

## SUPPLY CHAIN MODELS FOR NON-REUSABLE PACKAGING LOGISTICS

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**Abstract:** Packaging logistics plays an important role in today's economy, because a well-chosen packaging can significantly increase the market share of a company. However, packaging has advantageous impacts on the purchasing, production and distribution processes, but negative impact must be also taken into consideration focusing on sustainability, costs, environmental impacts and logistics. Within the frame of this article, the author suggests a potential model structure for non-reusable packaging logistics focusing on the type of the collection and distribution routes, number of senders and receivers, location of recycling or disposal, maintenance and cleaning location, existence of agents, logistics centers and central depots. The suggested approach makes it possible to derive the typical supply chain models for both non-reusable and reusable packaging. Within the frame of this article, the most important supply chain models for non-reusable packaging logistics are described.

**Keywords:** packaging logistics, recycling, transportation, non-reusable and reusable packaging, collection, distribution

### 1. INTRODUCTION

Packaging logistics is today an integrated part of supply chain solutions. In their research in the field of inverse logistics, Leo Kroon and Gaby Vrijens already in 1995 formulated three typical types of supply chains for reusable packaging, based on Lützebaure's earlier work [1], which can be used to characterize even today's cyber-physical systems in the Industry 4.0 environment [2]. Kroon and Vrijens distinguish three basic types of supply chains for packaging devices, while focusing on the use of multipath packaging devices. One of the most important research field of the Institute of Logistics at the University of Miskolc focuses on packaging logistics. The research results are focusing on the following topics: packaging management system based on digital technology [3], operational concept of an innovative packaging management system [4], operational concept of an innovative management framework for choosing the optimal packaging system for supply chains [5], Industry 4.0: challenges and opportunities in packaging logistics [6]. The research topics include both materials handling related aspects [7] and process related aspects [8].

Within the frame of this article, the author focuses on the modelling of non-reusable packaging logistics and related supply chain solutions.

The efficiency of reusable and non-reusable packaging is greatly influenced by the distance of the transport in the supply chain. In supply chains using reusable and non-reusable packaging, several types of transport distance can be defined:

- Length of transportation routes of the packaged goods: using reusable and non-reusable packaging may result in a difference in that, as reusable packaging is generally more robust in design, weight and volume, transporting the packaged

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goods over the same distance may result in higher energy consumption, higher environmental impact and higher costs.

- Collection and return of empty packaging to the receiver: In this case, transportation costs are not incurred for non-reusable packaging, but for reusable packaging it does not represent a significant item in the overall logistics cost.
- Transportation distances related to the disposal of used packaging: both reusable and non-reusable packaging need to be disposed after use, which means that care must be taken to ensure that they are destroyed or recycled in a sustainable and environmental friendly way. This occurs after one use for non-reusable packaging and after several uses for reusable packaging. As there is no possibility to offer an environmental friendly disposal, recycling process of empty packaging at the place of the last use of packaging, therefore empty packaging must be transported to the place of recycling, which can result in significant transport costs, especially for non-reusable packaging, as transport to the place of recycling must be ensured after each cycle.
- Transport distances related to the maintenance and cleaning of packaging: for reusable packaging, cleaning and maintenance are important operations. Especially in the case of larger or specially designed packaging, it may not be possible for the recipient to carry out the maintenance and cleaning of the packaging, but it may be necessary to transport it to a contractor who will carry out the cleaning and maintenance required. This is a particularly important task in the case of reusable packaging, since maintenance and cleaning is not a typical task for non-reusable packaging.

As the international research results in the field of packaging logistics show, the design and control of packaging supply chain plays an important role in the business processes of both production and service companies. The research works are focusing on the following main topics:

- packaging container choice in the food industry [9],
- reengineering and rethinking of packaging from used materials, design and processes point of view for a sustainable circular economy [10],
- the role of the government in packaging logistics [11],
- emerging technologies for the design and control of packaging logistics (data-driven decision support) [12],
- networking in packaging logistics, collaboration and cooperation [13],
- role of Industry 4.0 technologies in packaging logistics, cyber-physical systems in packaging supply chain [14],
- impact of mechanical stress (shock and vibration) on the quality of goods from packaging point of view [15],
- circular economy and plastics packaging [16],
- metrics to measure the performance and impact of different types of packaging on costs, efficiency and sustainability [17],
- low carbon packaging supply chain [18],
- standardization in packaging design and packaging logistics processes [19],
- impact of packaging design on the sustainability of packaging supply chain [20,21],
- mathematical modeling and optimization of packaging supply chain [22],
- main drivers of packaging supply chain [23].

Based on the focuses of the packaging logistics related research direction it is possible to summarize, that the design and optimization of packaging logistics processes is a significant and important part of business processes in production and service industry.

The paper is organized as follows. Section 2 presents the general model structure of supply chain models for packaging logistics. Section 3 describes the potential supply chain models for non-reusable packaging logistics. Conclusions and future research directions are discussed in Section 4.

## **2. MODELL STRUCTURE**

The typical variations in supply chains using reusable and non-reusable packaging can be analyzed from different point of view, in this article the author focuses on transportation distances. In order to discuss the main transportation operations in the supply chain of reusable and non-reusable packaging, it is useful to construct a general model structure from which the typical system variations can be derived. The main aspects of the model are summarized as follows:

- Type of shuttle: depending on the complexity of the supply chain and the number of partners involved, it is possible to implement shuttles and/or round trips.
- Number of consignors: depending on the number of places from which the partners of the supply chain is supplied to the receiving points, a distinction is made between systems with one and systems with several consignors. Supply chains with only one consignor (supplier) are very rare, since in practice almost all companies rely on many suppliers to carry out their activities.
- Number of receivers: the number of receivers is essentially determined by the way, in which the supply chain is defined. If the purpose of the limitation is to examine the packaging supply chain from the sender (supplier) point of view, then supply chains with several recipients are typical, since one supplier usually supplies several destinations, whereas, on the other hand, when the purpose of the analysis is to examine the supply chain from the receivers' point of view, the system is characterized by several senders (suppliers) and one recipient. When examining the whole supply chain, it is appropriate to consider the variant with multiple senders (suppliers) and multiple receivers.
- Type of packaging: the supply chain can be designed for reusable and non-reusable packaging, but in practice it is mainly hybrid systems that are used, which can handle both reusable and non-reusable packaging.
- Disposal site: the disposal site is typically not located at the receiving party's site, hence the need to transport the packaging at the end of its life cycle.
- Cleaning station: Although cleaning is an essential part of the service contract, as the service provider must provide clean, functional packaging at all times to enable transport and storage, the service provider may not have its own packaging cleaning capacity and may need to use a third party, which can significantly increase the supply chain transport tasks associated with reusable packaging.
- Location of maintenance: Since the maintenance of reusable packaging is not as frequent as the cleaning of reusable packaging, outsourcing maintenance tasks to a third party does not cause as significant an increase in transport as cleaning tasks, but even in the case of maintenance, it is advisable to choose a location close to

either the sender or the receiver, or in the case of a central depot, it may be economical to allocate the maintenance activity to a central depot.

- Transportation service provider: Transport can be provided by the sender, the receiver, a third party service provider or by a multi-partner arrangement.
- Agents: The role of agents in packaging supply chains is growing, as they can organize the implementation of material handling (transportation, loading and unloading, storage) tasks related to the packaging, based on one or more logistics centers.
- Logistics center: for complex systems, especially those involving a large number of suppliers and users, the use of logistics centers is essential, as they can offer a more cost-effective solution for the implementation of individual logistics tasks through a task-specific infrastructure.

Based on these considerations, a general model structure can be defined (see Figure 1) which makes it possible to derive the typical system variants. In the following, let us examine some supply chains for reusable and non-reusable packaging that can be derived from the model structure presented in Figure 1, in terms of transportation distances.

Type of the route	Shuttle	Milkrun	Hybrid	
Number of senders	Single		Multi	
Number of receivers	Single		Multi	
Type of packaging	Non-reusable	Reusable	Hybrid	
Location of recycling	Sender	Receiver	Third party	Hybrid
Maintenance location	Sender	Receiver	Third party	Hybrid
Cleaning location	Sender	Receiver	Third party	Hybrid
Transportation by	Sender	Receiver	Third party	Hybrid
Agent	Yes		No	
Logistics centre	Yes		No	
Central depot	No	Single	Multi	

Figure 1. Structure of typical supply chain models of reusable and non-reusable packaging logistics (own edition).

### 3. SUPPLY CHAIN MODELS FOR NON-REUSABLE PACKAGING LOGISTICS

For a supplier and a user, there are three typical supply chain configurations for non-reusable packaging. The simplest, and the most advantageous in terms of transportation distances, is when the disposal of the non-reusable packaging can be carried out in an environmentally friendly way on the receiver's own premises, as no further transportation of the packaging is required (Figure 2).

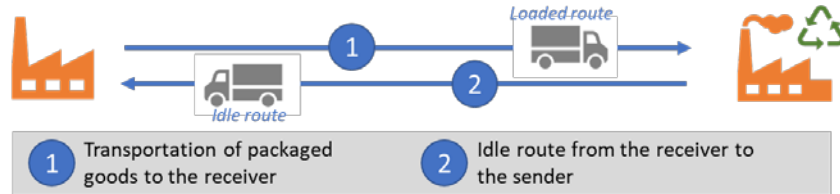


Figure 2. Supply chain for non-reusable packaging: the recycling of packaging is possible at the receiver (own edition).

The second option is where the recycling of the used packaging can be done at the sender, in which case the empty packaging must be returned to the sender. The return transportation can be carried out by the sender, the receiving party or a logistics service provider. If the return is performed by the sender, it is advisable to match the return date of the empty non-reusable packaging with the arrival date of the loaded shipment, since a new shipment is not necessary to return the used packaging stored at the sender's site to the recycling site, which in this case is the same as the sender's site (Figure 3).

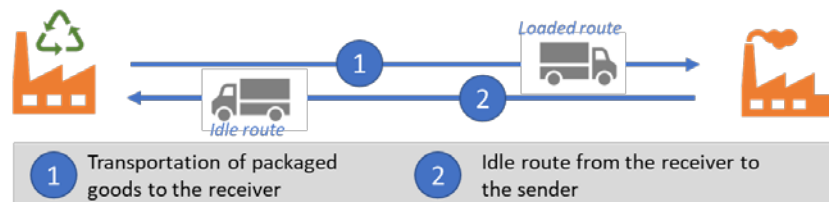


Figure 3. Supply chain for non-reusable packaging: the recycling of packaging is possible at the sender (own edition).

If it is not possible to return the used non-reusable packaging to the sender in the form of a return shipment, a new route has to be organized, which significantly increases the transportation costs, regardless of whether the sender, the receiving party or a third party is responsible for the transportation (Figure 4).

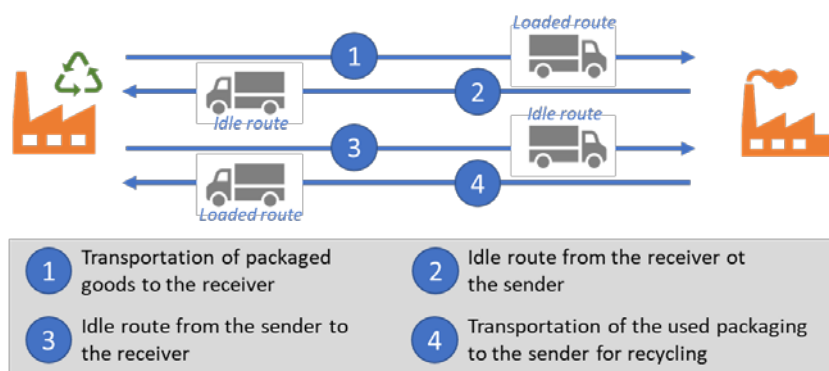


Figure 4. Transportation of non-reusable packaging: recycling by the sender (own edition).

In the fourth, and perhaps most typical case, the recycling of used non-reusable packaging is carried out at a third party site, in which case the used non-reusable packaging must be transported from the receiving party to the recycling site. In the model illustrated in Figure 5, the used non-reusable packaging is transported by the receiving party to the recycling site, but this transportation process can also be performed by the recycler or a third party partner.

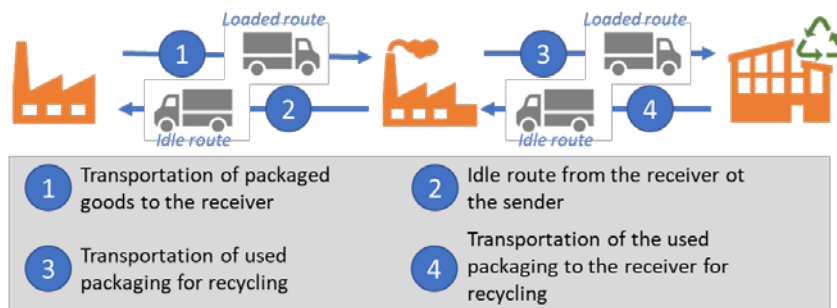


Figure 5. Transportation of non-reusable packaging: third party recycling (own edition).

In the following, let us review typical supply chain solutions where the transportation of non-reusable packaging is organized as a milkrun. The simplest supply chain as a milkrun is the following: the recycling of used non-reusable packaging can be done at the receiving party, as no transportation is required (Figure 6).

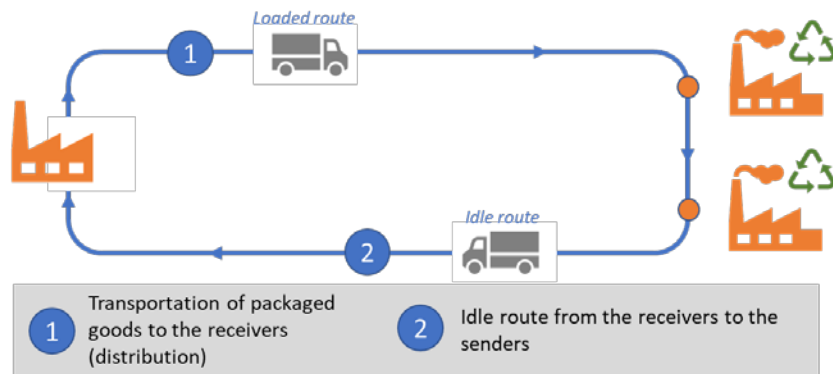


Figure 6. Transportation of non-reusable packaging: milkrun-based supply, recycling by the sender (own edition).

In the next option, the recycling of used non-reusable packaging can take place at the sender. In the model shown in Figure 7, the transportation is carried out by the sender. Two options are possible in this case: if the collection route for the collection of the used packaging can be synchronized with the distribution route for the delivery of the packaged goods, a single round trip is sufficient, otherwise two round trips are required by the sender.

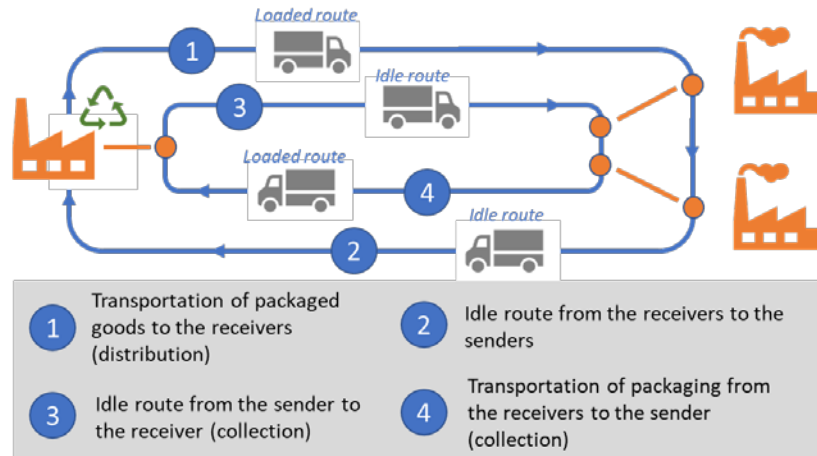


Figure 7. Transportation of non-reusable packaging: milkrun-based supply, recycling by the receiver (own edition).

A third solution to the non-reusable packaging supply chain could be a system where recycling is carried out by a third party. In the system shown in Figure 8, the transportation of the loaded goods and the transportation of the used packaging to the recycling site are not synchronized, so two separate routes have to be implemented. If the two different types of transportation tasks can be synchronized, it is possible to carry out the distribution and collection tasks as a single route.

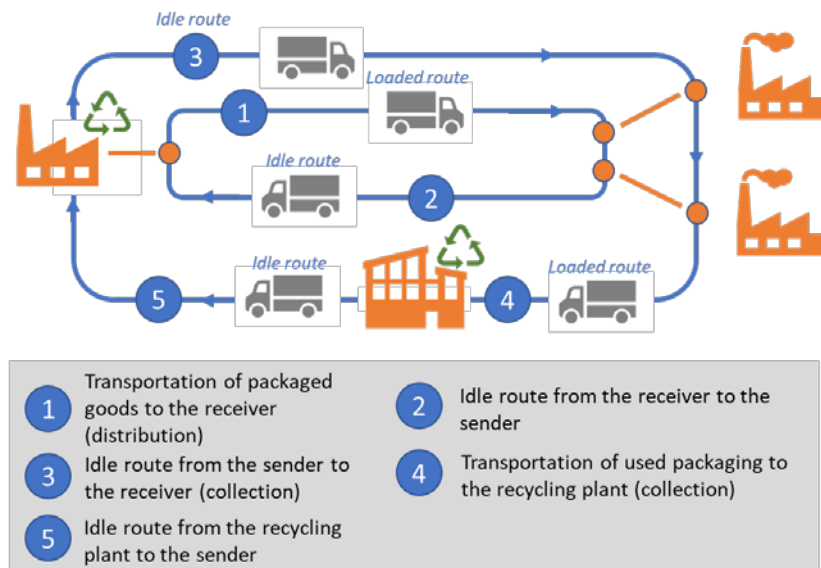


Figure 8. Transportation of non-reusable packaging: third party recycling, transportation tasks are performed by the sender (own edition).

#### 4. CONCLUSIONS

Today, packaging logistics become more and more important both in the field of services and production. The logistics aspects of packaging related processes become more and more important as they have a major impact on cost efficiency, but also have a significant impact on logistics performance and environmental aspects. Within the frame of this article, the author describe a potential model structure of supply chain models for packaging logistics. It is possible to derive the most important supply chain models for both non-reusable and reusable packaging. In this article, the focus is on the non-reusable supply chain models.

The added value of the paper is the description of the model structure and the description of typical supply chain models, which makes it possible to understand the main processes in packaging supply chain solutions. Based on the mentioned models it is possible to define new mathematical models to describe the main processes of packaging supply chain solutions and define optimization models and methods, which can support the improvement of cost efficiency and sustainability of packaging supply chain. One potential future research direction is to discuss the typical supply chain models for reusable packaging and develop new optimization models to design cost efficient, sustainable and environmental friendly supply chain for packaging logistics. The concept of virtual companies [24] and the cooperation and collaboration of logistics service providers [25] is also a potential research direction to find new ways for the improvement of packaging supply solutions.

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