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# Reverse Logistics for the Construction Industry: Lessons from the Manufacturing Context

**M. Reza Hosseini[1,*], Nicholas Chileshe[1], Raufdeen Rameezdeen[1], Steffen Lehmann[2]**

[1]School of Natural and Built Environments, Barbara Hardy Institute (BHI), University of South Australia, Adelaide, Australia
[2]School of Built Environment, Faculty of Humanities, Curtin University, Perth, Australia

**Abstract** Reverse logistics (RL) has emerged within manufacturing organisations as an effective measure for achieving sustainable development alongside enhancing productivity. Yet, the construction industry has not kept pace in reaping the benefits of RL compared to the manufacturing industry. One reason for this might be due to the insubstantial RL literature in the construction field as opposed to the manufacturing context. Consequently, knowledge of RL and its application in construction sphere is limited. To address this issue, this study attempts to identify and highlight the fundamental aspects of the RL concept that dramatically influence its adoption and implementation through an integrated review of the literature. Subsequently, the study focuses on comparing the body of knowledge in the construction field in regards to the identified central aspects of RL against those of the manufacturing industry. The discussions will conclude by developing a conceptual model to underscore the strategic aspects of RL for construction organisations. This would further establish the body of knowledge in the construction field by highlighting the gaps in the RL knowledge base. Additionally, the discussions and the conceptual model presented could facilitate raising the level of awareness regarding RL within the construction industry.

**Keywords** Reverse logistics, Construction industry, Manufacturing industry, Supply chain management, Design for reverse logistics, Harvesting of information

## 1. Introduction

The limitations of the built environment in terms of the natural resources depletion and absorbing the generated wastes has become broadly known [1]. In this context, many organisations in a wide range of industries have shown an increasing interest in enhancing the eco-efficiency of their Supply Chain Management (SCM) systems [2]. One available measure to address environmental concerns has been the implementation of RL principles [3], which would also culminate in noticeable cost-savings for organisations in various stages of their SCM [4]. Likewise, RL has been considered a key source of competitiveness [5] and an innovative business opportunity for contemporary organisations [6]. RL is gradually becoming an inseparable element of SCM systems [7] or, as stated by some authors, a necessity for organisations [8].

Evidence has demonstrated the great advantages of RL in terms of alleviating the environmental concerns and generating cost savings in the manufacturing context [9, 10]. There are seminal publications suggesting that RL frameworks developed for the manufacturing industry would beequally advantageous and effective for other contexts including the construction industry [9, 11].

However, the construction industry has been a laggard in harnessing the benefits of RL in comparison to the manufacturing industry [12, 13]. The limited knowledge of RL practices within the construction context could be regarded as one of the main barriers of RL adoption in this industry [14-17].

Carter and Ellram [18] highlighted that RL encompasses cross-functional and multidisciplinary activities and coordination, hence, a wide range of factors can affect various aspects of its adoption in organisations. This perspective, therefore, necessitates gaining a deep appreciation of the concepts of RL and its strategic aspects.

The paucity and fragmented nature of available research studies on RL in the construction literature could be deemed to be a contributor to the lack of knowledge and accordingly low-level adoption of RL. As opposed to the substantial body of knowledge of RL in the manufacturing context, RL has remained an overlooked area within the construction industry. As pointed out by Schultmann and Sunke [11], RL has received attention from academia in construction field only recently. Consequently, conducting studies aiming at drawing from the available knowledge in the manufacturing context to augment and integrate the available knowledge on

* Corresponding author:
Reza.Hosseini@unisa.edu.au (M. Reza Hosseini)
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RL in the construction industry becomes relevant.

To address this need, this study aims to collate the available literature on the major aspects of RL in the manufacturing context. The concept of RL will be explained and then the collated information will be applied as the basis to critically compare it with the RL literature in the construction industry. The discussions will draw attention to the relevant areas in need of further consideration within the construction context.

The goal of this approach is to raise the level of awareness on RL within the construction industry. In addition, the study aims to facilitate identifying the gaps in the knowledge on strategic aspects of RL in the construction literature. Additionally, it is intended that the discussions of this study will stimulate and direct further research studies on RL in the construction field that in turn would yield further establishment of the young field of RL in this industry.

## 2. Research Methodology

The study draws upon an integrative literature review approach and then synthesises the literature [19]. This research methodology was chosen due to the evidence based reports to achieve the following objectives [20]:

- Identify the instrumental variables affecting a phenomenon.
- Map the relationships between the identified variables.
- Identify the overlooked areas in the body of knowledge to direct further research studies.

The above mentioned objectives are consistent with the aims of this study. Moreover, many references attest to the novelty of RL literature [21], recommending integrative literature reviews. The perception is that synthesising the literature of any emerging phenomenon (e.g. RL) would add value to its body of knowledge by conceptualising and categorising the relevant factors and assimilating the existing information into conceptual models [19]. By the same token, previous studies have stressed the necessity of synthesising the extant literature on RL into an integrated body of knowledge to clarify the strategic aspects of RL [6].

Given the multidisciplinary nature of the study, searching for materials to be reviewed was conducted in the following two sectors:

The Manufacturing Industry: the databases accessed in the broad review of the literature on RL (Seuring and Müller [22] were selected as the source of materials for review. Consequently, Ebsco, Elsevier, Emerald, Scopus and Wiley were searched. The main keywords utilised were “closed loop supply chain”, “product recovery”, “reverse logistics”, “reverse flow”, “reverse channel”. Besides the publications focusing on the keywords “green supply chain”, “remanufacturing”, “sustainable supply chain” and “sustainable logistics” were controlled to select the literature mentioning RL as a policy for the above umbrella practices.

The Construction Industry: The method utilised in the broad review of the literature by Yi and Chan [23] to collect the relevant treatises from construction field was adopted to search and select the relevant literature. This involved a thorough search using the “title/abstract/keyword” fields. “Reverse Logistics”, “Closed Loop Supply Chain”, “Deconstruction” and “Material Reuse” were used as the search statement keywords for the relevant studies.

The journals reviewed for the construction industry included Construction Management and Economics (CME), Journal of Management in Engineering (JME), Engineering, Construction and Architectural Management (ECAM), Automation in Construction (AIC), International Journal of Project Management (IJPM), and Building Research and Information (BRI) according to [24]. In addition, journals in the construction sector containing highly cited papers including Building and Environment (BAE), Canadian Journal of Civil Engineering (CJCE) and Journal of Computing in Civil Engineering (JCCE), were added to the search list as stated by Yi and Chan [23].

The study applied the strategy recommended by Webster and Watson [25] and utilised previously in RL concept by Pokharel and Mutha [26]. That is, the papers cited in the publications found in databases were evaluated for their relevance to the objectives of the study by at least two of the researchers for this study. The relevant publications were incorporated in the review process. A total of ninety six articles from the construction context were reviewed and a total of 231 sources from the manufacturing industry.

The conceptual model was presented in a casual loop diagram (CLD) format. CLDs are useful and flexible tools for illustrating the feedback composition of systems and showing the causal relations between elements of systems for any domain as pointed out by Sterman [27]. The Vensim PLE package was used to construct the model and the casual charts.

## 3. Strategic Aspects of RL

To address issue of the strategic aspects of RL that is the main objective of this study, the following features were considered as the most important aspects of RL within both construction and manufacturing industries. Commenting on the four major aspects was deemed necessary for this study. This comprised clarifying the concept as stated by Wacker [28] for exploring any phenomenon, alongside investigating the drivers, barriers and major practices as suggested by Schultmann and Sunke [11] as the major aspects of RL.

(1) *RL background, concept and definitions*: this aspect was regarded as fundamental, because explaining the conceptual definition of any phenomenon is an absolute prerequisite for conducting further inquiries on the subject, otherwise the findings of investigations may result in misleading conclusions as stated by Wacker [28].

Other strategic aspects of RL relate to the main drivers that lead organisations towards adopting RL, the barriers to adoption and implementation of RL and the crucial strategies that should be considered for successful implementation of RL [11].

As a result, the strategic aspects of RL regarding the (2) *major drivers*, (3) *main barriers* and (4) *key strategies for implementing RL* were considered and are discussed and clarified later within this study.

# 4. RL Background, Concept and Definitions

## 4.1. Background

As one of the earliest references to the phenomenon, RL was described as "going the wrong way" by Lambert and Stock [29]. During the 1980s, RL was defined by some researchers through referring to the movement of products from consumers back to suppliers or producers within a distribution channel. Salient examples of such authors were Murphy [30] and Murphy and Poist [31] that termed this concept as "reverse distribution" with an apparent bias towards warehousing and transportation aspects.

Council of Logistics Management conceptualised RL as "the role of logistics in product returns, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing" Stock [32]. Consequently, Carter and Ellram [18] put forward the definition that "Reverse logistics is a process whereby companies can become more environmentally efficient through recycling, reusing and reducing the amount of materials used".

At the end of 1990s, the definition proposed by Rogers and Tibben-Lembke [33] used the objectives, the procedure and the definition of *logistics* as the bedrock for defining RL. They defined RL as "the process of planning, implementing and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or for proper disposal" [33]. This definition extended the concept of RL by broadening the applicable types of products to RL (i.e. both used and virgin products).

## 4.2. Definition of RLwithin the Manufacturing Industry

In the contemporary literature of manufacturing field, RL is deemed an integrated new logistics chain to the structure of a redesigned SCM for enhancing its performance [34]. Similarly, RL facilitates fulfilling the objectives of the conventional SCM by complementing the forward logistics system [35]. Even more, some authors have opined that the line between forward and reverse logistics is becoming indistinct because both chains act in tandem as the building blocks of SCM system [5]. Likewise, the definition of RL by Dowlatshahi [9] asserts that "a RL system defines a supply chain that is redesigned to efficiently manage the flow of products or parts destined for remanufacturing, recycling, or disposal. The enhanced supply chain is, therefore, capable of effectively using resources that were not previously considered or utilised". RL has become "a specialized segment of logistics" dealing with managing products after sale and delivery to consumption points [36].

It can be interpreted that the conceptual definition of RL within the manufacturing industry has continuously evolved during the previous decades. Preliminary definitions focus on the point of origin of products. Consequently, the proposed concepts referred to the objectives of organisations i.e. reducing the amount of waste and raw materials. Yet, the contemporary concept of RL considers it a central element of a high-performance SCM arrangement [21].

## 4.3. Definition of RL within the Construction Industry

The definitions for RL within the construction literature are imported from the manufacturing studies such as that by [37]. Even more, *reuse* [38], *deconstruction* [39], *closed loop supply chain* [40] and in some cases *recycling* [41] have been used largely instead of the term RL.

It could be inferred from the review of the literature in the construction context that RL is yet to be regarded as an independent system for construction researchers. The term has been used in different contexts to describe various activities and in various classifications and hierarchies for other concepts. This highlights the lack of a definition for RL for explicit reference to the construction industry as discussed in the following sections.

## 4.4. Confusions Surrounding RL

Due to the lack of a definition for RL in the construction context, misunderstandings and confusions have arisen regarding the true boundaries between RL and analogous phenomena such as waste management or forward logistics [42]. To address this, the following sections discuss the common terms of the RL concept.

### 4.4.1. RL versus Forward Logistics (FL)

Forward logistics largely deals with the movement of materials from points of origin towards points of consumption. Conversely, RL manages the movement of goods, products and materials from the typical consumption points towards the typical points of origin [43].

The intuitive notion of RL might indicate that the direction of goods, materials and products in reverse flow should exactly mirror that of the forward flow. Nonetheless, RL is a symmetric picture for forward logistics most of the times [21]. In real SCM systems, materials, goods and products might deviate from the reverse route towards a wide range of potential channels and destinations such as secondary markets (see Fig. 2 and Fig. 3), while still be included within the RL system [44]. In this view, returning materials, goods and products should not necessarily go back to the exact points of origin [5].

### 4.4.2. RL versus Green Logistics (GL)

The dominance of environmental issues in recent years accompanied by the remarkable surge in the introduction of environmental legislations [45] have influenced both the fields of RL and GL and according to Fernandez [46] have linked the two concepts wrongly. RL is different from GL in that, GL is concerned with FL from the point of production to the point of consumption [47] only in regards to environmental aspects of logistical activities [5]. It may be inferred that RL and GL are virtually two different concepts with only some overlaps [48].

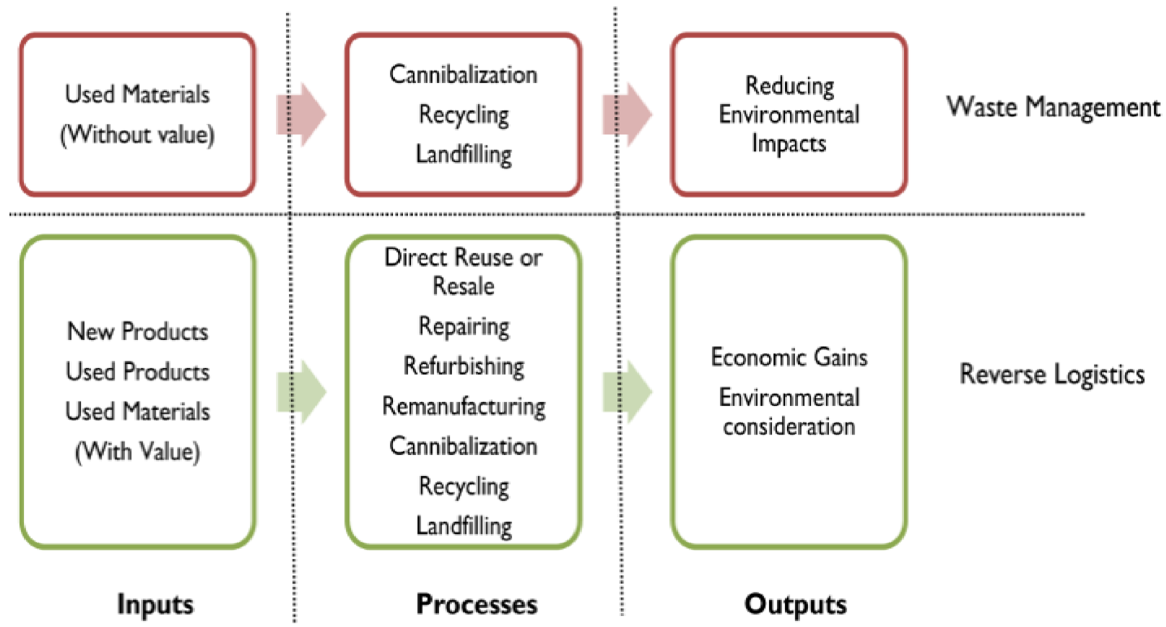


**Figure 1.** Overlaps and differences between RL and WM from the IPO perspective (source: authors)

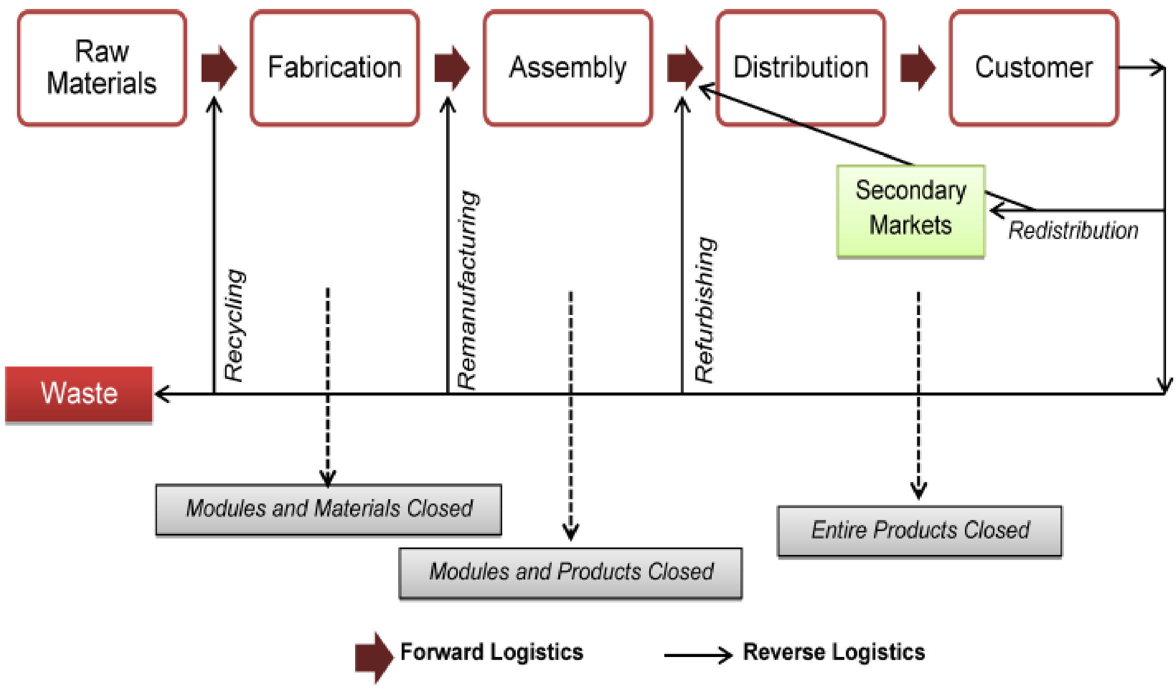


**Figure 2.** A simple model of CLSC and RL for the manufacturing industry (adapted from [55])

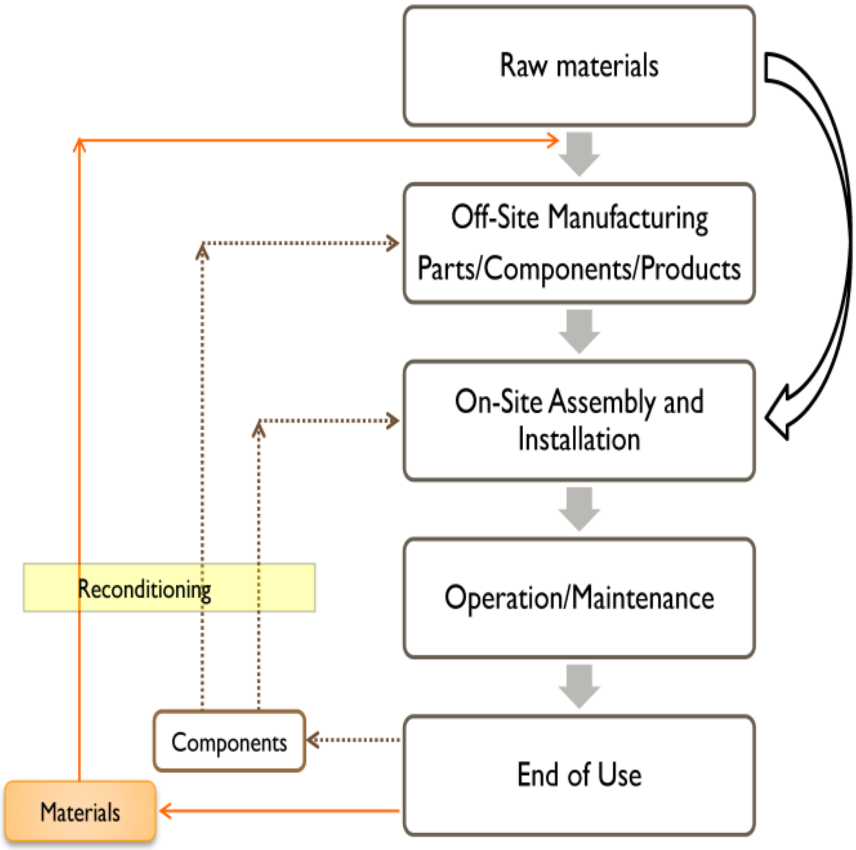


**Figure 3.** A simple model of CLSC and RL for the construction industry (adapted from [11])

4.4.3. RL versus Waste Management (WM)

The major overlaps and discrepancies between the RL and WM are concisely illustrated in Fig. 1 utilising the input-processes-output (IPO) model. As noted by Brito and Dekker [5], WM concerns collecting and processing the waste materials in an effective and efficient manner, minimising the generation of waste, increasing reuse, recovery and recycling of wastes [46]. Likewise, materials are not new and mostly are regarded as waste, implying goods and materials without value [5]. On the other hand, RL products have value, although a wide range of products in RL might be consumed and used items [46]. This refers to the focal point of RL namely to "recover as much as the economic (and ecological) value as reasonably possible" [44].

Unlike WM, RL processes target those resources that otherwise could end up in waste [49]. Nonetheless, WM deals with products at their end of life point whilst RL attempts to extend the life of materials and products [50], before they reach the end of life point [3]. Hence, according to Fernandez [46] and implied by Hu, et al. [51], dealing with waste and its reduction is only one of the underlying objectives of RL.

The fundamental difference between WM and RL could be considered from an economic perspective as well. From this vantage point, organisations regard RL as a policy yielding benefits [49], whereas waste management practices usually include extremely costly activities [52].

### 4.5. RL concept within the Manufacturing Industry

Products mainly move from suppliers or manufacturers to end-users. However, large amounts of products and materials with some value move backwards from end-users [49]. Restructuring SCM system through closing the supply chain loop is considered an effective approach for reducing costs, adhering to the environmental regulations and conforming to clients' expectations [53]. A closed loop supply chain (CLSC) is described by Guide and Van Wassenhove [54] as "the design, control and operation of a system to maximise value creation over the entire life-cycle of a product with dynamic recovery of value from different types and volumes of returns over time".

As shown in Fig. 2, closed loop supply chain as an enhanced version of traditional supply chain comprises the functions associated with the conventional supply chain in relation to activities and functions of RL [56]. As in Fig. 2, RL in the manufacturing industry would close the loop of supply chain in different points resulting in reusing the products as an entire product, as modules, or a combination of modules and materials [57]. The CLSC extracts the value of the returned products by taking different measures at different stages. Only returned products and materials with no retainable value will be regarded as waste and deviate at some point from the loop.

### 4.6. RL Concept within the Construction Industry

The traditional flow of materials and products in the Construction Industry has been linear; meaning all the materials comprising a building would end up in landfill after the building was not able to meet the requirements in terms of the expected functions. However, demolishing the buildings and sending the pile of debris to landfills would not be the best available alternatives anymore. The ideal flow of materials in the construction industry should act as natural mechanisms using resources efficiently with no waste [58,59]. Similar to the case of manufacturing context, the ideal supply chain in construction field should be a CLSC [14,15,60] as in Fig. 3.

In construction CLSC, life of building materials would be extended after the end of life of the buildings by keeping them in the loop through systematically extracting them from buildings and reusing them in some parts of other buildings or secondary markets. This procedure might include reusing the extracted items directly or after different levels of recovery processes [60] as in Fig. 3. RL and CLSC concepts represent the different processes of sending the materials back to the construction markets. However, different alternatives as the potential scenarios for materials after extraction from established buildings could be expected as the options; as illustrated in Fig. 3.

When one compares Fig. 2 and Fig. 3, there is a difference between the CLSC concept (i.e. the bedrock of RL) between the manufacturing and the construction contexts. This relates to the main source of returned items and the stage at which they become available. In the case of the construction industry, major parts of materials become available after the end of life of a building, which might take a long time [11]. Yet, as stated previously, returning items in the manufacturing industry would occur in different stages of the SCM unlike in the construction context. This might give rise to many issues impeding the implementation of RL and CLSC in the construction context. This also reiterates the necessity of conceptualising RL for particular use within the construction industry due to the observed discrepancies of the associated processes between the manufacturing and the construction contexts.

## 5. Major Drivers of RL

RL practices are mainly attributed to alleviating the environmental concerns alongside extending the life and profitability of products [61]. There are many evidences referring to the various advantages acting as the drivers for adopting RL. Yet, the major identified drivers of RL could be categorised under three headings: (1) economic, (2) environmental and (3) social (corporate citizenship) [5, 34].

Review of literature revealed that the drivers leading corporations towards participating in RL activities, particularly the economic drivers, are the same for different industries including the construction industry [62]. Similarly, some studies have used the same classification for the drivers of RL within the construction context [63] and have suggested that the influences of implementing RL is enhanced by the same three major drivers as the case for the manufacturing sector (i.e. environmental, economic and social) as described below.

### 5.1. Economic Drivers

#### 5.1.1. The Manufacturing Industry

As stated previously, some of the value of the returned products could be retained by refurbishing or remanufacturing the returned items, which in some cases might only entail cleaning the products or changing some parts using much less equipment and energy. This means gaining added value by putting in much less effort as opposed to the case of manufacturing using virgin materials [64]. In doing so, organisations gain the same output by putting in less inputs. This enhances the competiveness of organisations, as according to Lau and Wang [65], effective implementation of RL could act as a weapon for a firm to defeat the competitors in the industry. The economic benefits of RL may be underpinned with a quote from Nikolaidis [49] stating that RL "should not be considered as a cost centre, but as a profit one".

#### 5.1.2. The Construction Industry

According to the literature, the economic drivers for RL in the construction industry include the below items [15,16,41].

- Cost savings (using less material and energy, lower inventory, less equipment maintenance, lower transportation, procurement, labour and disposal costs)
- Revenues from selling recovered items (see Fig. 4)

Implementing RL practices in the construction field may result in reusing and recycling up to 85% of the total weights of buildings. Even more, some studies have estimated that the costs of construction activities that apply RL concepts would be reduced by 30%-50% [38]. The initial costs of deconstruction of facilities for RL might be around 21% higher than mechanical demolishing a building without using the extractable materials. Yet, taking into account the revenues out of reusing and reselling the recovered items and the disposal costs, overall costs of construction by implementing RL could be around 37% less than traditional demolition and sending the whole items to landfills. This is demonstrated in the calculations by Guy and McLendon [66].

### 5.2. Environmental Drivers

#### 5.2.1. The Manufacturing Industry

Organisations are bound by legislation, regulatory frameworks and consumers pressure to perform activities efficiently and reduce harm to the environment [21]. As companies are increasingly obligated to be responsible for their end-of-life products [67], implementing RL can reduce the amount of waste sent to landfills, reduce the adverse effects of transportation activities, and use recovered products instead of raw materials [64]. Subsequently, RL would greatly contribute to resolving issues such as climate change and pollution in the built environment [68]. Some studies have considered RL as a subset of environmental green supply chain management to address the environmental concerns [69].

5.2.2. The Construction Industry

Conforming to the principles of sustainable growth is becoming a necessity for the contemporary construction industry. Given the undeniable dramatic effects of the construction industry on the environment [70], taking measures to facilitate closing the loop of materials in the construction context seems crucial [71]. As a result, implementing RL to reuse the components extracted from established facilities and diverting them from going to the landfills is vital to the sustainable growth within the construction industry [72].

A summary of the major environmental drivers of RL reported in construction literature by various authors [38, 60, 63, 71, 73-76] is as follows: (see Fig. 4)

- Using less raw materials in constructing activities
- Less energy consumption for producing products and transport of goods
- Generating less waste
- Lower levels of pollution
- Meeting environmental regulatory requirements

### 5.3. Social Drivers or Corporate Citizenship

5.3.1. The Manufacturing Industry

Social drivers also expressed as *corporate citizenship* by Brito and Dekker [5], refer to the social values dominant in a community, which compel an organisation to implement RL in order to enhance its green image in the society. Furthermore, a green image is an effective marketing element for any organisation [77]. Therefore, many organisations attempt to enhance their corporate image in society by showing their success in complying with environmental concerns [21].

5.3.2. The Construction Industry

The intention of organisations to fulfil environmental requirements in order to enhance their green image for satisfying the public largely relies on the legislations enforced by the local authorities and the social values governing the community [11]. According to some studies e.g. [16, 39, 63], the benefits of RL in terms of the social drivers for companies could be summarised as; and also, are as reflected in Fig. 4:

- Generating large number of jobs in performing RL, which demonstrates a better social image for the company within the community
- Improving the green image and reputation of the businesses

The drivers for implementing RL seem to be too enticing to be ignored by organisations. Nevertheless, major barriers impede adopting RL in organisations as will be discussed below. The major barriers of RL in this paper are categorised into internal (i.e. intra-organisational) and external (inter-organisational) barriers drawing from the approach utilised by Walker, et al. [45].

## 6. Major Barriers to RL

As implied by Pirlet [64], the starting point for promoting RL in organisations should be clarifying and ascertaining the major barriers to the implementation of RL. This perception will be discussed in the following sections.

### 6.1. The Manufacturing Industry

6.1.1. Internal

- Major internal barriers obstructing implementing RL in manufacturing organisations include:
- Lack of knowledge regarding RL within organisations [78]
- Resource limitations to implement RL in terms of human resources [79] and budget [34]
- Lack of support from managers [43] due to uncertainties of RL outcomes [3]
- Resistance to changing the organisation structure and business routines [80]

6.1.2. External

- Lack of knowledge in the industry [79]
- Lack of support from SCM partners [81]
- Lack of support from customers due to perceptions regarding the inferior quality of returned items [3]
- Lack of support or incentives from the government [3, 78]
- The structure of the industry does not befit the RL requirements [81]
- Inadequacy of essential facilities and technologies in the industry [78]
- Design of products does not suit the RL concept [68]

### 6.2. The Construction Industry

6.2.1. Internal

- Considerable initial costs of adopting RL [11, 74]
- Risks, uncertainties and potential liabilities for using recovered items [16, 17], which result in the lack of support in organisations [38]
- Operational complications such as necessity of providing on-site space [82], high labour costs [14] and the demanding and time-consuming nature of RL [11]
- Lack of awareness regarding the potential advantages of RL for organisations [15]

6.2.2. External

In case of the construction industry, external barriers could be classified under two headings: barriers imposed by the governing business environment in the industry, and barriers due to the nature of construction products (e.g. buildings) and activities. The negative effects of such barriers are by far more detrimental to implementation of RL within the construction industry in comparison to the general barriers that affects the manufacturing sector as well. In essence, the same set of barriers are applicable to a wide range of industries including construction as pointed out by Kibert, et al. [59]. However, the key issues associated with implementing RL in the construction industry come from the complicated and fragmented nature of the materials flow and supply chain in the construction context [71] as described in detail below.

6.2.2.1. Environment-based Barriers

- Lack of recovery facilities, infrastructure and established second hand materials markets [11, 12]
- Lack of awareness of RL within the construction industry [14, 15]
- Lack of technical support (i.e. building standards, codes and guidelines) in favour of using recovered items [60, 63]
- Lack of financial and regulatory incentives [16, 17, 39]
- Consumer culture and attitude towards the quality of salvaged and used items [15]
- Low costs of disposal of materials in landfills which does not justify the costs of RL [15]

6.2.2.2. Products Nature

- Long lifecycle of buildings with different owners in which the owner of the buildfng during the designing and construction process is not usually the same owner when it comes to the end of life point of the building. As such, what happens to the building at the end of its life is not of any consequence to the builder or the first owner [11].
- Immobility, huge size, existence of hazardous substances, difference in deterioration rates and vast variety in quality of extracted materials from buildings [11, 59, 74]
- Existing buildings are not designed for easy disassembly. Thus, the necessary time and labour for disassembly of buildings make RL enviable [14, 59]
- Wide variety and uncertainty of the location of origin points in RL system (buildings as the sources of used items) [11].

As inferred from making a comparison between the barriers of RL in the manufacturing industry with those of the construction context, similarities between the barriers associated with the internal aspects are understandable. On the other hand, due to the characteristics of the construction industry and the nature of construction products, the external barriers pose a significant hurdle to implementing RL. Hence, strategic planning and implementation requires profound consideration to minimise the risks and effectively utilise the resources. The next section will elaborate on these fundamental aspects of RL implementation in this industry.

While the internal barrier and drivers for RL implementation are within strategic management decision-making system, it is worth noting that the major aspects of implementing RL are external to organisations and subject to legislation and regulatory bodies. Hence are uncontrollable by organisations.

## 7. Necessary Strategies for Implementing RL

As affirmed by Carter and Ellram [18], organisations should consider implementing relevant, integrated management policies as the prerequisites for implementing RL successfully. The following section discusses some of these policies with reference to reports by Dowlatshahi [9].

### 7.1. Minimising RL Costs

Implementing effective measures to minimise the initial costs of adopting RL as well as the recurring costs of implementing it is significant to moderate the price of the output products [32,83]. Hence, strategic cost management decisions regarding RL implementation are central to its success [84]. Similarly, the nature of the facilities and the processes of the RL system adopted will affect costs. Additionally, as stated by Dowlatshahi [9], the nature of the inputs of the RL process utilise may have a knock-on effect on overall costs.

Consequently, basic design of products would play a pivotal role in determining the costs of implementing RL in organisations and ultimate price of output materials. The causal effects of RL costs on barriers, drivers and other pivotal aspects of implementing RL are illustrated in Fig. 4.

### 7.2. Enhancing the Quality of Recovered Items

The quality of recovered items is considered usually in comparison to the quality level of the raw or virgin materials by taking into account the consumers overall level of the desired quality [9]. Hence, the quality of outputs of the RL system should be designed to be at the least equivalent to the level of quality of virgin products as one of the major criteria expected [44]. Presumably, a high quality of products would result in higher prices, which in turn gives rise to more revenues for organisations (see Fig. 4). The quality of recovered items is determined by the basic design of the products as well. This is because quality of output is defined by the level to which the product lends itself to be recovered as reflected in Fig. 4.

### 7.3. Optimising Pricing

Deciding the appropriate price of recovered products in any RL system might be a challenge and a complicated process [85]. Generally, recovered products should be sold at lower prices compared to virgin products [9]. Therefore, pricing of recovered items would be an effective strategy to control the inventory and increase the revenues out of the RL system. Besides, demand is affected by changing the selling price of the recovered items as well [86].

Presumably, any decision affecting the costs of the RL system becomes a determinant for the market price of the recovered products as illustrated in Fig. 4.

### 7.4. Choosing an Effective RL System Structure

The design of the RL system encompasses incorporating a wide range of factors including optimisation of the geographical location and layout of the facilities and centres. The optimal structure of the RL systems has been the focus of investigation by many studies including [87]. The objective for designing the RL structure is to define the optimal number and locations of the centres for collection, recovering and the transportation routes between these centres.

Another fundamental aspect to be considered for designing the structure of the RL system relates to determining the personnel to be involved in the RL system to execute the necessary operations [5]. This can be achieved through outsourcing the work to third parties as recommended by Pirlet [64] or by assigning the organisations' own resources [9].

The costs and operational requirements of a RL system varies greatly based on the chosen structure for the RL system [34] as reflected in Fig. 4. Even more, any decision regarding the quality of returned items and the decisions for dealing with each level of quality is made within the chosen structure by the designated personnel [5]. Presumably, the structure will affect the kind of facilities necessary and the amount of materials, which can be recovered in such facilities. The causal effects of RL system structure on other elements of the system are depicted in Fig. 4.

### 7.5. Ensuring Information Availability

As illustrated in Fig. 3, making decisions in regards to the fate of the returned items should be made as soon as possible. Besides, such decisions should be based on the most accurate information available concerning the quality, location and attributes of returned items. Even some studies have conjectured that this decision should be made before transportation of materials from the points of consumption in order to prevent delivering huge amounts of unrecoverable materials to other places [9] ending up in excessive costs. In fact, the discrepancies of the quality of returned items impose high levels of uncertainty on RL activities and processes. Likewise, high levels of uncertainty and perceptions about the low quality of some products were regarded as major barriers in adopting RL in organisations [49].

Some studies have stressed the value of acquiring information about quality of returned items as soon as possible and the significant advantages of acquiring such knowledge by information communication technology [88]. Continuous access to on-time information regarding the different features of products has positive effects on modifying the risks and uncertainties and accordingly enhances the overall efficiency of RL systems, which in turn results in lowering the costs of the system. This view has been widely advocated in the RL literature [68, 89]. Such improvements directly facilitate fulfilling the requirements associated with costs and pricing of RL system and reduces the uncertainties in regards to quality of outputs namely other fundamental managerial aspects of RL. On top of that, barriers such as the long lifecycle of buildings, quality variety, diversity of locations, operational complications and lack of awareness would be modified through ensuring the availability of information within the RL system as reflected in the corresponding causal effect of Fig. 4

## 8. Discussions

The five managerial polices discussed in the above sections reflect the central aspects of managing the RL systems as mentioned in the literature from the manufacturing industry. As mentioned, implementing such strategies should be given a particular priority in order to overcome the inherent barriers facing RL in the construction industry. On the other hand, construction researchers have accepted the idea of reconceptualising the construction lifecycle as a manufacturing procedure when it comes to utilisation of materials [59, 90]. These efforts mostly have been driven by the intention of the construction industry for adoption of the newly developed procurement and production practices of the manufacturing sector [91]. The procedure of production in construction could be regarded as an assembly-type, where different material flows are connected to the end-product [92, 93].

In this context, managerial decisions to enhance the performance of RL in the manufacturing industry would be equally applicable to the corresponding processes in the construction industry. This premise is underpinned by the statements of previous studies. As an example, Dowlatshahi [9] opined that RL pivotal principles are applicable to products from most of the industries. This view is further reiterated within the construction literature by pointing out that major aspects of RL implementation are not affected by the structural dissimilarities between the construction industry with other sectors such as manufacturing [11].

As pointed out by Akbarnezhad, et al. [94], researchers are of the view that implementing two practices as described in the following sections would scale down some of barriers to implementing RL particularly for the construction sector. This approach would also facilitate applying the five strategies for implementing RL as discussed in the previous section.

### 8.1. Harvesting of Information (HoI)

#### 8.1.1. The Manufacturing Industry

With reference to discussions regarding the necessity of availability of information reflected in Fig. 4, many major aspects of RL system are influenced positively as long as adequate information and knowledge are provided. Furthermore, many treatises have attested to the great benefits of systematic sharing and exchanging of information within organisations and between parties involving in a supply chain [95]. This view similarly applies to RL as an advanced SCM as put forward in Chouinard, et al. [96], "to benefit from the complementary nature of material and information flows of the supply chain and reverse logistics, a total network vision should be used to improve the coordination and collaboration among the various actors." Therefore, availability of on-time information is one of the central elements of an efficient RL [9].

Considering the concepts of supply chain integration by Yu, et al. [95] and knowledge harvesting as defined by Snyder and Wilson [97], harvesting of information (HoI) in regards to RL could be described as:

"an integrated set of processes in a RL system geared towards on-time capturing of any intra- and inter-organisational available information regarding the nature, quality, amount, flow, locations and relevant aspects of logistics of returned products from main performers and convert this knowledge into actionable awareness that can be transferred and shared with others within the RL network to maximise the benefits of the RL system".

#### 8.1.2. The Construction Industry

Researchers in construction field have regarded information exchange as central to an effective SCM for construction projects [98]. Likewise, information is treated as a building block for the RL system in the construction context. As evidenced by Nunes, et al. [37], RL has been defined as: "how the area of business logistics plans, operates and controls the flow of logistics information corresponding to the return of post-sale and post-consumption goods to the productive cycle through reverse distribution channels, adding value of various types to them: economic, ecological, legal, logistical, corporate image, etc.''.

The main advantages envisaged for harvesting of information in a RL system according to construction literature could be as mentioned in the items below and in Fig. 5.

- Eliminating risks and uncertainties [99], which result in reducing the costs of the system [12].
- Raising awareness of the benefits of RL in the industry and within organisations, which increases the support level from managers and promotes adopting RL [60].
- Increasing the overall efficiency level of the RL system through enhancing the cooperation between key players in the RL system. This would reduce the costs of transportation, inventory, and prevent losses of time in this process [82], which indirectly facilitates reduces the waste and pollution within the system

On top of that, harvesting of information (HoI) directly supports managerial policies to ensure availability of information as discussed previously. As it is reflected in Fig. 4, implementing HoI has causal effects on many fundamental aspects of a RL directly or indirectly.

In accordance to the above-mentioned discussions, the positive outcomes of adopting HoI initiatives in RL systems would facilitate meeting the objectives of main managerial aspects of RL, which would yield in suppressing the barriers, and promoting the drivers of RL.

### 8.2. Design for RL (DfRL)

#### 8.2.1. The Manufacturing Industry

Reconditioning the returned items could be deemed the cornerstone of RL systems as pointed out by Dowlatshahi [9]. Thus, the ability of an organisation to amend the basic designs of products in order to facilitate the efficacy of reconditioning activities is central to the success of RL system [26, 44, 49]. This strategy largely concerns designing the products in order to enhance the ease and the potential of value recovery of returned items. The strategy to use the potential of product designs has been referred to by different titles in the literature e.g. design for environment, design for remanufacturing, and design for recycling [100].

This paper encapsulates different aspects of this strategy within the design for reverse logistics (DfRL) which focuses on the products' design attributes that support the implementation of cost-effective reverse logistics practices for the returned products and the materials embodied in the products. DfRL is built on the premise that products should deliver some value to end-users alongside maintaining a "return value" that must be extractable from returned items with minimal costs, risks, uncertainties and effort [101]. Thus, DfRL directly concerns the economic aspects of RL systems (i.e. costs, pricing). Moreover, basic designs of products could be considered to yield the higher quality of returned items (output quality). In addition, basic product design affects structural and arrangement aspects of a RL system. It is because recovering products with different designs takes different levels of expertise, facilities and recovery technology [44]. This would change the requirements of the system such as the attributes of personnel and the arrangements of actors necessary for RL systems as stated by Das and Chowdhury [102], which affects RL system structure as well.

#### 8.2.2. The Construction Industry

When it comes to construction literature, terms such as design for disassembly, design for deconstruction, design for recycling, design for reuse, and design for salvage ability have been used interchangeably [103]. Yet, the purpose of such terms relates to the environmental impacts alongside enhancing the efficiency of the processes of recovering returned products through design policies. Design policies should ideally factor in the requirements for recovering materials [59]. This strategy could influence every stage of the process of reusing or recycling the construction components (i.e. RL). Hence, as implied by Nordby, et al. [104] all the associated concepts could be condensed within the DfRL principles. In this context, DfRL implies keeping all materials in the loop indefinitely, along with reducing waste [60].

Implementing RL for contemporary buildings is fraught with serious problems given that most of current buildings have been designed without considering the requirements of RL [59, 74]. The nature and characteristics of a wide range of building materials and products (e.g. bricks) gives us the opportunity to use them in different buildings many times. Yet, this totally relies on the design of a building and its construction methods. In some cases, the particular construction method deployed in one building might bring the material to the end-of-life point such as using strong cement mortar for bricklaying [103].Disassembling a building not designed for deconstruction might not recover sufficient materials with the acceptable quality. This would make the RL unviable for the building as one of the main barriers [105, 106].

Likewise, the efficiency and cost-effectiveness of the recovery procedures are largely influenced by the designers of buildings [75]. On top of that, designers can decide to use salvaged materials from deconstructed buildings, which provides a market for salvaged items that could affect the customer behaviour towards RL system.

Based on the above discussions, incorporating DfRL within construction projects could affect all the strategic managerial policies of RL. This comprises the cost and pricing [14, 75], the quality of returned items [74], the requirements of RL structure [75], risk and uncertainties, and modifying the barriers due to the design of buildings as illustrated in Fig. 4. As a result, DfRL is a strategy to meet the objectives of all strategic managerial aspects of the RL system within the construction industry as well as the manufacturing context.

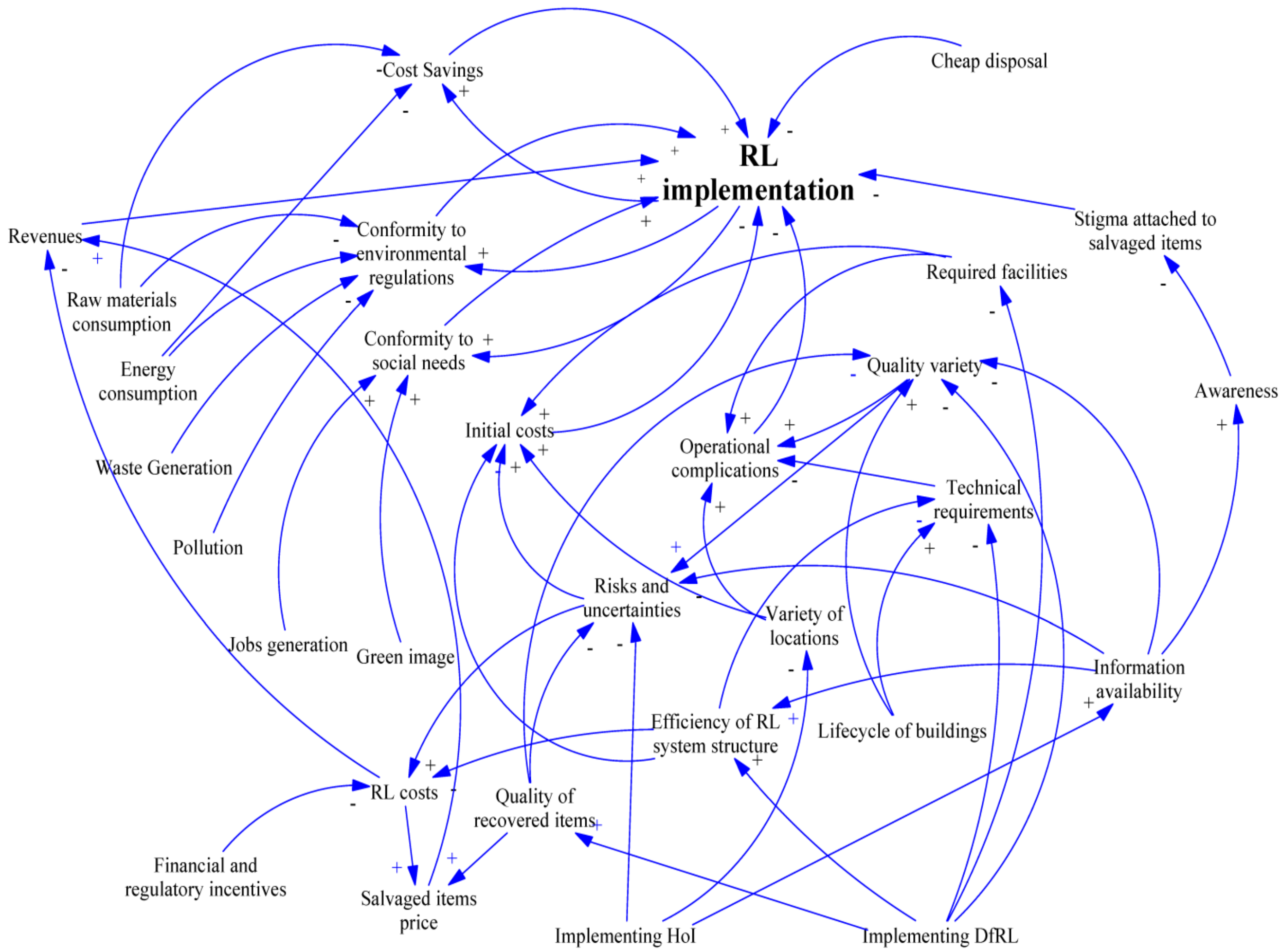


**Figure 4.** Causal loop diagram illustrating the elements responsible for the major aspects of RL system (source: authors)

### 8.3. Integration of DfRL and HoI

HoI and DfRL represent two managerial systems. On the other hand, integration of isolated management systems would result in cost savings and the reduction in the use of resources. Furthermore, in an integrated management system routine activities are performed without the necessity of asking for management consent. This also would save organisational resources allocated to supervision, continuous audits and paperwork as stated by Douglas and Glen [107] and Zutshi and Sohal [108].

In case of RL within the manufacturing industry, Umeda et al. [68] stated that effectively designing of products takes acquiring accurate information about the lifecycle of the products including practical lifetime of products, customer behaviour, reusing patterns and rates, and collection and recycling rates.

There are indications from the construction literature in regards to support for an integrated approach towards deploying DfRL and HoI. As an example, according to Shakantu and Emuze [13], the primary focus of any attempt to enhance the effectiveness of logistics activities by implementing RL in construction context should be to improve the exchange of information and coordination between the involved parties during the design and construction stages. In addition, as pointed out by Guy et al. [75], exchange of information between the design and construction phases of a building with the time of deconstruction will ease up the deconstruction process; reduce the uncertainties about the quality and quantity of products. Additionally, the accessibility of reliable information about the characteristics of available recovered materials during the initial phases of design is crucial for the success of RL implementation for a building as it assists the designers to make right decisions [38, 103].

Building on the above discussions, authors are of the view that deploying an integrated system to incorporate the synergistic abilities offered by DfRL and HoI might be one of the most effective approaches to promote harnessing the benefits of RL in construction organisations. In sharp contrast to its salience for the field, this topic has yet to be addressed within the construction literature. The following section will attempt to discuss this.

## 9. Conclusions

There are compelling evidences advocating for the great benefits of the RL system for organisations within a wide range of industries including the construction industry. Despite the detrimental effects of construction activities on the built environment, the level of implementation of RL has yet to become satisfactory within the construction context. Therefore, no effort should be spared in promoting the adoption of RL in the construction industry.

To this end, centring on the strategic factors that affect the major aspects of implementing RL in organisations is of outmost importance. The findings revealed through the review of the literature established that deploying a system aiming at integrating the capabilities offered by HoI along with potential benefits of DfRL would fulfil the requirements prescribed by the strategic aspects of the RL system. Even more, major barriers of implementing RL in construction organisations would be suppressed and the drivers would be promoted through implementing such integrated approach.

This study highlighted some drawbacks within the literature of the construction industry and opened the door for future investigations. Besides, the comparison between the construction and the manufacturing industry detected some glaring differences between the structures of effective CLSC and accordingly RL systems within these industries. This makes further investigations on RL within the construction field relevant and necessary. The main lucrative grounds for future enquiries would be to:

- Conceptualise the RL phenomenon for the construction context considering the specific idiosyncrasies of this industry
- Design frameworks in order to facilitate integration of DfRL and HoI for construction organisations
- Examine the drivers and barriers associated with DfRL and HoI within the context of the construction industry.
- Investigate the policies to increase the motivation of each of the parties to fulfil the allocated tasks and to enter the partnership to implement RL actively

On top of that, as reflected within the conceptual model and stressed in previous sections, some major aspects associated with RL and its strategic factors are under the control of regulators, governments, and policy makers. Lack of studies to throw some light on such aspects and its central role for the success of RL systems in the construction industrycalls for further studies focusing on regulatory and financial aspects of the environments surrounding the RL system.

The study contributes to the field as discussed above and opens doors for future investigations, yet the findings and discussions should be considered in view of the limitations of the study largely stemmed from its conceptual nature. That is, the factors identified as the main causes and the causal effects described have not been validated through the scrutiny of empirical investigations. Besides, the factors in any particular study should be considered only in light of the effects of the context at hand, including the socioeconomic attributes of the environment. Nevertheless, this shows a path for future studies namely validating the conceptual model and the causal relationships defined in it alongside testing the model in countries and contexts with different socioeconomic environments.

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