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Analysis of the factors stimulating and conditioning application of reverse logistics in construction

Anna Sobotka[a], Joanna Czaja [b]*

[ab]*AGH University of Science and Technology Al. Mickiewicza 30, Cracow 30-059*

Abstract

Waste minimization and recycling are principles of the concept of sustainable development that is now globally introduced. Construction in the sense of manufacturing goods and construction and exploitation of buildings generates a significant amount of waste. Therefore, the developing of the concept of waste management and the reverse logistics is implemented to the construction industry. A statement released by the European Commission on July 1, 2014, indicates, however, the presence of inefficient management of raw materials in construction. The primary purpose of initiatives published in the statement is to increase the efficiency of resource management by new and renovated buildings and also by the reduction of their overall impact on the environment that occurs in all phases of building life cycle. The main idea of the article is to define the concept of reverse logistics in relation to the construction industry and to analyze factors stimulating and conditioning the implementation of reverse logistics in construction projects, while giving the expected results. Physical flow of raw materials and products in the building life cycle has been analyzed. The article discusses the allocation of reverse logistics tasks among the participants of investment process, so that it has become an economically effective and profiting branch for construction companies along with a profitable environmental aspect. Problems that should be taken into consideration in order to manage the waste and raw material in construction in an effective way have also been indicated. As a conclusion, article shows an example of reverse logistics model, that may be the foundation for creating a decision making supporting system.

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Keywords: waste management; construction project; building’s life cycle; reverse logistics

* Corresponding author. Tel.: +48 12 617 47 67
E-mail address: sobotka@agh.edu.pl

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1. Introduction

In many industries, such as automobile, electronic, automotive, reverse logistics (RL) has been successfully implemented and has become a strategic tool to reap the economic benefits. RL can also be a source of sustainable competitive advantage [1]. However, there are sectors of the economy including construction, where RL is still not implemented on a large scale, despite the social and environmental importance and potential benefits for entrepreneurs. The answer to the existing state of the inefficient management of raw materials in the construction industry in the EU is the European Commission's statement [2]. The primary purpose of initiatives is to increase the efficiency of waste management by new and renovated buildings and also by the reduction of their overall impact on the environment that occurs in all phases of the building life cycle [2]. There are many reasons to implement demands of the postulate. These include the protection of natural resources, waste reduction, energy consumption and CO_2 emission reduction, creating new jobs and more.

The research on issues connected with RL implementing in various economy sectors have been carried out. However, note that raw materials and construction products are characterized by a relatively long life cycle and logistic processes related to them are carried out by many participants, and backflows are most likely of a large size and asymmetric in relation to the original flows. Therefore, it is not possible to apply solutions directly from other industries.

Currently there are two names - reverse logistics (RL) and ecologistics (GL), which address the issue of product backflow, putting a different emphasis on the social, economic and environmental aspects. Those two are synonymous enough to cause problem in nomenclature in the area of consideration. Moreover, as indicated by Reza Hosseini [4], the lack of definition of the RL in construction is still noticeable. Therefore, the part of the publication is devoted to this issue. The article attempts to indentify and analyze factors stimulating and conditioning the implementation of reverse logistics in constructions projects, giving the expected results. Physical flow of raw materials and products in the building life cycle has been analyzed. The article discusses the allocation of reverse logistics tasks among the participants of investment process, so that it has become an economically effective and profiting branch for construction companies along with a profitable environmental aspect. Problems, that should be taken into consideration in order to effective manage the waste and raw material in construction, have also been indicated. As a conclusion, article shows an example of reverse logistics model, that may be the foundation for creating a decision making supporting system in terms of logistics, recovery, and during the renovation works.

2. General and construction definition

The first known description of the reverse logistics was developed by Lambert and Stock in 1981, and it is identical to the definition given by Murphy and Poist in 1986, defining RL as backflow of goods. In 1998, Stock defined RL as *"the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing"*. In the same year, Carter and Ellram described RL as *"the process whereby companies can become more environmentally efficient through recycling, reusing, and reducing the amount of materials used"* [5].

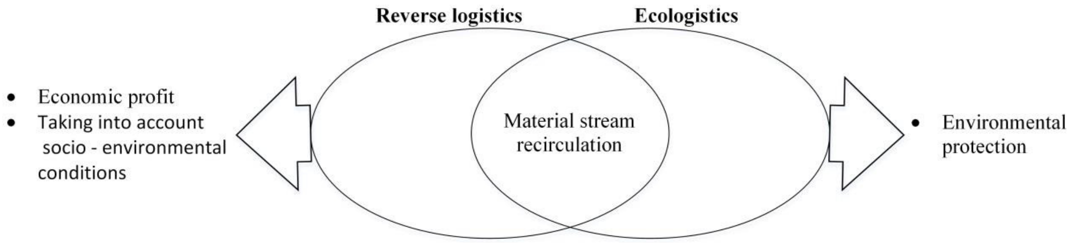


Fig. 1. The relation and orientation of LR and GL (own data)

At this stage, the distinction between the RL and ecologistics began to blur. Rogers and Tibben-Lembke point out that actions motivated by aspects of environmental protection are the better representation of the term *"ecologistics"*, but they also note, that there are obviously many more actions for which the use of both terms may be appropriate. Unlike ecologistics, the main goal of RL is economic profit while still taking into account the environmental and social conditions as required by the principle of sustainable development. Similarities and differences of RL and GL have been shown in the Fig. 1. The author found the definition of reverse logistics by Rogers and Tibben-Lembke as the base one. It is formulated as follows: *"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 proper disposal"* [6].

Reverse logistics in construction should be based on systemic approach to the management of resources in the building life cycle, meaning collection, sorting, processing and reusing of construction waste in accordance with the rules and technical standards of the construction industry, the law, and on the basis of efficient construction waste management plan. However, it should be noted that the knowledge and experience in the recovery of raw materials and construction products should be taken into account in the process of design and construction. The environmental aspects should also be considered. You can therefore define the reverse logistics in construction as: the process of planning and design, implementation and monitoring of flow of raw materials and construction products, along with related to them information flow from the place of their consumption to their place of origin within effective construction waste management in the building life cycle and in accordance with best building practice and, therefore, on the basis of the legal and technical standards [7].

3. RL in the building life cycle

The European Commission standard [2] calls for initiatives resulting in an increase in resource management efficiency in construction industry and in reduction in their negative impact on the environment throughout the building life cycle that consists of: the planning phase, construction phase, exploitation and conducting and supervising phase, rebuilding or demolition phase or changing its purpose. One of the proposed solutions is to reduce the amount of construction waste ending up on dumping grounds by activating running backflow of raw materials and construction products. Therefore, within the entire building life cycle, you should be aware of construction waste management issues because from the very start of construction of the building, through the repairs, alterations, rebuilding and demolition - in all these stages the recovery of raw materials and construction products is possible (Fig. 2).

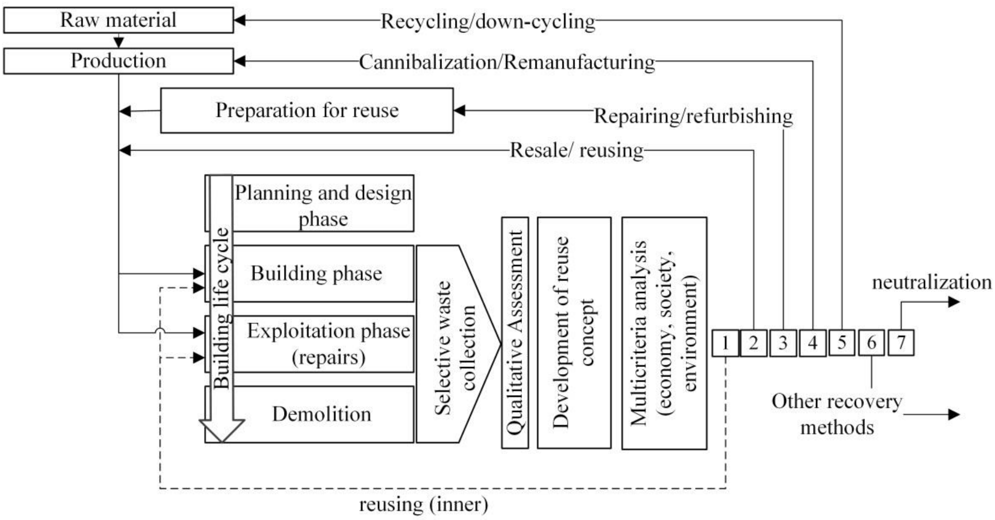


Fig. 2. RL in the building life cycle (own data)

Logistic cycles may close up at various stages of the main logistics chain, depending on whether it includes reusing, refurbishing, remanufacturing, or other. What's more, it's possible to name logistic cycles closing up within a single project (internal), that follow each other in a natural way and on a large scale when renovating historic buildings on account of the historic nature of its bearing structure and finishing and also in search for savings [7].

3.1. Planning and design phase (construction, demolition)

The key step for effective recovery process are the tasks of the design phase. Already at the stage of development of the features of the product, we will decide about the ease of its removal from the construction and therefore the effectiveness of its recovery. The problem was first identified and described by Pacheco-Torgal F. [9].

The possibilities and ways of obtaining raw materials in processes of reverse logistics are strictly dependent on original material. Multicriteria analysis of building layout should include the life cycle assessment (LCA). Materials that are cheap in production may eventually be of a high cost when processed in order to recover value in economic sense and when considering the negative impact on environment, CO_2 emission, and energy cost. For example, the cost of producing concrete is high and causes high carbon emissions, but the possibility to reuse it weigh in favour of it and attest to its eventual low influence on environment with its little need to process and close to no need of extracting natural resources.

Current development strategies indicate the ecological and social activities as core elements of sustainable economic system. The validation recovery processes should therefore be multicriteria. Previously developed concepts of material management and the choice of the best option should be analyzed - in case of RL, the cost issue should be of the highest importance.

3.2. Building phase

For the efficient recovery of raw materials and construction products in the final stages of buildings life cycle, all designed decisions "for easy disassembly" should be respected and executed on construction site. Therefore, it is necessary to prepare employees to perform work toward the new - unusual solutions, as well as conducting ongoing quality control of the works and their compliance with the project. Due to the different characteristics of recycled products than their new counterparts, construction engineer should gain special knowledge in this field and acquire experience with time, to make the right decisions. The building phase also produces waste. Efficient use of raw materials and construction products as well as selective waste collection during the works should be ensured, and direct to disposal in accordance with the plan of effective management.

3.3. Exploitation phase

During the building life cycle and, in particular, in its longest phase - exploitation phase, the potential future raw material is exposed to corrosive agents and other impairing its output parameters, hence it is extremely important to take research samples from the portion of material that is to be reused in order to determine technical parameters of the future raw material. The developing branch of construction concerning the research of incorruptible building materials, create more opportunities to determine technical parameters of recovered material, and hence provides expert analysis in terms of its reuse (these methods are particularly useful in the field of reusing whole construction elements) [8]. The operation phase consists of the object renovation which is necessary to maintain its proper technical condition. Executing the everyday repairs is associated with relatively small waste emissions in relation to the rebuilding or demolition of the object, but the incidence of this type of work is relatively large, which will significantly contribute to an increase in the amount of waste.

3.4. Reverse logistics on construction site in demolition phases of buildings

In the process of waste management on site, it is recommended that you develop a plan for effective management of waste. This project should contain (within a site):

- analysis of the construction process regarding the formation and management of waste,
- waste classification in accordance with the law,
- segregation method,
- a local storage,
- waste disposal schedule.

To basis of waste logistics will be the information about the quality and quantity of waste, utilization or neutralization options. Acquisition of the material involves waste sorting (most often manual), which should start on the site in accordance with the proposed plan for the efficient management of waste. The quality of the sorting works will affect the product and ultimately determine the quality of material as a recyclable material. An additional benefit of the implementation of the waste management system on site is the safety of the work – meticulous and systematic emptying of the waste container prevents occurrence of hazardous waste within the workplace.

Existing buildings are not well - adjusted for easy and efficient demolition, and therefore the efficiency of the recovery process is low [11]. Considering the option of recovery in detail design of currently raised objects will ensure the possibility of future recovery of raw materials and products in construction.

3.5. Duties of participants of the construction projects connected with the implementation of RL

The rapidly developing material recovery industry branch creates new opportunities but also requirements in the implementation of construction projects. Therefore, new responsibilities resulting from additional tasks should be reallocated between the various participants in the investment process that are involved in logistics and recycling of construction products. Examples of their allocation are shown in Fig. 3.

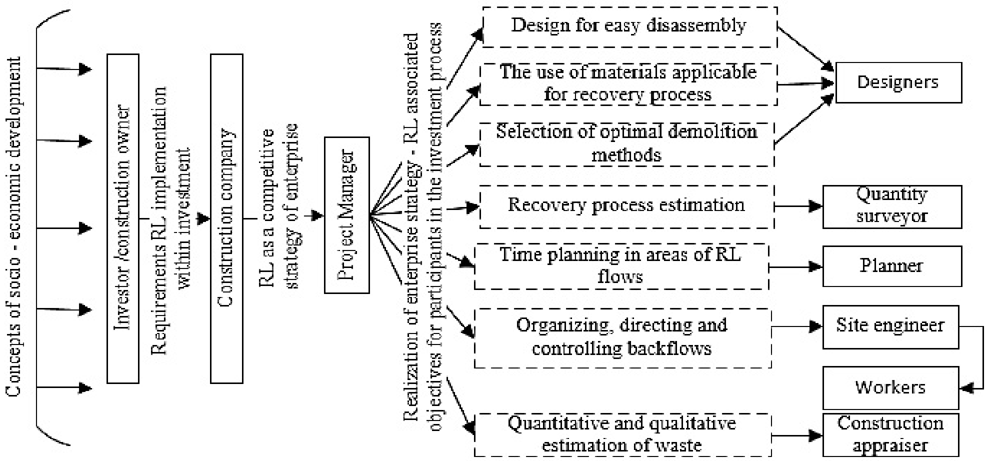


Fig. 3. Duties of the participants of the investment process connected with RL requirements (own data)

4. Factors stimulating the implementation of the RL in construction

Among others, economic, environmental and social factors are mentioned in literature as factors stimulating the implementation of RL. They have been identified in construction through analogy with manufacture industry. There are also non – destructive, still being developed, methods that should be taken into consideration when talking about construction diagnosis and the development of processing technology of recycled materials. A more detailed description of individual factors stimulating the implementation of RL in construction is given in sections 4.1 to 4.5.

4.1. Economic factor

Reverse logistics can be a part of the economic strategy of the company. In the literature in terms of reverse logistics the following financial sources have been identified [4]: Reducing the production cost (using less material and energy, reduction of transport costs, supply cost, disposal and utilization of material); Profits from the sale of recovered raw materials and construction products.

Literature sources mention that the implementation of RL in construction may result in the recovery of up to 85% of the total mass of the work. Thus, the cost of the building can be reduced by 30 - 50% [12]. The arguments given above are unquestionable. It should be noted though, that some actions generate additional costs that need to be considered. Exemplary costs are: deconstruction costs, research and expertise costs, storage costs, processing costs, rise of the project maintenance costs, other.

To be entirely objective on the matter of taking recovery actions for specific solutions, one should conduct the cost analysis of individual options. Exemplary decision model is shown in section 5.

4.2. Environmental and social factor

Eurostat estimates that the amount of waste generated in the EU in 2010 exceeded 2.5 billion tones, of which 35%, that is 860 million tons, is generated in construction industry in terms of construction and demolition of buildings [13]. Large consumption of building materials leads to extraction of natural resources while processing and transport are energy - consuming and generate pollution. Processing and transport processes related to RL have also negative impact on the environment, but typically this impact is less than it is at the production stage. The smaller logistics cycles are the smaller the logistic processes cost and interference with the environment seems to be. But also, as in case of the costs, a detailed analysis should be conducted in order to get a specific assessment of particular processes of reverse logistics. Nevertheless, companies are obliged to fulfill social responsibilities. Implementation of the RL may favourably affect the image of the company and thus result in its higher competitiveness.

4.3. Development of diagnostic methods of the structure – through the example of renovation works

Diagnostics attendant of the construction set to be demolished evaluates, examines and can plan options of recovery from the very beginning, even at the pre - design stage. A good diagnosis of the technical characteristics of the material will be crucial in the matter of relevance/appropriateness of the decision about conducting recovery and the selection of its logistics processes. Non - destructive methods are a class of diagnostic methods easy and quick to execute. Their disadvantage is relatively big result error but is more than sufficient for the purposes of the estimation.

4.4. Processing technologies

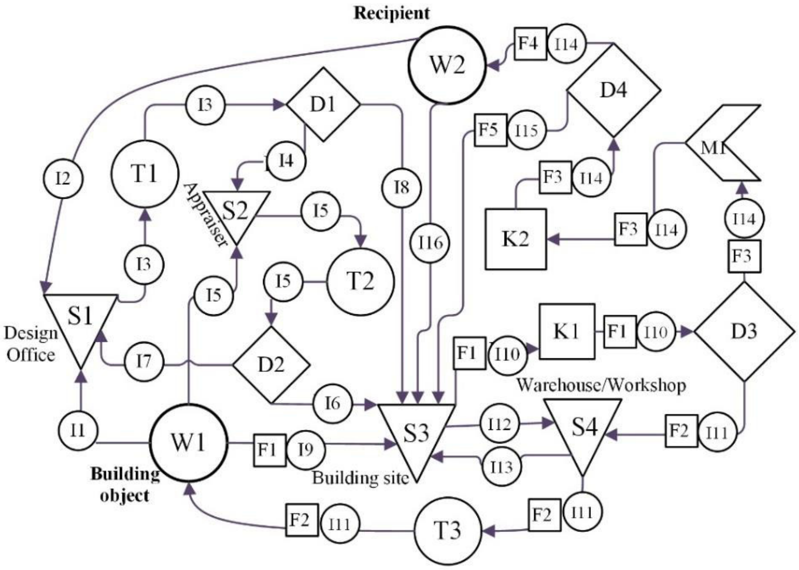
Processes, to which recovered raw materials and construction products are subjected, are the critical stage in RL, often of crucial importance regarding economic efficiency and the extent of the impact on the environment. Development of processing technology contributes to the increase in the number of recovery options and decides on the competitiveness of the prices of the material or recovered construction product in comparison to newly manufactured ones.

4.5. Site conditions

Site conditions have a great influence on whether the RL can be implemented on the site (renovation/demolition). That is dependent on conditions as following: the possibility (place) of material storage, preparation of raw materials and construction products and also the duration of the project. It is possible to carry out those processes outside of the site, or on account of other investments, but the increase in the cost of transportation, storage and maintenance of the workshop may be too high. In this case, it is advised to apply the decision making supporting system, estimating the costs of each recovery option.

5. Example of reverse logistics model

Physical flows in reverse logistics can undertake various directions. The decision about the way to manage raw materials and construction products influences logistics costs and thus determines the economic profits from RL implementation (4.1). Every decision to undertake recovery process involves environmental aspect. If the company (contractor) takes reverse logistics into consideration in terms of its mission and vision and also as a strategic element and think of it as of an economic advantage, it can make use of logistic system models to determine its objectives. The main indicators steering the implemented method will be profits and impact on the environment. Therefore, it is necessary to develop a mathematical model that will represent a particular reverse logistics system.



Legend:

I1 Quantitative and qualitative estimation of wastes; **I2** Information about the prices and purchase terms; **I3** Information about the material potential for recovery; **T1** Multicriteria analysis; **D1** The decision of material testing to assess its utility for reuse in renovation works; **I4** Order of tests; **I5** Obtained information about an object, material or construction product (technical tests results); **T2** The transformation of research results into the expert opinion about the possibilities and conditions of reuse of the raw material/construction product; **D2** The decision to allow the raw material/construction product to be built into the structure of the construction; **I6** Information about the acceptance of the raw material/construction product to be built with the conditions for its application etc.; **I7** Information about rejection of the raw material/construction product to be reused; **I8** Information about the disposal of material (the conditions and way of delivery to the recipient); **F1** The flow of decomposed raw materials/construction products; **I9** Information about the flow of decomposed raw materials/construction products (quantity, quality, cost); **I10** Information about the requirements for storage and use of raw materials/construction product, preparation conditions etc.); **K1** Storage of raw materials and construction products; **D3** Managing the internal waste for outside recovery of recipient; **F2** The stream of raw materials and construction products from their place of storage to the warehouse/workshop; **I11** Information about the flow of raw materials and construction products (destination, preparation and use conditions); **I12** Information about the demand for the material in time; **I13** Information about the stock of finished elements; **T3** Repairing/ Refurbishing; **F3** The stream of materials to be transported from the construction site; **I14** Information about the order (recipient, price, time, quantity, quality, transport requirements, etc.); **M1** Load and transport of raw materials/construction products; **K2** Control of raw materials/construction products carried out by the recipient; **D4** Decision on the acceptance of order; **F4** Delivery to the recipient; **F5** Sending back raw materials/construction products; **I15** Information about the return (quantity, quality, reasons, etc.); **I16** Information about the order acceptance and other.

Fig. 4. Graphic model of RL for a single material during renovation work (own data)

Optimization of control will be about finding the decision variables, for which the profit reaches the maximum with minimal environmental impact (emissions, energy consumption, etc.). The objective of enterprise strategy on the tactical level is achieved by controlling the logistics system. Methods of controlling the logistic processes are determined by the rules of the designation of the model variables and the selection of the type and values of controlling variables [14]. A sample graphical model of the system of reverse logistics supporting the process of material recovery for renovation purposes is presented in Fig 4. It illustrates the operation of the RL system with a single element (more specifically: with an element of certain class) recovered from the demolition.

The model shown, supplemented by quantitative characteristics of model variables and by relations between model elements, can be explored/experimented upon using simulation modeling, with the use of Monte Carlo method, because construction works, including demolitions, are often carried out in uncertain or risky conditions. Thanks to such models and simulation research you can obtain a proper tool to choose the optimum solution for a variety of conditions while realizing the construction project: internal and external [14].

6. Conclusions

Undoubtedly, the construction activity constitutes a huge portion of undeveloped economic activity in which reverse logistics must be implemented on a large scale. Two main purposes may be achieved in this way: economic and environment, including compliance with the concept of sustainable development.

Introduction of reverse logistics into building practice is a very complex process, dependent on many conditions. The support of active manufacturers involved in the recovery of raw materials from waste is a very important factor as well as processing technologies development etc., and obviously the economic balance. One of the greatest challenges in the modern construction economics is efficient decision-making. Contemporary decision-making problems can be solved by using multiple criteria decision support methods, modelling procedures as well as various IT supported systems. It is commonly agreed that use of these applications will significantly speed up processes in construction sector, improve the quality of the built environment, value of decisions made and decrease the overall cost of a built environment's life cycle [15].

In Poland and abroad, there are many excellent examples of reuse of materials recovered from demolition sites, recycling, while waste neutralization is the last resort. A historical building renovation shown is certainly worth to mention.

There is a need to spread the knowledge about reverse logistics implementation in construction and to develop tools - computer systems to conduct research and analyses supporting decision making in many types of construction projects of a unique nature.

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