An approach to the facility layout problem in reverse and bi-directional logistics context

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Abstract During the past decades, Reverse Logistics (RL) has received much attention. Its incorporation and implementation modify the space necessity of the enterprises and the optimal way of the plant resources configuration, basically because new needs of space arise for recovery products, inspection, storage, and for disposal activities. Hence, the facility layout problem (FLP) for enterprises with RL needs should consider new aspects derived from reverse and bi-directional (forward and reverse) flows. However, research results show work mainly focused on FLP and on RL separately. Nevertheless, the lack of a review study on this subject is a gap that has not been regarded so far. In this paper, a literature review is presented to define the FLP in a reverse and bi-directional logistics context. The literature references in the field of facility layout and reverse logistics are gathered, categorized, and reviewed. The contributions are analysed form different perspectives. Finally, several issues are highlighted to be investigated in future work.

Keywords: Facility Layout; Reverse Logistics; Bi-directional Logistics; Remanufacturing

1 Introduction

RL has become a relevant aspect for the organizations. According to Agrawal, Singh and Murtaza (2015) it has become a field of importance due to growing environmental concerns, legislation, corporate social responsibility and sustainable

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competitiveness. Also, government environmental regulations, shorter product life cycles, and the explosion of e-commerce are reasons why RL has emerged with closed-loop supply chain (Sahyouni, Savaskan and Daskin, 2007).

RL is evolving, and it requires an appropriate logistics infrastructure for the recovered products. RL is a complex and dynamic process and not merely a reversal of the direction of the supply chain (Rajagopal, Sundram and Naidu, 2015). Also, RL is based on a new concept that its design, based exclusively on direct logistics, can make it inefficient and expensive (Dey, LaGuardia and Srinivasan, 2011; Alarcón et al., 2021).

Amir *et al.* (2022) emphasize on their research the integration of forward and reverse flows as crucial in Circular Economy (CE). There is a close relation between RL and CE. Several works have pointed out the relevance of RL processes in CE and sustainability; the work published by Alarcón *et al.* (2020) stands out.

According to Tolio *et al.* (2017), factories in a CE perspective should be designed considering the requirements deriving from product manufacturing as well as post-use product demanufacturing and remanufacturing. In this perspective, a new set of manufacturing system engineering methods for the design of circular factories shall be developed.

RL differs from forward logistics in different aspects such as the variety, quality and complexity of the products and treatment activities. Those differences forces companies to make changes to their current systems. One relevant aspect to consider for a company's operation to remain efficient is the FLP.

However, besides the relevance that RL seems to have in a facility layout design, there is scarce bibliography that connects these terms. According to Omatseye and Urbanic (2022), researchers have investigated the processes of RL but very few papers are found focusing on the RL processes and the challenges in manufacturing/remanufacturing. As it is mentioned by Topcu, Benneyan and Cullinane (2013), little work has focused on remanufacturing facility design. In this work a review for FLP in a reverse and bi-directional logistics context is presented.

2 State of the Art

Facility Layout has proven repercussion on production systems' operation costs, efficiency and productivity (Pérez-Gosende, Mula and Díaz-Madroñero, 2021). Drira, Pierreval and Hajri-Gabouj (2007) have highlighted some of the factors and design issues in a FLP: the production variety and volume, the material handling system chosen, the different possible flows allowed for parts, the number of floors

on which the machines can be assigned, the facility shapes and the pickup and drop-off locations. Monga and Khurana (2015) show the importance of re-layout; as long as the company grows it has to be adapted to internal and external changes of three types: production volumes, processes and technology, and in the product.

RL plays an important role in the return and the remanufacturing processes of products to meet specific demands (Omatseye and Urbanic, 2022). Uncertainties are unavoidable in RL and some examples that occur in remanufacturing are the quantity and quality of the returned products, level of demand, price, time of return, high congestion at facilities and buffer location/allocation (Zaman et al., 2020; Omatseye and Urbanic, 2022). Ding, Wang and Chan (2023) introduce the term bi-directional logistics, which integrates forward logistics, RL and the related mechanisms to close the loop for Circular Economy. Most articles in the bibliography use the RL term for a two-way product flow or for a one-way return flow. Bi-directional logistics is an unexplored term. There is very little work that identifies the specific requirements for layout in reverse and bi-directional logistics systems. Topcu, Benneyan and Cullinane (2013) highlight variables from remanufacturing facilities focused on space allocation: yield rates, returned product volumes, refurbished demand, and storage capacities for each type of part and at each location in the process.

3 Methodology

The methodology for a characterization about FLP in a reverse and bidirectional logistics context is composed of six steps: 1) field labels, key words, and boolean operators' selection, 2) database sources definition, 3) articles criteria selection, 4) filtering and articles collection, 5) documentation review and characterization, and 6) summary of results and categorization. Table 1 summarizes the methodology.

Table 1 References collection methodology

Field labels, keywords, and boolean operators	(TI= ('facilit* layout AND reverse logistic*') AND TI= ('facilit* layout AND bidirectional logistic* OR bi*directional logistic*'))
	(TI= ('reverse logistic* AND bidirectional logistic* AND definition'))
Database	Scopus and Web of Science (WoS)
Document Type	Research articles
Time window	No
Initial Number of articles	47
Removed duplicates	37
Snowball articles	10
Final Number of articles	20

Steps one, two and three are detailed in Table 1. Step four have defined the relevant retrieved bibliography for this review; the exclusion criteria used was irrelevant and duplicate articles. Step five has allowed to identify specific characteristics for RL and bi-directional logistics. Finally, results are categorized according to the factors affecting plant layout proposed by Monga and Khurana (2015).

4 Results

Lastly, twenty reviewed articles have contributed to identify FLP, RL and bi-directional logistics relevant information for this work. However, only five provide sufficient detail to relate RL with FLP. Thus, to organize and classify the information of these relations Table 2 has been constructed based on the factors affecting plant layout identified by Monga and Khurana (2015). Process factor has been added due to the founded information.

Table 2 Facility Layout Characterization for forward, reverse, and bi-directional logistics

Source	RLP Characteristics	a. Material	b. Machinery	c. Labour	d. Material Handling	e. Waiting Time	f. Auxiliary Services	g. Building	h. Future Changes	i. Process
Topcu, Benneyan and Cullinane (2013)	Recovered Product Physical Characteristics: dimensions/size, volume, weight, fragility	X			X					
	Required materials or equipment depending on the recovery items condition	X	X							
	General flow of parts depends on the necessary disassembly, cleaning, and testing processes				X					
	Variable processing times dependent on age, wear, and condition					X				X
	Storage space requirements that change by yield rates, variable returned product volumes, and random demand for reclaimed, returned, and remanufactured items							X		
	Processes determined by the unknown condition of the item. Required processes: Disassembly, Inspection, and Storage									X

Table 2 (continued)

		a.	b.	c.	d.	e.	f.	g.	h.	i.
Omatseye and Urbanic (2022), & Zamani et al. (2020)	Uncertain condition or quality of the items (Work to be performed in the returned items)	X								X
	Uncertain quantity of the returned products	X								
	Buffer location/allocation							X		
Sangwan (2017)	Sorting and testing can be done parallel to disassembly to check reusability of parts									X
Suzanne, Absi and Borodin (2020)	Performance of processes: manufacturing and remanufacturing in two separate processes or share the same production routes									X

Principal results are regarding to: a) uncertainties in the quality and quantity of the product, b) different and parallel activities that must be performed in the facilities for disassembly, cleaning, testing, and remanufacturing, c) space for storage the recovered items, and d) some RL processes can share some production routes of the forward flow.

5 Conclusions

Very few works have been identified that connects FLP and RL. Information for FLP review in reverse and bi-directional logistics has been obtained, classified, and presented in this work. Uncertainties are presented regarding the quality and quantity of products. Space for storage and different parallel activities from forward flows in facilities have been identified as requirement. Also, found articles refer as RL characteristics the ones that are about bi-directional logistics; they recite the introduction of remanufacturing, re-assembly, and other processes in forward flows. There is an unexplored found gap for RL and bi-directional logistics in FLP. Academic implications of this article include understanding the importance of FLP in the RL and bi-directional logistics context, identifying the impact on each factor.

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