Link sito dell'editore: https://www.sciencedirect.com/science/article/pii/S0925527315001826

Link codice DOI: 10.1016/j.ijpe.2015.05.030

Citazione bibliografica dell'articolo:

Elia, V., & Gnoni, M. G. (2015). Designing an effective closed loop system for pallet management. *International Journal of Production Economics*, *170*, 730-740.

Designing an effective closed loop system for pallet management

Valerio Elia, Maria Grazia Gnoni

Abstracts: Pallets are currently the most widespread system for internal material handling and logistics of goods through a supply chain: they represent a critical asset for all firms, especially for Logistics Service Providers (LSPs). Analyzing pallet management systems according to a logistics point of view is quite a new research trend. Open or closed loop networks are now applied worldwide for pallet logistics: the latter is more complex to design and manage due to the presence of a reverse logistics process; several inbound and outbound processes have to be assessed. On the other hand, closed loop systems are the most effective, both from an environmental and an economic point of views. The aim of the paper is to outline critical factors (such as the pallet logistics network, the interchange system) in designing closed loop pallet management systems; a simulation-based tool has been developed in order to support logistic managers in designing effective organizational scenarios for these systems. Cost and time based KPIs will be estimated by the simulation model. A case study about a LSP firm has been also analyzed in order to validate the proposed model. A sensitivity analysis has been carried out aiming to evaluate impacts on supply chain performance due to context parameters. The proposed study could support both practitioners and academics in better understanding the key management aspects involved in closed loop pallet management, thus allowing a most effective design of this critical reverse logistics system.

Keywords: Closed loop; Pallet management; Logistic service provider; reverse logistics, Discrete-event simulation; Scenario analysis.

1 Introduction

Packaging nowadays could represent for all companies an important source for improving the efficiency of their operations, especially for Logistics Service Providers, LSPs, (Marasco, 2008; Prockl et al., 2012; Kye et al., 2013). The most widespread packaging type used for material handling and transportations is the pallet: a pallet is a portable, rigid platform used as base for assembling, storing, stacking, handling and transporting goods. Palletized loadings allow companies to optimize logistics costs as the load could be transported and stored as a unique unit. Several pallet types are available in the market in order to respond to the huge variety of goods loading requirements; furthermore, pallets could be made of various materials, such as wood, metal and plastic (Clarke, 2004), although wooden ones are the most common (Buehlmann et al., 2009) in the U.S. as in Europe. The number of pallets in use all over the world is very high: Kim et al. (2009) report that the total number of pallets in use in the U.S. is estimated to be 1.9 billion. A recent market research (Freedomia, 2013) forecasts an increasing trend of the annual demand for new pallets: about 3.5% per year until 2017. According to an economic point of view, Dallari (2010) outlined in a recent field analysis about the Italian market, an unitary management cost for LSPs about 1.2 € and a unitary purchase cost about 9 € for wooden pallet; the average annual number of pallets in use in Italy has been estimated about 350,000 items.

These data outline pallets as critical assets for optimizing the functioning and costs of companies, especially for the logistic service provider firms; main research fields on pallet are focusing on three issues: *the product* *design problem, the pallet loading and pallet logistic system design problems*. Briefly, the first one focuses on evaluating how different materials and technologies for producing pallets could improve their performance e.g. in terms of durability, recyclability, etc. The latter refers to determine the optimal configuration of pallet loading in order to reduce transportation costs. Finally, the third one affects the design of the logistics network for managing pallet as critical company assets. One relevant decision regards the logistics system that could be based on an open or a closed network. In open logistics networks, empty pallets are not physically recovered from customers by the company even if the customer pays the company the actual empty pallet value (Breen 2006). On the other hand, in closed loop models, empty pallets are picked back up by the company after or during the delivery process. Economic as well as environmental issues could affect the decision problem. Following this last research topic, the purpose of this paper is to propose a framework to design closed loop pallet management systems. At first, the decision problem: several issues affecting traditionally reverse logistics systems characterize it; moreover, specific features are typical of pallet management systems.

The paper is organized as follows: in section 2, a brief state of the art analysis is proposed to outline current research issues affecting pallets in supply chains; a general framework for the decision problem affecting the pallet logistics problem is proposed in Section 3. Next, a discrete event simulation model has been developed in order to support the decision problem in analysis: the model is based on a three-level supply chain where closed loop pallet management systems are applied for all actors. The focus of the model is on the LSP point of view, which is also the central actor of the supply chain by considering product deliveries. The description of the model is in Section 4. Finally, a test case concerning an Italian LSP company is proposed in order to validate the simulation tool.

2. Literature analysis about pallet design and management

Pallets currently represent an important asset for LSPs as well as for producers and end-retailers: actors involved in a supply chain use pallets for both internal material handling and external transportation through the supply chain. Analyzing the scientific literature about pallet management through google scholar using key words such as “pallet design”, “pallet logistics”, research topics could be classified in three main issues:

1. *the product design problem*: it usually affects the pallet producer companies. Research studies in this field focus on analyzing how different materials and process technologies could improve the performance (e.g. in terms of durability, recyclability) of pallets applied in material handling operations. Masood and Haider Rizvi (2006), Kim et al. (2009) and Soury et al. (2009) proposed different approaches to assess performance of different alternative materials in pallet design. Patricio and Maravall (2007) described the application of innovative technologies for monitoring pallet conditions in order to guarantee its performance;
2. *the pallet loading problem*: it affects logistics as well as producer companies, which provide palletized loading to customers. It refers to define the “optimal” loading level of a pallet in order to optimize its warehouse and transportation costs. Research studies focus on evaluating analytical (Bischoff et al., 1995; Letchford and Amaral, 2001; Martins and Dell, 2007, 2008; Yaman and Sen (2008); Kocjan and Holmström,

2010) as well as heuristic (Falcone et al., 2005; Alvarez-Valdes et al. 2005a, b; Pureza and Morabito, 2006; Lau et al., 2009) models for assessing "optimal" configuration of palletized loads under different operational conditions;

3. *the pallet logistic system design problem*: designing the logistics network for packaging is usually a complex activity as it could involve both direct and reverse flows if re-usable containers are applied. The first issue is to define the logistics system that could be based on an open or a closed network. The application of these two models affects investment as well as operational costs: costs due to new pallet replenishment averagely decrease in closed loop models, as the overall lifetime of a single pallet increases. A recent survey (Trebilcock, 2010) carried out by the National Wooden Pallet and Container Association has outlined that closed loops are the most widespread models: the usage life time varies from "more than 20 times" to "two and six uses" from each pallet. Furthermore, these two models also have different environmental impacts: pallet re-use could contribute to the reduction of waste quantity and CO_2 emissions of a company (Gasol et al., 2008; Mazeika Bilbao et al., 2011; Paksoy et al., 2011; Atamer et al., 2013; Silva et al., 2013); an interesting recent review is proposed by Carrano et al. (2014). Recent studies have also been focused on applying innovative technologies - such as Radio frequency identification- for tracking a pallet in a closed loop pallet management system (Gnoni and Rollo, 2010; Kim and Glock; 2014).

This brief analysis has outlined that economic as well as organizational issues have to be integrated in order to design an efficient logistic system for managing pallets in a supply chain: critical processes in open as well as closed logistics network have to be outlined aiming to support the decision problem analysis.

3. Designing pallet logistics in a supply chain: the decision problem

A process analysis has been carried out through a direct observation study of pallet management processes in Italian companies by focusing on LSP firms; a sample of 30 companies has been studied. The field observation has outlined common problems and factors that currently affect pallet logistics in supply chains.

Results of the field observations have supported a framework, which is proposed as follows: main activities involved in the design process of the pallet logistics system are reported in Figure 1.

The first problem (Step 1) is the definition of the organizational model characterizing the pallet logistic network, i.e. *open versus closed logistics models*. When an open network is working, the j-th company, which receives palletized loadings from the i-th company, do not return back empty pallets to the i-th company; thus, the j-th company refunds the cost of empty pallets to the company that has carried out the delivery. If a closed loop is working, reverse flows of empty pallets have to be managed from downstream companies to upstream ones.

Open logistics networks are usually simpler to manage as the return of items from customers increases the complexity of both inventory and logistics activities carried out by all involved companies. On the other hand, closed loop systems could allow us to reduce replenishment costs due to a multiple utilization of each empty pallet thus affecting the inventory management of empty pallets. Furthermore, from an environmental point of view, closed loop networks could contribute to the reduction of the overall environmental impacts of pallet logistics systems.

If the open model has been evaluated, the next step (step 3) consists of designing the inventory management system (e.g. in terms of warehouse capacity, replenishment models, etc.) for the empty pallet storage system.

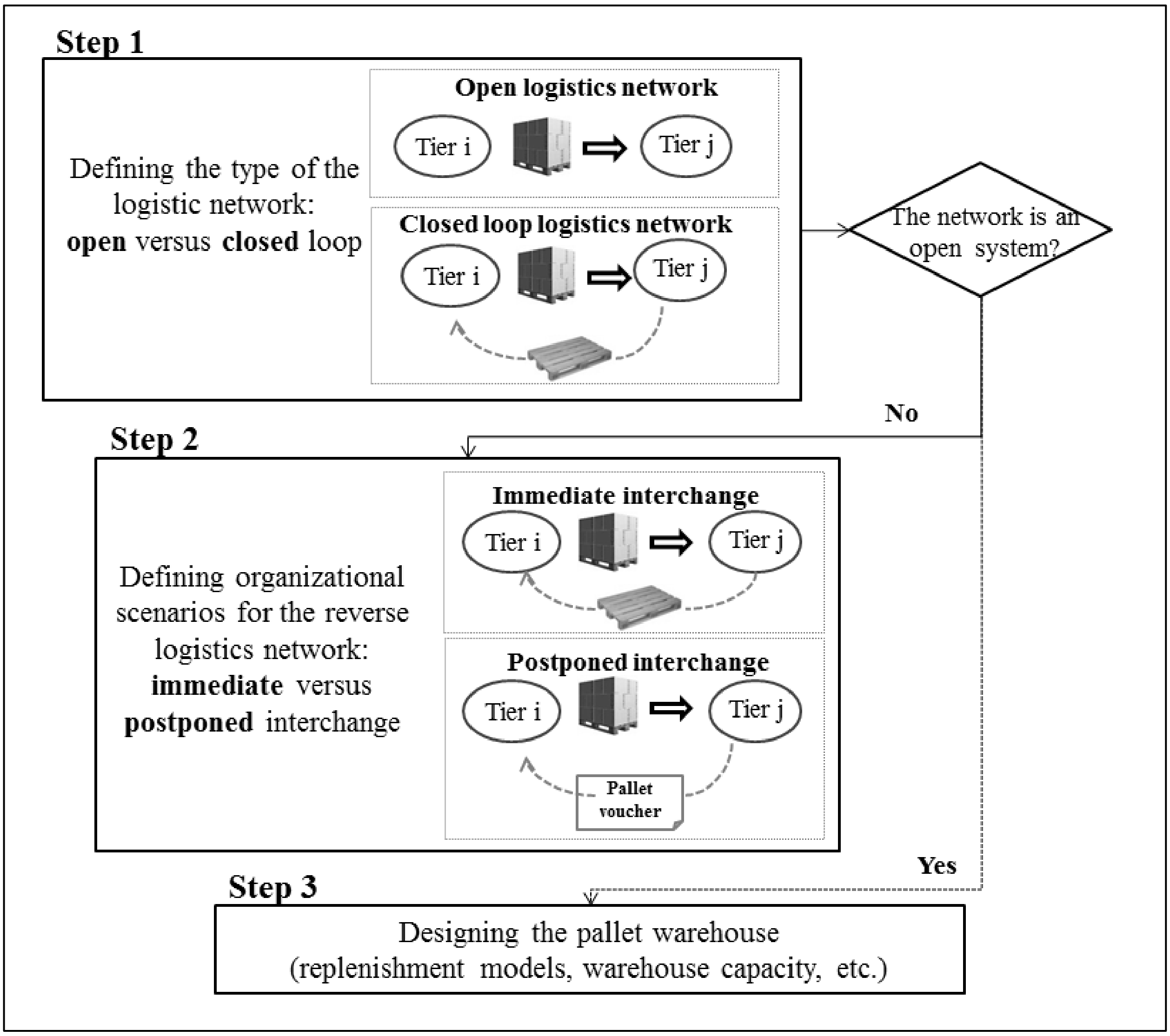

Figure 1. The decision making process in pallet logistics design

On the other hand, if a closed loop system is working for pallet management, reverse logistics issues have to be introduced in the analysis. By focusing on a LSP point of view, closed loop pallet management involves forward as well as reverse flows that have to be synchronized; all potential flows which could be managed by the LSP are depicted in Figure 2.

Inbound pallet flows to the empty pallet storage system could derive from three sources:

4. New pallets: the entity of this flow depends on the replenishment rate of new empty pallets defined by the LSP company for replacing old or un-usable pallets;
5. Pallets derived from unloading activities of palletized deliveries from upstream customers: upstream customers are producers which delivery goods through pallets to the LSP distribution centers. The flow depends on the delivery rate of each LSP upstream customer;

6. Empty pallets returned back to the LSP storage center from its downstream customers (e.g. final retailers). The flow rate mainly depends on the organizational scenario defined by the LSP for the reverse network applied to recover empty pallets after delivering goods to downstream customers (see Step 2 in Figure 1).

Outbound pallet flows from the LSP storage are:

1. Old pallets sent to disposal: if defectiveness is too high, pallets are sent to disposal or to companies which could recycle them;

2. Empty pallets required for preparing deliveries to downstream customers: the rate mainly depends on downstream customer demand and LSP delivery planning;

3. Empty pallets, which have to be returned back to upstream customers after a delivery if a closed loop system is applied.

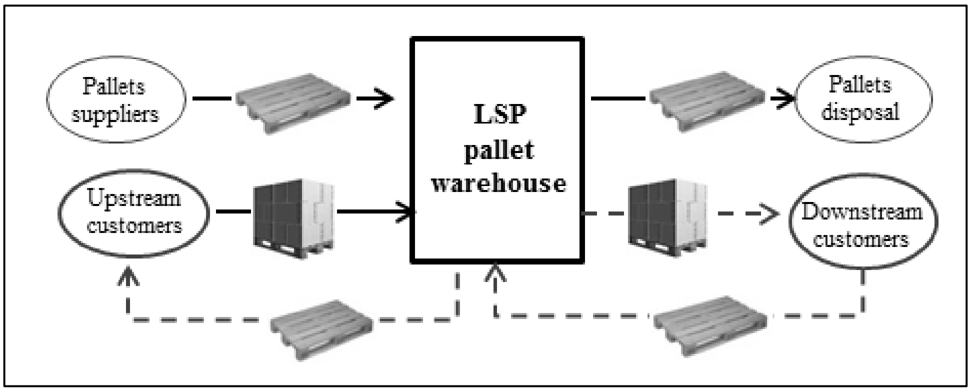

Figure 2- The closed loop pallet management system according to a LSP point of view

Thus, the next step (step 2) will affect the evaluation of different organizational scenarios that could be applied for interchanging empty pallets: two are the most widespread models defined as *direct and postponed interchange* systems. Main activities in the two organizational scenarios are depicted in Figure 3.

In the direct interchange system, empty pallets are collected by the LSP from downstream customers in the same trip used to deliver palletized loadings: the total number of empty pallets delivered back to the LSP has to be equal to the number of pallets used to deliver goods in the same trip. Thus, as the reverse flow of empty pallets has to be coordinated with forward deliveries, the courier must wait until all goods are unloaded from its own pallets. Furthermore, if a standardized pallet system is working, pallet quality and features are strictly defined. It has to be noted that a unique pallet standard that is universally accepted has not yet been applied as several pallet standardization models (e.g. in terms of size and materials) are now working all over the world (Li, 2006). In this case, the courier could accept standardized empty pallets already available at the downstream customer site; thus, the courier does not wait pallet unloading for recovering its own empty pallets as the same number of standardized pallets are provided immediately by the customer. Direct interchanges allow to reduce waiting times at the customer location: the courier only has to verify empty pallet features (based on the standard specifications) before loading empty pallets provided by the downstream customer. If provided pallets do not comply to standard specifications, the customer has to pay the total cost for these pallets to the courier as empty pallets are not delivered back.

In the *postponed interchange*, the aim is to reduce waiting times at the downstream customer: thus, the courier does not wait until the end of the unloading process as the customer, after verifying the quality of pallets delivered by the courier, releases the so called "pallet voucher". The total number of vouchers is equal to the total palletized loadings delivered in the trip. Pallet quality check and inspection activities have to be also carried out, as the actual cost of the delivered pallet has to be assed in the voucher. When a pallet voucher is emitted, the downstream customer does not provide empty pallets immediately as he could postpone the physical delivery within a specific time interval (e.g. one, two months). As an example, the time interval defined for the European interchange system has been fixed within three months (ECR, 2006). Otherwise, if pallets are not provided to the LSP in time, the customer will pay their whole costs to the LSP. Similarly to direct interchange, the LSP will carry out a quality check on pallets delivered in a postponed time period by the downstream customer as he has to verify the quality of pallets delivered compared to those defined in the vouchers.

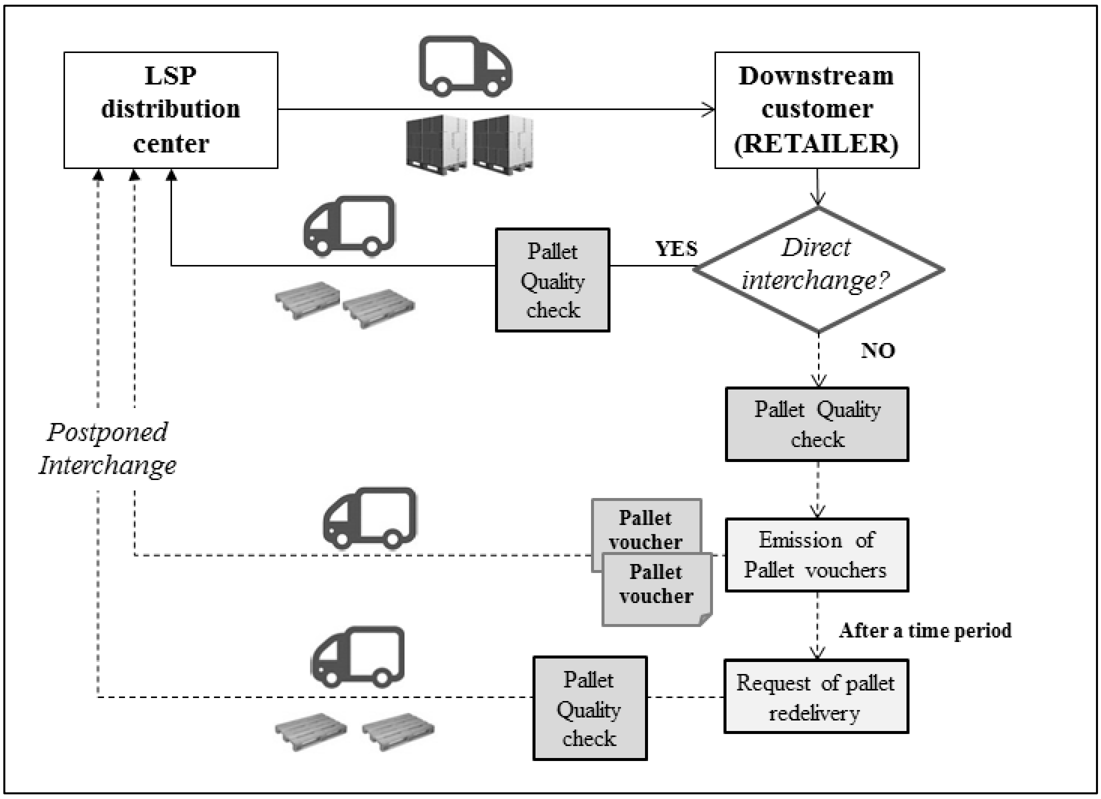

Figure 3 – Direct and postponed pallet interchange schemes (adapted from Gnoni and Rollo, 2010) applied for a standardized pallet system

Finally, according to the LSP point of view, the postponed interchange could contribute in the reduction of the overall cycle time for a round trip, as it allows to reduce waiting times mainly due to pallet quality check activities at the customer site. On the other hand, it does not guarantee an immediate physical availability of pallets - a delay time (e.g. with a maximum value) has to be evaluated - at the distribution center, even if the economic value of the pallet delivered is recovered. Direct interchange systems provide an easier inventory management process, as reverse flows are not present even though replenishment rates of new pallets increase.

4. Designing a simulation model based on a closed loop pallet management system for a LSP company

4.1 The methodology

A process analysis has been carried out through a direct observation study of a sample (about 30 companies) of Italian LSP companies working in a supply chain context: companies are characterized by a medium size dimension; these companies provide logistics services in a regional area; international deliveries are not yet provided. Companies have customers in different sectors, e.g. from the Fast Moving Consumer Goods (FMCG) to fashion and food sectors. The field observation has been carried out by a preliminary survey analysis and, subsequently, by direct interviews with LSP logistics managers. The field analysis has highlighted common features characterizing pallet logistics in this supply chain. Main outlined issues are reported as follows:

- Main services provided by the LSP companies in a supply chain are warehousing of palletized loadings delivered from producers, and transportation to retailers. Palletized loadings consist of one product or multi-products to be delivered to the customer location; the LSP companies could carry out internal picking activities aiming to increase customer satisfaction and/or to optimize transportation costs;
- Especially in the FMCG sector, arrival rates of palletized loadings at the LSP distribution center are known and quite constant; in the same way, deliveries rates from the LSP distribution center to the customer site are also known and constant. Several LSP companies provide dedicated services for each customer aiming to reduce replenishment lead times;
- Open logistics networks are not often used by the LSP companies as they are too much expensive, based on previous features characterizing the LSP logistics process. Thus, empty pallets are used multiple times based on a closed loop system. The standardized pallet system is based on model defined by the European Pallet Association (EPAL): it is also the most widespread in the European area. The EPAL system provides dimensions as well as technical features to support effective pallet interchange systems;
- Due to an high density of pallet producer and repair companies characterizing the Italian market (EC, 2012), new and repaired pallets could be available in short lead times.

The field analysis has also provided quantitative average data characterizing the supply chain in analysis which will be used in the simulation model proposed in next section.

4.2 The simulation model

Based on the field study, a discrete event simulation based tool has been developed in order to support an effective design of these closed loop systems. Discrete event simulation models have yet to be revealed effective in assessing the performance of reverse logistics systems in supply chains (Kara et al., 2007; Jayant et al., 2014), due to their intrinsic capability to model complex systems.

The simulation model is composed by **three echelons**, i.e. the **producer company** (which is the upstream customer of the LSP), **the LSP firm**, and **the retailer** (which is the downstream customer of the LSP). The producer company deliveries goods to the LSP using pallets; palletized loadings arrive at regular intervals in the LSP distribution center. It has to be noted that a percentage of incoming palletized loads are stored "as is" – i.e. without any handling activity – by the LSP; on the other hand, a percentage of incoming goods are unloaded due to picking activities carried out by the LSP. Empty pallets are required for delivering unloaded (e.g. picked) goods to the retailer.

Thus, the main activities characterizing an empty pallet warehouse are described as follows:

- *Inspection activities*: used pallets could not be directly moved to the empty pallet storage area, as an inspection activity has to be carried out to verify their overall functionality. First of all, a quality control check is required in order to avoid the risk of product breakage during shipment. Defective pallets are sent to maintenance companies or to the disposal (or recycling) center according to inspection results. Furthermore, inspection activities are also critical for guaranteeing the safety of workers as outlined by a recent alert launched by the Western Australia Government's department of Commerce (DoC, 2013). If a standardized pallet system is working, these activities are developed according to predefined procedures and common standard quality requirements are verified. As an example, defect detection systems usually applied could vary from optical, acoustic/ultrasonic, microwave as well as X-ray, or dielectric scanning systems (Kabir et al. 2003; Patricio and Maravall, 2007);
- *Maintenance activities*: after inspection, the outlined defectiveness has to be removed in order to guarantee pallet quality and its full functionality. Different actions could be carried out: most widespread activities regards removing and refurbishing blocks, stringers, lead boards and deck boards e.g. by adding new nails or metal brackets (Bejune et al., 2002; Carrano et al., 2014). In standardized pallet models, all activities are strictly defined according to specific procedures. A recent field analysis developed in the European area (EC, 2012) has outlined that for an average pallet life time of 8 years, the estimated number of repair cycles is equal to once/year or 0.5 times/year (i.e. 4 – 8 repair/life) for wooden pallets. Maintenance cycle times depends on type of equipment (manual or automatic) used by repairers;
- *Replenishment activities:* similarly to other storage systems, new pallet purchase is carried out by each firm as some pallets have to be replaced due to losses during deliveries and/or disposal. A replenishment process is carried out to provide the replacement of un-usable pallets.

Furthermore, an additional cleaning activity could be required for specific pallet application: this process is mandatory for wooden pallets, which will be used for international deliveries. The purpose is to stop the diffusion of potentially harmful plant pests derived from wooden packaging, which negatively affects plants or ecosystems. Thus, a standard – i.e. the ISPM (International Standards for Phytosanitary Measures) 15 – (FAO, 2002) – defines procedures for carrying out a sterilization activity based on a specific heat treatment; several nations currently apply this standard, including the EU and USA. Otherwise, a periodic voluntary cleaning activity could also be carried out for other types of pallets, e.g. plastic ones. This process has not been introduced in the proposed simulation model as the LSP provides only national deliveries, thus cleaning activities on re-usable empty pallets are not mandatory.

Pallet maintenance and recovery are carried out by an external supplier, which also provides new pallets.

The two organizational scenarios previously described for pallet interchange (i.e. direct and postponed interchange) have been introduced in the simulation model aiming to compare how these alternatives could affect the pallet management process of the LSP and the whole supply chain.

When firms in the supply chain (i.e. the LSP, the retailer) apply only “direct interchange”, empty pallets have to be redelivered to upstream actors in the same trip. Thus, if the firm (e.g. the LSP) hasn’t any empty pallets to be returned, goods could not be unloaded and carriers have to wait until empty pallets are available; the same could happen for the retailer when the LSP delivers goods. This burden contributes negatively on firm performance: its total delivery cycle time could increase due to an increase in waiting times for empty pallets. On the other hand, if a postponed interchange is applied, empty pallets are not returned immediately to upstream actors in the supply chain, but a voucher is emitted thus allowing a postponed return of empty pallets. This approach aims to reduce waste times (i.e. waiting times for unloading goods) even if an increase in the replenishment rate of new pallets could happen thus allowing an increase in firm purchase and inventory costs.

Main processes introduced in the simulation model are depicted in Figure 4: detailed activities in pallet warehouse management are in Figure 4 only for the LSP firm aiming to simplify the picture; they have been introduced in the simulation model for both the producer and the retail firm.

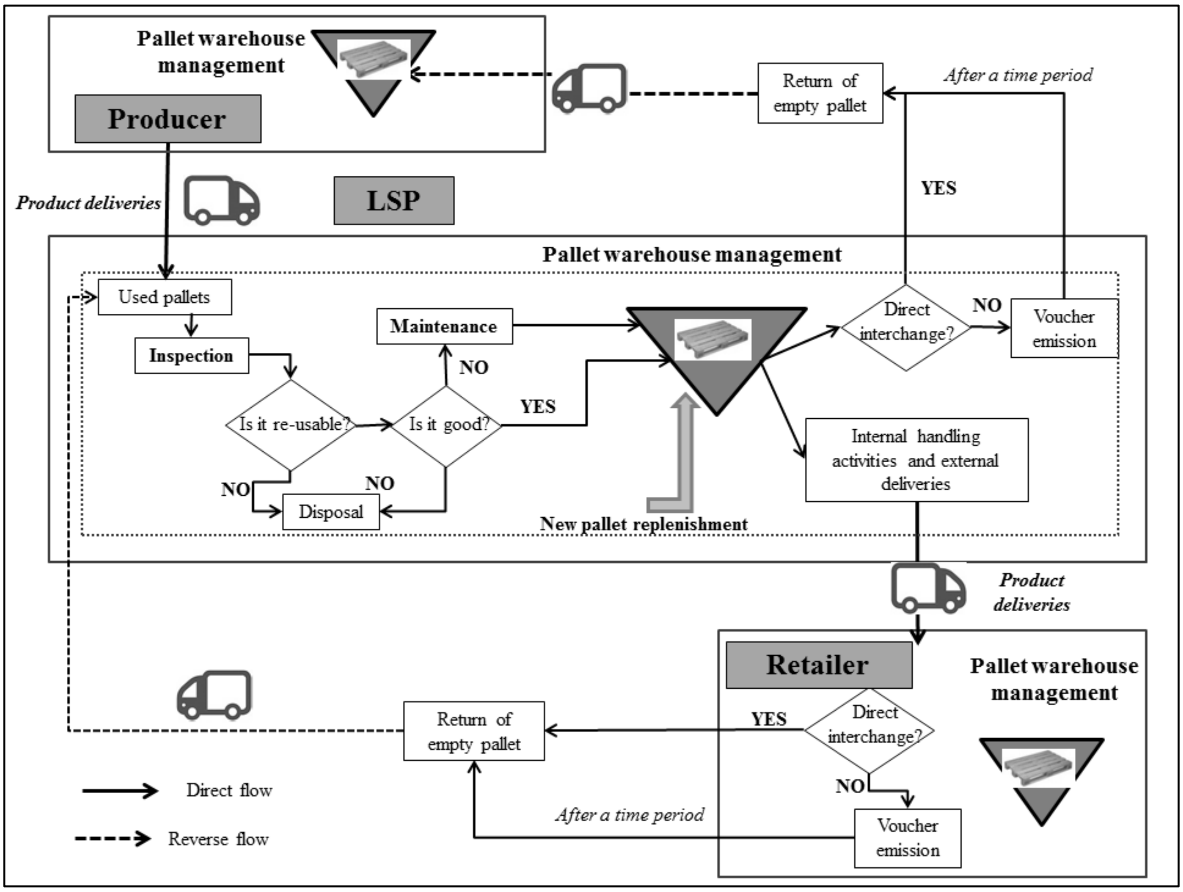

Figure 4 –Main processes in the proposed discrete event simulation model

5. The case study

A case study regarding an Italian LSP company is proposed in order to validate the simulation model. The LSP manages a medium size distribution center: upstream customers (i.e. the producer in the simulation model) and downstream ones (i.e. the retailer in the simulation model) are located in the proximity (i.e. the distance is less than 200 km) of the LSP distribution center: thus, deliveries from/to producer and from/to retailer could be carried out within a workshift (8 hours).

All actors of the supply chain apply a closed loop pallet management system: thus, the simulation model will allow to evaluate the most efficient interchange systems that the LSP firm should apply to increase internal operation costs without reducing its service levels in terms of delivery times.

Three different operational scenarios for pallet interchange have been introduced:

- **Scenario 1**: all firms in the supply chain (the LSP, the producer and the retailer) apply the direct interchange system;
- **Scenario 2**: a mixed approach is applied by the two actors (LSP and the retailer), which could generate empty pallet reverse flows. In detail, the LSP immediately provides empty pallets to upstream customers if there is availability; when no pallets are available, a postponed interchange system is applied as the LSP provides vouchers to upstream customers (the producer). Furthermore, the LSP accepts the postponed interchange of its pallet by downstream customers.
- **Scenario 3:** the LSP always applies a direct interchange with upstream customers (as in scenario 1) and it accepts a postponed interchange from its downstream customers (as in scenario 2). This is the scenario with a lower degree of coordination characterizing the reverse logistics flow.

Model assumptions and data are reported in detail in the next section.

5.1 Model assumptions

Operational data introduced in the simulation model have been deducted by field data provided by the LSP company. A detailed description is proposed as follows:

- the simulation (i.e. observation) period is one year, i.e. 300 working-days;
- the total number of pallets handled (i.e. the sum of incoming and outgoing pallets in the distribution center) has been fixed and it is the same in all scenarios. In detail, the arrival rate of loaded pallets from upstream customers is constant and equal to 30 pallets per hour. Furthermore, for the LSP, the estimated ratio between delivered and received palletized loadings is constant and equal to 1.15: this value is not equal to 1 due to picking up activities carried out internally by the LSP;
- as resources are limited at the LSP, unloading goods could be carried out one pallet at a time; the total unitary unloading cycle time is constant and is equal to 1 hour per pallet;
- all actors in the supply chain manage their new pallet replenishment according to a fixed quantity re-order point level model; threshold values and fixed replenishment quantities have been defined internally by each firm. As the pallet supplier is located near to all companies, the replenishment time has been fixed within 1 day; this value has been assumed as fixed due to a wide availability of companies that could provide in the same period the empty pallets;

- main parameters characterizing reverse logistics processes are the return cycle time of the empty pallet, which is equal to 1 day (i.e. the same day of delivery to the final customer). The average return time has been fixed for 1 month. Furthermore, a fixed percentage (4%) of total handled pallets are lost during transportation activities.
- loaded pallets are immediately shipped to downstream customers without any other delay;
- when a closed loop pallet management system is working, all pallets used in this supply chain are based on a specific pallet standard, i.e. the EPAL (ECR, 2006).

The simulation model has been developed by using the Anylogic® software release 6.9.

Key Performance Indicators (KPIs) have been introduced in order to compare effectiveness of each analyzed scenario: they regard both the operational and economic performances of each company. Time-based KPIs evaluated by the simulation model are:

- ***the Total Unloading Time (TUT) per SKU (Stock Keeping Unit)***: it represents the total average time requests to unload a pallet incoming; the simulation model allows to estimate values for the LSP (TUT_{LSP}) and the retailer (TUT_{Ret}). It is the sum of a fixed unitary technical cycle time for unloading a palletized SKU and a delay time, which could vary, as empty pallets are not available for deliveries. This last contribution is scenario dependent as its values depend on the specific interchange scenario applied;
- ***the Time in the Picking Queue (TPQ) per SKU***: it is the delay time that goods in the delivery process wait for an empty pallet to be palletized after the picking process. If empty pallets are not yet available in the LSP warehouse, unloaded goods wait in a queue until empty pallets are available. The simulation model has evaluated two indicators: TPQ_{prod} and TPQ_{LSP} are times estimated at the producer and at the LSP firm respectively.

These two types of KPIs outline how different organizational scenarios of pallet management could affect the internal performance of each firm. Economic-based KPIs have also been introduced in analysis:

- ***the Total Cost for pallet Purchase (TCPU):*** it represents the total cost for new empty pallet purchase; it will be estimated for all firms in the supply chain as all three actors directly manage their own pallet warehouses. The total cost will be estimated at the end of the simulation time (i.e. one year); the unitary purchase cost has been assumed as constant in the period and it is equal to 8 € per pallet for all firms;
- ***the Total Number of Vouchers released and/or emitted (TNVO):*** this parameter will be introduced only in scenarios where a postponed interchange system is working, i.e. scenario 2 and 3. It has to be noted that as the voucher number increases, the administrative cost also increases due to a high resource effort required by additional activities (e.g. expiration date check, legal controversy management, etc.). The unitary cost for administrative procedures due to voucher management has not been introduced in the model.

5.2 *Results analysis*

The total numbers of incoming and outgoing SKUs is equal in all three scenarios due to a constant arrival rate: the total number of incoming SKUs to the LSP estimated by the simulation model is equal to 215,970 pallets per year, and the total number of SKUs delivered by the LSP to retailer at the end of the simulation period is equal to 249,332 pallets. This data is not equal due to picking up activities carried out internally by the LSP on inbound flows of goods (as defined in the previous paragraph).

Statistical values (i.e. minimum, maximum, mean, standard deviation values) estimated for KPIs introduced previously are analyzed in details. Results outline a relevant impact due to different organizational model for pallets interchange. Firstly, internal operational performance of each firm in the supply chain are compared in each scenario by the two time-based KPIs, i.e. TUT_{LSP} and TUT_{Ret} : estimated values are reported in Table 1.

KPIs	**Scenario**	**Minimum value [min/SKU]**	**Maximum value [min/SKU]**	**Mean value [min/SKU]**	**Standard deviation value [min/SKU]**
TUT_{LSP}	1	90.00	94.00	91.90	1.98
	2	60.00	64.00	60.00	0.07
	3	90.00	4493	424.16	913.30
TUT_{Ret}	1	61.00	97.00	84.78	11.10
	2	60.00	60.00	60.00	0
	3	60.00	60.00	60.00	0
TPQ_{LSP}	*1*	0	12.00	0.63	1,958.00
	2	0	64.00	2.87	26.81
	3	0	1,021.00	4.16	25.94
TPQ_{Prod}	*1*	0	12.00	4.00	3.26
	2	0	604.00	5.83	26.81
	3	0	456.00	5.11	17.71

Table 1 – Estimated data for time-based KPIs for each scenario

By analyzing the performance of the LSP unloading process, the lowest estimated TUT_{LSP} values is provided in scenario 2 where the postponed interchange system is applied by the firm both for its downstream and upstream customers; furthermore, the obtained value is almost equal to the fixed unitary unloading time (i.e. 60 minutes) thus confirming that this organizational model contributes to avoid wasting time at the LSP firm. This result is also confirmed by the monitoring retailer internal performance of the material handling process: thus, lowest values of TUT_{Ret} have been obtained in scenario 2 as well as 3. When the LSP applies different interchange scenarios for upstream and downstream customers (i.e. scenario 3), performance characterizing its unloading process decreases as TUT_{LSP} has the highest value (about 424 minutes).

Data about TPQ parameters outline how the internal pick up process is affected by the specific interchange system: lowest values for both the LSP and the producer (the only two firms in the supply chain carrying out the pick up process) have been obtained under scenario 1 differently from previous results. This result is due to the overall higher availability of empty pallets to be used for forward deliveries, when a direct interchange model is applied in all supply chain tiers.

By analyzing cost-based KPIs, data about total purchase cost, estimated by the simulation model in each scenario, are reported in Table 2.

SC actor	TCPU [€/year]		
	Scenario 1	***Scenario 2***	***Scenario 3***
Producer	152,000	168,000	168,000
LSP	152,000	144,000	144,000
Retailer	164,000	140,000	140,000
Total SC Cost	**468,000**	**452,000**	**452,000**

Table 2- Total purchase cost for new empty pallets in each scenario

The highest total cost value has been estimated for the producer in scenarios 2 and 3 where downstream firms (LSP and retailer) apply postponed interchange for pallet management; on the other hand, the application of immediate interchange (scenario 1) allows to reduce producer internal costs.

By analyzing data from the LSP and the retailer point of view, the most effective interchange system is based on the application of postponed interchange. This result is also confirmed by analyzing the total purchase cost for the whole supply chain: the introduction of postponed interchange systems could allow us to reduce the overall replenishment cost even if one actor has increased its own cost.

Furthermore, by analyzing the trend of empty pallet inventory levels (reported in Figure 5) in each scenario, results show that applying an immediate interchange provides a more “stable” inventory management system in all supply chain firms.

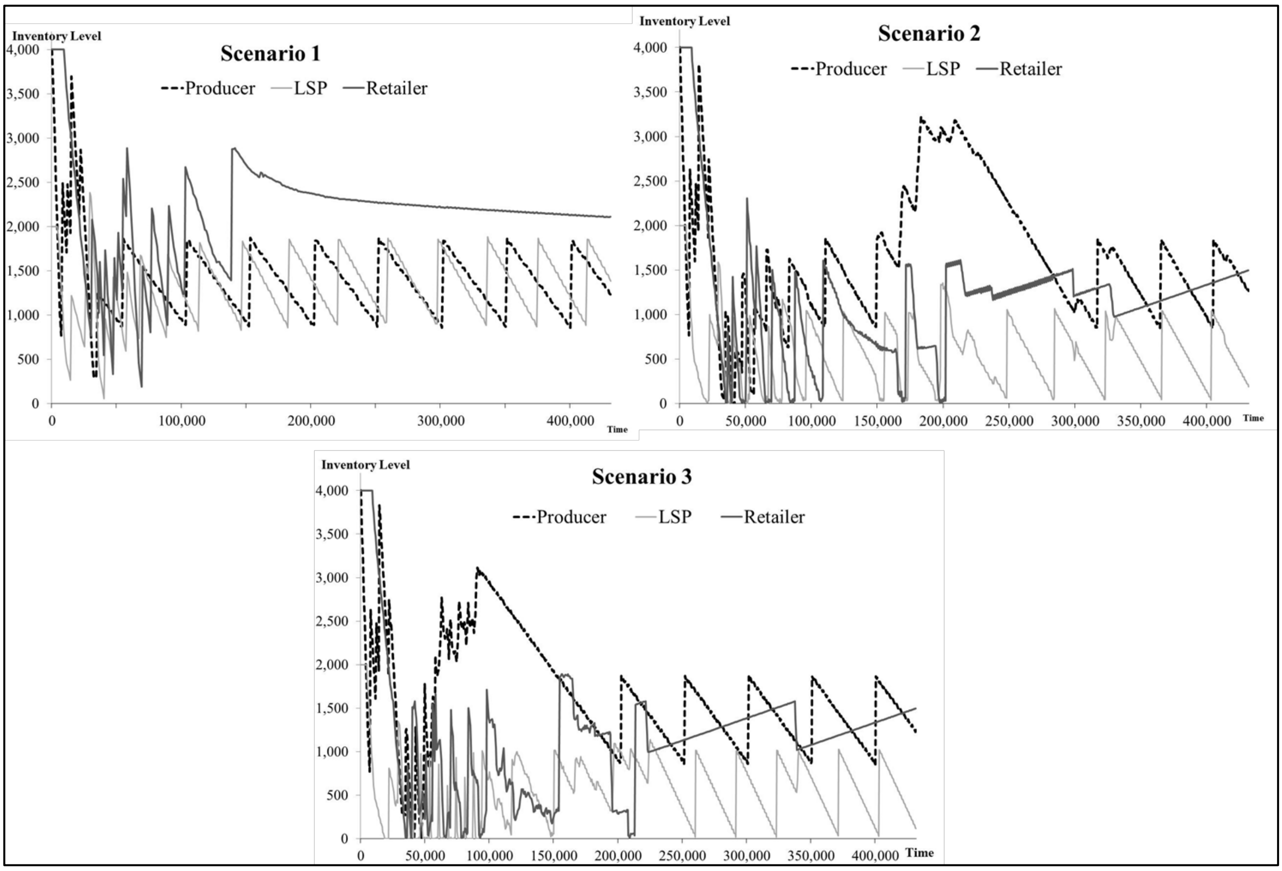

Figure 5- Empty pallet storage inventory trend estimated during the simulation period

This phenomenon is mainly due to the application of postponed interchange in scenario 2 and 3. Total vouchers emitted and received in postponed interchange scenarios have been reported in Table 3: data about

TNVO emitted by the retailer to the LSP in the two scenarios are characterized by a slight difference (about 5%) even if the variation of inventory level in scenario 2 is greater than in scenario 3.

	Scenario 2 TNVO Emitted				Scenario 3 TNVO Emitted		
TNVO Received	Producer	LSP	Retailer	**TNVO Received**	Producer	LSP	Retailer
Producer	-	4320	-	Producer	-	-	-
LSP	-	-	3990	LSP	-	-	3780
Retailer	-	-	-	Retailer	-	-	-

Table 3- Data about total number of voucher emitted/received under the two postponed scenarios

The proposed simulation model has revealed to be an effective tool to evaluate impacts due to different organizational scenarios for pallet interchange according to a supply chain: quantitative results obtained in the case study confirm that coordination between upstream and downstream customers plays an important role for improving effectiveness of a LSP company (Li, 2011; Huemer, 2012; Wagner and Sutter, 2012): this becomes essential when reverse logistics processes are heavily involved when designing a complex closed loop supply chain (Olorunniwo and Li, 2010; Hazen et al., 2012).

5.3 The sensitivity analysis

A sensitivity analysis has been carried out to evaluate performance of the analyzed supply chain under different operational conditions. As the focus of the study was mainly on time performance, two time-based parameters have been modified in the proposed sensitivity analysis: the transportation time between all actors in the supply chain (i.e. from producer to the LSP site and from the LSP site to the retailer), and the replenishment time characterizing new and refurbished pallets provided by an external supplier to all actors in the supply chain.

Firstly, an increase of 50% in the transportation time (i.e. from 1 day to 2 days) has been introduced in the simulation model: the aim is to evaluate if longer transportation time (e.g. required by customers located not in the proximity to the distribution center) cold heavily modify previous results obtained.

Main time-based as well as cost-based KPIs under the three previous scenarios have been estimated, and data are reported in Table 4 (row B). Data show not significant impacts on retailer performance: only a very slight variation in TUT_{Ret} value estimated in scenario 1 has been obtained; estimated TCPU values are all equal to previous ones, thus they are not introduced in the table.

The trend previously outlined for the unloading process at the LSP is confirmed also in this case: scenario 2 provides the lowest TUT_{LSP} value which is also characterized by a slight variation; on the other hand, an higher impact (about 63%) could be outlined in scenario 3 which still is characterized by the worst TUT. A similar trend is outlined for the waiting time for picking (i.e. the TPQ_{LSP}) estimated at the LSP distribution center. On the other hand, the lowest TPQ_{Prod} values has been estimated under scenario 3 (instead of scenario 1): this result could mainly be due to an increase in empty pallet inventory level estimated at the LSP site (i.e. $TCPU_{LSP}$ values) under this scenario which allows to provide "more quickly" empty pallet to upstream. Thus, when direct interchange is working between the LSP and the producer, if the empty pallets availability at LSP center increases, upstream deliveries, and consequently, picking processes at the producer site speed up. By analyzing cost-based KPIs, the total SC cost is confirmed lower in scenario 2 and 3 even if the absolute values are increased: the higher impacts due to a variation in the transportation time is outlined for the LSP total purchase cost $TCPU_{LSP}$ which increases under all three scenarios.

KPI	**Scenario**	**Mean value (A)**	**Mean Value (B)**	**Δ(B-A)** [%]	**Mean Value (C)**	**Δ(C-A)** [%]
TUT_{LSP} [min/SKU]	1	91.9	98.10	*6.75*	95.29	*3.56*
	2	60.00	60.02	*0.03*	60.05	*0.09*
	3	424.16	689.60	***62.58***	2,235.05	***81.02***
TUT_{Ret} [min/SKU]	1	84.78	85.6	***0.97***	*90.07*	***5.88***
	2	60.00	60.00	*0*	*60.00*	*0*
	3	60.00	60.00	*0*	*60.00*	*0*
TPQ_{LSP}[min/SKU]	1	0.63	0.75	*19.05*	0.77	*2.98*
	2	2.87	2.74	*-4.53*	2.05	***-33.72***
	3	4.16	6.59	***58.41***	7.31	*9.89*
TPQ_{Prod}	1	4.00	9.23	*130.75*	4.00	*0*
	2	5.83	20.07	***244.25***	183.82	***96.83***
	3	5.11	4.52	*-11.55*	124.8	*96.38*
$TCPU_{Prod}$ [€/year]	1	152,000	168,000	***10.53***	152,000	*0*
	2	168,000	184,000	*9.52*	176,000	*4.55*
	3	168,000	168,000	*0*	152,000	***-10.53***
$TCPU_{LSP}$ [€/year]	1	152,000	168,00	*10.53*	152,000	*0*
	2	144,000	152,000	*5.56*	144,000	*0*
	3	144,000	176,000	***22.22***	160,000	***10.00***
Total SC cost [€/year]	1	468,000	500,000	*6.83*	468,000	*0*
	2	452,000	476,000	*5.30*	460,000	*1.74*
	3	452,000	484,000	***7.07***	452,000	*0*

Table 4 – KPIs values estimated with baseline parameters (row A), with a 50% variation in transportation times (row B), and with a 20% variation in the pallet replenishment process.

Next, a variation equal to 20% has been introduced in the replenishment time of both new and refurbished pallets provided in the whole supply chain; this condition refers to a more uncertain replenishment process. Data are also reported in table 4 (see row C): compared to the previous case, an overall lower impact could be outlined as several values do not heavily change. As an example, estimated values for cost-based KPIs outlines very limited increase. Higher impacts could be outlined for time-based KPIs for the producer: TPQ_{Prod} values heavily increase in scenario 2 and 3. The main cause is that longer lead times more influence performance of the upstream tier in the supply chain.

In conclusion, the sensitivity analysis has outlined that even if some context parameters could vary, coordination is essential when complex pallet reverse logistics is working in a supply chain.

6. Discussions

Reverse logistics now represent a critical activity for companies: environmental as well as economic impacts are now forcing producers to integrate forward and reverse flows of such a product (Coronado Mondragon et al., 2011; Gobbi, 2011; Zeballos et al., 2012; Keyvanshokooh, et al., 2013; Lai et al., 2013). Reviews about reverse logistics and closed loop systems have been proposed in Pokharel and Mutha (2009); a recent update is in Govindan et al. (2015). When LSP companies are involved in managing reverse logistics flows, one issue regards how to select the LSP company according to features of the reverse network and products (Ko et al. 2007; Govindan et al., 2012; Senthil et al., 2012). Designing the network of the LSP company is also a critical issue (Krumwiede and Sheu, 2002): several studies applied mathematical programming to define the LSP optimal network design when reverse logistics activities are considered simultaneously with forward supply chain activities (El-Sayed et al., 2010; Min and Ko, 2008; Cardoso et al., 2013; Ramezani, et al., 2013). The research problem in analysis regards the integration between forward and reverse flows from an organizational point of view. Similarly to production reverse logistics systems (Kenne et al., 2012), pallets after the use phase (i.e. each delivery trip) could be collected and re-used for a delivery. The type of interchange system applied by the company heavily affects its inventory management process of empty pallets: the aim of the proposed simulation model is to support logistics managers in designing an effective organizational model for balancing outgoing loaded pallet flows with incoming flows of empty pallets in order to support efficiently a company in delivering goods.

The impact of different organizational alternatives of reverse logistics has been discussed in the paper by analyzing a specific research problem, i.e. the pallet logistics system in a supply chain. Designing and managing closed loop pallet logistics systems have common issues with traditional reverse logistics system, but specific features also characterized it. Similarly to other closed loop systems, forward and reverse flows have to be coordinated aiming to optimize inventory and logistics costs, and to provide high service levels (de la Fuente et al., 2008). Problem complexity arises when the LSP is working in a supply chain where a coordination process between forward and reverse flows is essential (Gnoni et al., 2003; Pokharel and Mutha, 2009): demands of empty pallets required by inbound deliveries from upstream customers have to be synchronized with ones required for deliveries to downstream customers (Bogataj and Bogataj, 2003).

Two main issues traditionally affect reverse networks: uncertainty in quantity and quality of reverse flows. These uncertainties could influence the demand management process of a company as reverse and direct flows have to be coordinated. The direct demand process of such a product and the return process are traditionally evaluated as independent even if recent studies (Cardoso et al., 2013; Zehrhouni et al., 2013) outlined a close relationship between the two material flows.

In closed loop pallet management systems, direct and reverse flows are influenced by organizational scenarios applied for the interchange system: if a direct interchange is working, return flows of empty pallets are directly connected to forward deliveries; thus, uncertainty in pallet quantity could be reduced. Otherwise when a postponed interchange system is applied, return flows are more uncertain even if a maximum delay period is allowed by the company. Uncertainty in quality of return products could also affect the performance of closed loop pallet management systems (Zebaldo et al., 2012; Ramezani et al., 2013); when direct interchange is applied, the quality of the returned flows is less uncertain than in postponed one as the quality check process is carried out immediately on the delivery trip. The proposed simulation model has allowed to evaluate all these features: direct and postponed interchanges have been introduced in all three echelons of the analyzed supply chain. Furthermore, based on field analysis, main processes involved in closed loop pallet management systems (e.g. inspection, repair, replenishment) have also been discussed and introduced in the model: the empty pallet warehouse management process has been introduced in all three levels of the analyzed supply chain. It has to be noted that the analysis is mainly focused on the LSP company perspective as quantitative data characterizing the case study belongs to a LSP company; thus, results obtained are greatly dependent on this point of view which is focal in the proposed supply chain. Pallet management heavily affects LSP companies compared to other ones, as pallets are critical assets for their business operations. Obtained results have also pointed out the positive impact of a more coordinated approach in designing pallet interchange systems that for closed loop systems. Even if some hypotheses are strictly connected to the case study - i.e. no uncertainty in the new pallet replenishment process and geographical proximity between all actors in the supply chain– the simulation model has revealed effective to support logistic managers in evaluating the most important factors for designing effective pallet interchange systems. However, it has to be noted that these operational conditions often characterize LSP companies especially in the FMCG sector.

Further developments will be oriented to test more complex inventory management models as the current one is based on a fixed quantity replenishment approach. In addition, impacts on economic as well as organizational performance of this supply chain in more uncertain scenarios will be also evaluated.

Conclusions

Pallets currently represent a critical asset for LSP companies: empty pallets are essential for handling, storing and delivering goods worldwide. Thus, pallets must “always” be available for LSP firms as they are essential for deliveries: this could determine a high inventory level of empty pallets thus contributing to increase in both replenishment and holding costs. An efficient pallet management process aims to optimize a pallets’ availability thus reducing operational costs: thus, it became critical to integrate the process of providing empty pallets for loading goods with other pallet-related services, such as reverse logistics. According to a LSP point of view, empty pallets along a supply chain could be managed by an open or a closed logistics network. The LSP customer located downstream in the supply chain could usually evaluate to return empty pallets (closed loop system) or not (open system) to the LSP. Based on its customer strategy, the LSP has to design and manage its own empty pallet storage in different ways. This paper proposes a comparison analysis for different organizational models for pallet interchange systems: the simulation analysis has been developed by a discrete event simulation model, which represents a three level supply chain where upstream customers deliver palletized loads to a LSP distribution center; next, the LSP delivers palletized loads according to customer demand to end-retailers. Process analysis and test case results have confirmed how the empty pallets reverse flow management is critical for upstream as well as downstream actors in a supply chain, and especially for a LSP firm. The analysis has outlined that more coordinated strategies between (upstream and downstream) customers and the LSP could allow us to support a more reliable and faster supply chain management.

References

Alvarez-Valdes, R., Parreño, F., Tamarit, J.M., 2005a. A tabu search algorithm for the pallet loading problem, *OR Spectrum* 27(1), 43-61.

Alvarez-Valdes, R., Parreño, F., Tamarit, J.M., 2005b. A branch-and-cut algorithm for the pallet loading problem, *Computers and Operations Research*, 32(11), 3007-3029.

Atamer, B., Bakal, I.S., Pelin Bayındır, Z., 2013. Optimal pricing and production decisions in utilizing reusable containers, *International Journal of Production Economics*, 143(2), 222-232.

Bejune, J., Bush, R., Araman, P. A., Hansen, B., Cumbo, D. 2002. Pallet industry relying more on recovered wood material. *Pallet Enterprise*, 22(10), 20-27.

Bischoff, E.E., Janetz, F., Ratcliff, M.S.W., 1995. Loading pallets with non-identical items, *European Journal of Operational Research*, 84(3), 681-692.

Bogataj, M., Bogataj, L., 2003. On the compact presentation of the lead time perturbations in distribution networks, *International Journal of Production Economics*, 88(2), 145-155.

Breen, L., 2006. Give me back my empties or else! A preliminary analysis of customer compliance in reverse logistics practices (UK), *Management Research News*, 29(9), 532-551.

Buehlmann, U., Bumgardner, M., Fluharty, T., 2009. Ban on landfilling of wooden pallets in North Carolina: an assessment of recycling and industry capacity, *Journal of Cleaner Production*, 17(2), 271-275.

Cardoso, S. R., Barbosa-Póvoa, A. P. F., & Relvas, S. 2013. Design and planning of supply chains with integration of reverse logistics activities under demand uncertainty, *European Journal of Operational Research*, 226(3), 436-451.

Carrano, A., L., Pazour, J.A., Roy, D., Thorn, B.K., 2014. Selection of pallet management strategies based on carbon emissions impact, *International Journal of Production Economics*. In press.

Coronado Mondragon, A. E., Lalwani C., Coronado Mondragon C.E., 2011, Measures for auditing performance and integration in closed-loop supply chains, *Supply Chain Management: An International Journal*, 16 (1), 43 – 56.

Dallari, F. (2010). La gestione dei pallet nella filiera del largo consumo, In Italian. Available at: http://www.liuc.it/ricerca/clog/cm/upload/opal_definitivo.pdf [Accessed 23 April 2015]

de la Fuente, M.V., Rosa, L., Cardo, M., 2008. Integrating Forward and Reverse Supply Chains: Application to a metal-mechanic company. International Journal of Production Economics 111(2), 782-792.

DoC, 2013. Wooden and general-purpose flat pallets. Government of Western Australia, Department of Commerce, Safety Alert 05/2013. Available from: http://www.commerce.wa.gov.au/worksafe/PDF/Safety_alerts/2013/05-2013_Wooden_and_general_purpose_.pdf [Accessed 10 June 2013].

European Commission, Directorate General for Health and Consumers, 2012, Quantification of the economic, environmental and social impacts of introducing mandatory treatment requirements for wood packaging material circulating inside the European Union, Final report. Available at: http://ec.europa.eu/food/plant/plant_health_biosafety/trade_non_eu/docs/report_ispm15_en.pdf [Accessed April 2015]

ECR, 2006. Interscambio Pallets EPAL. Raccomandazione ECR [online]. ECR Italia. In Italian. Available at: http://indicodecr.it/ecr_italia/download_documenti/Raccomandazione_ECR_Interscambio_Pallet.pdf [Accessed 1 March 2013].

El-Sayed, M., Afia, N., & El-Kharbotly, A. 2010. A stochastic model for forward–reverse logistics network design under risk, *Computers & Industrial Engineering*, 58(3), 423-431.

Falcone, D. , Duraccio, V., Silvestri, A., Di Bona, G., 2005, Technical and economical analysis of the layout of a palletization plant through simulation techniques, Summer Computer Simulation Conference 2005, 387-391.

FAO, 2002. International standards for phytosanitary measures. Guidelines for regulating wood packaging material in international trade [online]. FAO Corporate Document Repository. Available from: http://www.fao.org/docrep/006/y4838e/y4838e00.htm [Accessed 10 April 2013].

Freedomia, 2013. Pallets to 2017 – Industryreport, Freedomia group.

Gasol, C.M., Farreny, R., Gabarrell, X., Rieradevall, J., 2008. Life cycle assessment comparison among different reuse intensities for industrial wooden containers, *The International Journal of Life Cycle Assessment*, 13(5), 421-431.

Gnoni, M. G., Iavagnilio, R., Mossa, G., & Mummolo, G. (2003). Modelling dynamics of a supply chain under uncertainty: a case from the automotive industry. *International journal of automotive technology and management*, 3(3), 354-367.

Gnoni, M.G., Rollo, A., 2010. A scenario analysis for evaluating RFID investments in pallet management, *International Journal of RF Technologies: Research and Applications* 2(1), 1-21.

Gobbi, C., 2011. Designing the reverse supply chain: the impact of the product residual value, *International Journal of Physical Distribution & Logistics Management*, 41 (8), 768 - 796

Govindan, K., Palaniappan, M., Zhu, Q., & Kannan, D. 2012. Analysis of third party reverse logistics provider using interpretive structural modeling, *International Journal of Production Economics*, 140(1), 204-211.

Govindan, K., Soleimani, H., & Kannan, D. 2015. Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future, *European Journal of Operational Research*, 240(3), 603-626.

Hazen, B.T., Hall D.J., Hanna J.B., 2012. Reverse logistics disposition decision-making: Developing a decision framework via content analysis, *International Journal of Physical Distribution & Logistics Management*, 42 (3), 244 – 274

Huemer, L., 2012. Unchained from the chain: Supply management from a logistics service provider perspective, *Journal of Business Research*, 65(2), 258-264.

Jayant, A., Gupta, P., & Garg, S. K., 2014. Simulation Modelling and Analysis of Network Design for Closed-Loop Supply Chain: A Case Study of Battery Industry, *Procedia Engineering*, 97, 2213-2221.

Kabir, M.F, Schmoldt, D.L., Schafer, M.E., 2003. Time domain ultrasonic signal characterization for defects in thin unsurfaced hardwood lumber, *Wood Fiber Science,* 34(1), 165-182.

Kara, S., Rugrungruang, F., Kaebernick, H., 2007. Simulation modeling of reverse logistics networks, *International Journal of Production Economics,* 106(1), 61-69.

Kenne, J. P., Dejax, P., & Gharbi, A., 2012. Production planning of a hybrid manufacturing–remanufacturing system under uncertainty within a closed-loop supply chain, *International Journal of Production Economics*, 135(1), 81-93.

Keyvanshokooh, E., Fattahi, M., Seyed-Hosseini, S. M., & Tavakkoli-Moghaddam, R., 2013. A dynamic pricing approach for returned products in integrated forward/reverse logistics network design, *Applied Mathematical Modelling*, 37(24), 10182-10202.

Kye, D., Lee, J., Lee, K., 2013. The perceived impact of packaging logistics on the efficiency of freight transportation (EOT), *International Journal of Physical Distribution & Logistics Management*, 43(8), 707 – 720

Kim, S., Kim, H.J., Park, J.C., 2009. Application of recycled paper sludge and biomass materials in manufacture of green composite pallet, *Resources, Conservation & Recycling,* 53(12), 674-679.

Kim, T., & Glock, C. H., 2014. On the use of RFID in the management of reusable containers in closed-loop supply chains under stochastic container return quantities, *Transportation Research Part E: Logistics and Transportation Review*, 64, 12-27.

Ko, H. J., & Evans, G. W. 2007. A genetic algorithm-based heuristic for the dynamic integrated forward/reverse logistics network for 3PLs, *Computers & Operations Research*, 34(2), 346-366.

Kocjan, W., Holmström, K., 2010. Computing stable loads for pallets, *European Journal of Operational Research*, 207(2), 980-985.

Krumwiede, D.W., Sheu, C., 2002. A model for reverse logistics entry by third-party providers, *Omega* 30(5), 325-333.

Letchford, A.N., Amaral, A., 2001. Analysis of upper bounds for the Pallet Loading Problem, *European Journal of Operational Research*, 132(3), 582-593.

Lai, K. H., Wu, S. J., & Wong, C. W., 2013. Did reverse logistics practices hit the triple bottom line of Chinese manufacturers?, *International Journal of Production Economics*, 146(1), 106-117.

Lau, H.C.W., Chan, T.M., Tsui, W.T., Ho, G.T.S., Choy, K.L., 2009. An AI approach for optimizing multi-pallet loading operations, *Expert Systems With Applications*, 36(3), 4296-4312.

Li, L., 2011. Assessing the relational benefits of logistics services perceived by manufacturers in supply chain, *International Journal of Production Economics*, 132(1), 58-67.

Li, 2006, Study on the Problem of China's Logistics Pallet Exchange System and its Countermeasure, East China Economic Management, 5, 85-89.
Marasco, A., 2008. Thirdy-party logistics: A literature review, *International Journal of Production Economics*, 113(1), 127-147.
Martins, G.H.A., Dell, R.F., 2007. The minimum size instance of a Pallet Loading Problem equivalence class, *European Journal of Operational Research*, 179(1), 17-26.
Martins, G.H.A., Dell, R.F., 2008. Solving the pallet loading problem, *European Journal of Operational Research*, 184(2), 429-440.
Masood, S.H., Haider Rizvi, S., 2006. An investigation of pallet design using alternative materials for cold room applications, *The International Journal of Advanced Manufacturing Technology*, 29(1–2), 1-8.
Mazeika Bilbao, A., Carrano, A.L., Hewitt, M., Thorn, B.K., 2011. On the environmental impacts of pallet management operations, *Management Research Review*, 34(11), 1222-1236.
Min, H., Ko, H., 2008. The dynamic design of a reverse logistics network from the perspective of third-party logistics service providers, *International Journal of Production Economics*, 113(1), 176-192.
Olorunniwo F. O., Li X., 2010, Information sharing and collaboration practices in reverse logistics, *Supply Chain Management: An International Journal*, 15(6), 454 – 462.
Paksoy, T., Bektaş, T., & Özceylan, E. (2011), Operational and environmental performance measures in a multi-product closed-loop supply chain, *Transportation Research Part E: Logistics and Transportation Review*, 47(4), 532-546.
Patricio, M.A., Maravall, D., 2007. A novel generalization of the gray-scale histogram and its application to the automated visual measurement and inspection of wooden pallets, *Image and Vision Computing*, 25(6), 805-816.
Pokharel, S., & Mutha, A. 2009. Perspectives in reverse logistics: a review, *Resources, Conservation and Recycling*, 53(4), 175-182.
Prockl, G., Pflaum, A., Kotza, H., 2012. 3PL factories or lernstatts? Value-creation models for 3PL service providers, International Journal of Physical Distribution & Logistics Management, 42(6), 544-561.
Pureza, V., Morabito, R., 2006. Some experiments with a simple tabu search algorithm for the manufacturer's pallet loading problem, *Computers and Operations Research*, 33(3), 804-819.
Ramezani, M., Bashiri, M., & Tavakkoli-Moghaddam, R., 2013. A new multi-objective stochastic model for a forward/reverse logistic network design with responsiveness and quality level, *Applied Mathematical Modelling*, 37(1), 328-344.
Silva, D. A. L., Santos Renó, G. W., Sevegnani, G., Sevegnani, T. B., & Serra Truzzi, O. M., 2013. Comparison of disposable and returnable packaging: a case study of reverse logistics in Brazil, *Journal of Cleaner Production*, 47, 377-387.
Senthil, S., Srirangacharyulu, B., & Ramesh, A., 2012. A decision making methodology for the selection of reverse logistics operating channels, *Procedia Engineering*, 38, 418-428.
Soury, E., Behravesh, A.H., Rouhani Esfahani, E., Zolfaghari, A., 2009. Design, optimization and manufacturing of wood–plastic composite pallet, *Materials & Design*, 30(10), 4183-4191.
Suyabatmaz, A. Ç., Altekin, F. T., & Şahin, G., 2014. Hybrid simulation-analytical modeling approaches for the reverse logistics network design of a third-party logistics provider, *Computers & Industrial Engineering*, 70, 74-89.
Trebilcock, B., 2010. Pallet survey: What moves our readers, Modern Materials Handling, 24-29. Available at: http://www.palletcentral.com/files/MMH1009_SpecialRptPallet.pdf [accessed 17 October 2013].
Yaman, H., Sen, A., 2008. Manufacturer's mixed pallet design problem, *European Journal of Operational Research*, 186(2), 826-840.
Wagner, S.M., Sutter, R., 2012. A qualitative investigation of innovation between third-party logistics providers and customers, *International Journal of Production Economics*, 140(2), 944-958.
Zeballos, L. J., Gomes, M. I., Barbosa-Povoa, A. P., & Novais, A. Q., 2012. Addressing the uncertain quality and quantity of returns in closed-loop supply chains. Computers & Chemical Engineering, 47, 237-247.
Zerhouni, H., Gayon, J. P., & Frein, Y., 2013. Influence of dependency between demands and returns in a reverse logistics system, International Journal of Production Economics, 143(1), 62-71.