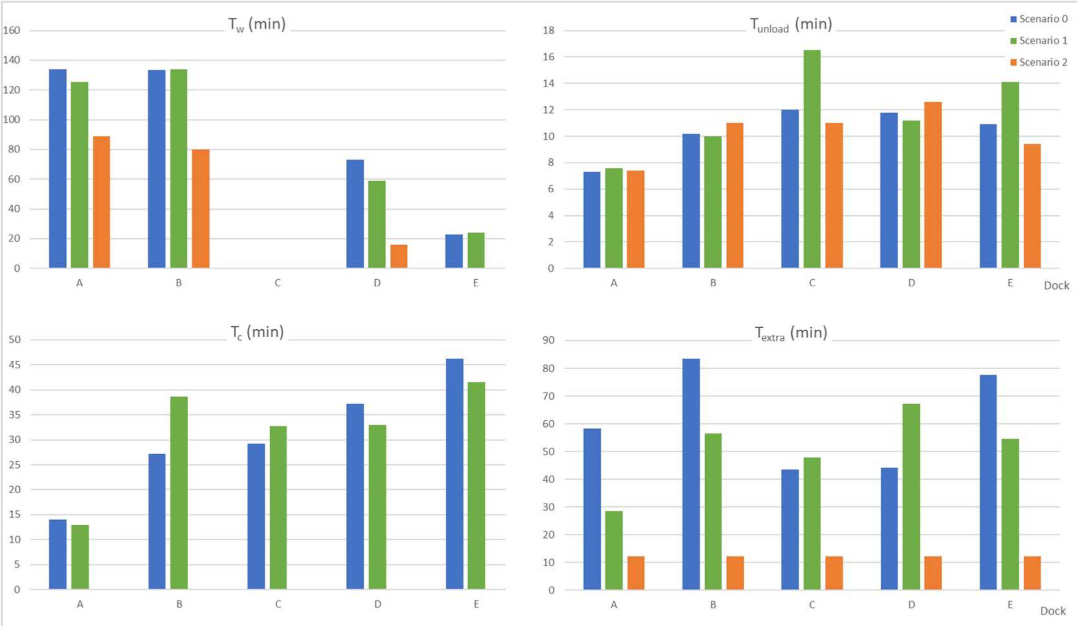

Figure 7: Time variables in the scenarios

Table 1: Values of N_q for different scenarios

	Scenario		
Dock	*0*	*1*	*2*
A	11	7	7
B	5	5	5
C	0	0	0
D	7	4	3
E	1	1	1
TOTAL	**24**	**17**	**16**

3.4 Workforce Deployment System for resources optimization

The considered tool in this case study is the WDS (Workforce Deployment System) that is a fundamental module of ERP. An efficient and effective management of the employees implies a logical allocation of operators with the right skills to the right positions at the right time. WDS significantly improves staff efficiency and increase profitability, allowing to create a working team based on skills and availability, monitoring and analysing progress and achievements. This solution prevents that the resources are allocated in excess or no effect on their activities.

The features and functions of the WDS include Project Resource Planning, Resource and Program Management, Call Center Staffing, Scheduling Retail.

The WDS system provides an integrated functionality to:

- automate and integrate the processes;
- access immediately to information with reduction of decision times for resources management;
- allocate the exact resource to the exact activity at the exact time;
- support managers and collaborators during the employee life cycle;
- qualify the collaborators to manage the process in teamwork.

The advantages related to the use of WDS system have been analysed with the support of a specialized software. In particular, with reference to the micro simulation model, the software allows a "what to" analysis for minimization of the time (T_I) spent by inbound trucks in a freight interchange node (Gattuso et al., 2014b). This procedure allowed to obtain different values of T_I in relation to the variation of m_i (doors number), a_i^{unload} (numbers of operators employed for goods unloading) and a_i^c (numbers of operators employed for checking). In relation to the comparison among the different system configurations it is possible to identify the optimal asset of the system that corresponds to a minimum value of T_I.

The algorithm used for the problem solution is the Simulated Annealing (SA). The current configuration is shown in Table 2.

Table 2: System configuration

Variables	*Description*	*Value*
N	Total inbound trucks number	130
m_A	Doors number in dock A	4
m_B	Doors number in dock B	9
m_C	Doors number in dock C	3
m_D	Doors number in dock D	9
m_E	Doors number in dock E	9
K	Total docks number	5
M	Total doors number	34
a_i^{unload}	Labours number for goods unloading in the i^{th} dock	2
A^{unload}	Total labours number for goods unloading	10
a_i^c	Labours number for goods checking in the i^{th} dock	2
A^c	Total labours number for goods checking	10

The values of objective function in the current state are shown in Table 3.

Table 3: Times T_I in current state

Dock	T_I *(min)*
A	407.13
B	420.78
C	141.63
D	394.32
E	439.18

The optimization procedure has allowed to obtain the best configuration for the logistics platform. Table 4 shows the comparison between the current state (Scen. 0) and the project state (Scen. 1) .

The results of the optimization problem underline a significant cut of the makespan; the trucks spend less time in the receiving area of the freight interchange node thanks to a better reorganization of the docks and to the reallocation of labours.

The makespan is cut by 27,7% in the dock 1; 3,9 % in the dock 2; 60, 7% in dock 3; 19,9% in dock 4 and 21,7 % in dock 5.

Moreover, in the optimal state there are 28 doors (6 less than the current scenario); 10 labours for goods unloading and 9 for the goods checking, 1 less than the current scenario

Table 4: Optimization results

	Current configuration				Optimal configuration			
Dock	*M*	a^{unload}	a^c	T_I *(min)*	*M*	a^{unload}	a^c	T_I *(min)*
A	4	2	2	407.13	9	5	2	294.38
B	9	2	2	420.78	8	1	1	404.43
C	3	2	2	141.63	1	1	2	55.723
D	9	2	2	394.32	2	1	2	315.74
E	9	2	2	439.18	8	2	2	343.78
TOTAL	**34**	**10**	**10**		**28**	**10**	**9**	

4. Conclusions and future developments

The freight interchange node is a key-ring of the whole supply chain; it provides a connection between the production and consumption; it is a buffer where the inbound freight flow turns in outbound flow. In a very competitive and constantly evolving market context, reducing supply chain costs is the main aim of the logistics manager who want to improve productivity by optimizing resources and reorganizing the system.

To pursue these objectives, a great help and support is given by the intelligent transportation systems, so creating an "intelligent logistics system". These advanced systems allow to digitize information, to monitor logistics processes, to overcome the problems of logistics activities, to communicate with other supply chain stakeholders, etc.

An intelligent logistic node has high performance in terms of time and monetary costs efficiency.

The paper proposes four cases study in order to analyse the advantages generated on node functionality and focuses on the receiving activities thanks to the introduction of ITS.

References

Adiono, T., Ega, H., Kasan, H., Carrel. (2017) "Fast Warehouse Management System (WMS) using RFID Based Goods Locator System", IEEE 6th Global Conference on *Consumer Electronics* (GCCE), Nagoya, Japan.

Apiyo, R.O., Kiarie, D. (2018) "Role of ICT tools in supply chain performance", *International Journal of Supply Chain Management*, Vol. 3 (2), pp. 17-26.

El Ouadaa, S., Bah, S., Berrado, A. (2017) "New classification framework of ICT deployments in supply chain". Proceedings of the International Conference on *Industrial Engineering and Operations Management*, Rabat, Morocco, April 11-13.

Gattuso, D., Cassone, G.C. (2012) "Micro-simulation model supporting the management of an interregional logistic platform", Proceedings of the 15th International scientific conference of the *Euro Working Group on Transportation*. Cité Descartes, Francia 10-13 September, 2012. Procedia – Social and Behavioral Sciences, Elsevier; vol. 54, pp. 557-566.

Gattuso, D., Cassone, G.C., Pellicanò, D.S. (2014a) "A micro-simulation model for an intelligent logistics platform: specification and calibration results", *Supply Chain Forum. An International Journal*, Vol. 15 (4), pp. 52-69.

Gattuso, D. Cassone, G.C., Pellicanò, D.S. (2014b) "What to" approach for the optimization of a logistics platform", *Proceedings of the Int. Conf. on Harbor Maritime and Multimodal Logistics M&S*, Bruzzone, Del Rio Vilas, Longo, Merkuryev, Piera Eds.

Hamdy, W., Mostafa, N., Elawady H. (2018) "Towards a Smart Warehouse Management System", Proceedings of the International Conference on *Industrial Engineering and Operations Management,* pp. 2555-2563.

Jabbar, S., Khan, M., Silva, B.N., Han, K. (2018) "A REST-based industrial web of things' framework for smart warehousing", *The Journal of Supercomputing* 74, pp. 4419–4433.

Kirch, M., Poenicke, O., Richter, K. (2017) "RFID in Logistics and Production – Applications, Research and Visions for Smart Logistics Zones". *Procedia Engineering* 178, pp.526 – 533.

Lee, C.K.M., Yaqiong, L.V., Ng, K.K.H., Ho, W., Choy, K.L. (2017) "Design and application of Internet of things based warehouse management system for smart logistics", *International Journal of Production Research*, vol. 56(8), pp. 2753-2768.

Liu, X., Cao, J., Yang, Y., Jiang, S. (2018) "CPS-Based Smart Warehouse for Industry 4.0: A Survey of the Underlying Technologies", *Computers* 7, 13.

Oner, M., Budak, A. Ustundag, A. (2017) "RFID-based warehouse management system in wool yarn industry", *International Journal of RF Technologies*, vol. 8, pp. 165-189.

Pane, S. F., Awangga, R. M., Azhari, B. R., (2018) "Qualitative Evaluation of RFID Implementation on Warehouse Management System", *TELKOMNIKA*, vol. 16(3), pp. 1303-1308.

Patil, A., Shah, A., Rokade, O., Kukreja, P. (2018) "Cloud Based Warehouse Management Firm", *International Research Journal of Engineering and Technology* (IRJET), vol. 5 (3), pp. 695-697.

Qin, W., Zhong, R.Y., Dai, H. Y., Zhuang, Z.L. (2017) "An assessment model for RFID impacts on prevention and visibility of inventory inaccuracy presence", *Advanced Engineering Informatics*, vol. 34, pp. 70-79.

Sahuri, G., Utomo, F.A.P. (2016) "Warehouse Management System", *Information System Application*.

Yan, B., Yan, C., Ke, C., Tan, X. (2016) "Information sharing in supply chain of agricultural products based on the Internet of Things", *Industrial Management & Data Systems*, vol. 116(7), pp. 1397-1416.