Organisation of reverse logistics tasks in the construction industry

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ABSTRACT: The construction industry is characterized by a high material intensity and hence by a large amount and a heterogeneous mix of construction and demolition waste (C&D waste). The high and diversified amount of C&D waste is not only a today’s challenge with respect to recovery of components and materials but also with respect to the organisation of the associated logistic activities.

The purpose of this paper is to sensitize for the difficulties of the design of efficient logistic processes in construction due to the characteristics of construction waste streams. Therefore, the concept of reverse logistics - which has already attracted intensive research in manufacturing industry - is applied to the construction industry particularly focusing on deconstruction projects. It is shown that the main structural difference between the construction industry and the manufacturing industry, regarding take-back of products, i.e. waste, does not refer to waste treatment or recovery processes, but to the organisation of the collection and the design of logistic processes from the building site to the recovery facilities.

1 INTRODUCTION

The research field of reverse logistics has attracted intensive research efforts during the last years. Its application covers a wide variety of products from different industries. Thereby, reverse logistics can, among others, defined in the following way: reverse logistics encompasses the logistics activities all the way from used products no longer required by the user to products again usable in the market. It is 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 value or proper disposal (Stock 1998, Jayaraman et al. 2003).

Comprehensive overviews on reverse logistics can be found, for instance, in Dekker et al. (2004) and Dyckhoff et al. (2004). Case studies, and other industry related work, concentrate, for instance, on the organisation of reverse logistic tasks in the automotive industry (e.g. Schultmann et al. 2006), in the industry for electrical and electronic equipment (e.g. Walter & Spengler 2005), or the publishing industry (e.g. Wu & Cheng 2006). Other research addresses issues of the organisation of reverse logistics in the context of closed-loop supply chains and reverse supply chain management (cf. Kovacs et al. 2006, Srivastava & Srivastava 2006, Jayaraman 2006, Krumwiede 2002, Tibben-Lembke 2002, Ferguson & Browne 2001, Pochampally & Gupta 2005, Boulton 2005) and the organisation of logistics networks (Fleischmann et al. 2000, Jayaraman et al. 2003). However, some papers also provide overviews on literature and conducted case studies in the field of reverse logistics, which are only briefly referred to in this paper. These papers comprise, for instance, Fleischmann et al. (1997) giving an overview on quantitative models for reverse logistics, Fleischmann et al. (2000) highlighting conducted
case studies, and Dowlatshahi (2005), who is developing a framework for effective design and implementation of remanufacturing/recycling operations in reverse logistics after analysing various case studies. A more recent literature review on green supply-chain management and, hence, also on reverse logistics can be found in Srivastava (2007).

The construction industry, however, has not yet attracted much research concerning the organisation of reverse logistic tasks. The return or take-back of construction and demolition waste (C&D waste) at the end-of-life of a building or during repair and renovation processes has not been subject to reverse logistic concepts.

Hence, the objective of the paper is to highlight challenges for the application of reverse logistics in construction, especially focusing on deconstruction projects. Therefore the remainder of the paper is organized as follows: At first, an overview on the concept of product return and of reverse logistics as applied in the manufacturing industry is given. Based on this overview, conclusions for the applicability of this concept to the construction industry are drawn. Therefore, waste streams of the construction industry are briefly discussed and resulting challenges for the organisation of the operational logistic tasks, i.e. the collection of C&D waste at the site as well as its transportation to recovery facilities or disposal sites are revealed.

2 PRODUCT RETURN AND REVERSE LOGISTICS

The stages of reverse logistics can be distinguished into

1. collection,
2. inspection/selecting/sorting processes,
3. reprocessing,
4. and redistribution.

All of the activities require a certain amount of operational logistic activities, i.e. transport of products or waste (cf. Dekker et al. 2004). Hereby, Fleischmann et al. (2000) state that product recovery not only reverses the product stream with the consequence that there are many supply sources (collection points, e.g. retailers) and few demand points (recovery facilities, disposal sites), but that the design is complicated by the high uncertainty in many factors.

Discussing reverse logistics, the following aspects need to be taken into consideration (Dekker et al. 2004):

1. motivation of enterprises to take action in reverse logistics as well as reasons for product return,
2. processes carried out in logistics with the aim of recovering value,
3. characterisation of returned products, and
4. actors executing the reverse logistics activities.

2.1 Motivation for reverse logistics, reasons for product return and recovery processes

The motivation for the involvement of companies into reverse logistic activities is differentiated into profit-oriented, legislative as well as corporate citizenship drivers (Dekker et al. 2004, Schultmann et al. 2006).

The profit-oriented drivers comprise direct as well as indirect benefits. While direct benefits can be achieved from returned products used as substitute for new input materials (for instance metal scrap for steel) as well as by cost reductions for disposal and new raw materials procurement. Indirect benefits are expected from the established “green image” of the enterprise, improved customer and supplier relations as well as the anticipation of legislation. Especially the indirect benefits refer to the movement of sustainable development and the increasing awareness of different stakeholders, for instance, the government, the common public, non-governmental institutions as well as interest groups to act environmentally friendly. Among others, typical tasks are to preserve natural resources, to reduce greenhouse gas emissions, and to prevent global warming. This holds true especially for the legislation for end-of-life products and wastes and social acceptance of the enterprise in the public.

Despite the profit-oriented drivers, legislative acts might force companies to take action in reverse logistics. This also comprises extended producer responsibility (EPR) where producers, in their role as manufacturer of goods, are legally obliged to take back and recycle goods. Ex-
amples in Europe are regulations for electrical and electronic equipment WEEE (European Parliament 2003) as well as the manufacturers' responsibility for the take back of batteries and cars.

In addition to profit-oriented and legislative drivers, an enterprise is also dependent on the “license to operate” issued by its stakeholders. This especially refers to the expectation of the companies environment that enterprises behave social as well as environmental conscious. Disregarding this issue might result in unfavourable influences on companies’ business operations by its environment, i.e. its stakeholders.

However, not just the take back of end-of-life products is subject to economic, legislative and social drivers. Reverse logistics in general comprises the reverse flow of goods from the end consumer back to the manufacturer, i.e. including processes after take back of products. This might happen because of several reasons. Generally, three return stages of products can be differentiated: manufacturing returns, distribution returns, and customer returns. Manufacturing returns comprise returns because of a material surplus, returns from quality controls or production leftovers or by-products. Distribution returns might be product recalls, business-to-business (B2B) commercial returns (e.g. unsold products, damaged delivery), and functional returns, such as distribution items or packaging. In comparison, customer returns are, e.g., reimbursement guarantees, i.e. business-to-consumer commercial returns, warranty or service returns (maintenance and repair), or end-of-use (e.g. returnable bottles or leased cars) and end-of-life returns (Dekker et al. 2004). The latter may also apply to C&D waste.

After return, the value in these products or waste can be recovered by various actions. Recovery actions are, for instance, reuse or resale, repair, refurbishing, recycling or incineration. For an overview as well as complete definitions of recovery actions for used products and waste it is referred to (Thierry et al. 1995, Dekker et al. 2004).

2.2 Characterisation of returned products

Performing reverse logistic activities depends on the characteristics of the returned product. These include the following (Dekker et al. 2004):
1. composition,
2. deterioration, and
3. use pattern.

The product composition describes factors like the presence of hazardous materials, the material heterogeneity of the product and the size of the product. The size of the product has significant impact on the transport and handling of the product, e.g. choice of appropriate mode of transportation as well as means of transport. Deterioration of a product considers the intrinsic deterioration of a product, i.e. aging during its use, the homogeneity of deterioration, i.e. if all parts age equally, and the economic deterioration, which addresses the decline of the value of the product, for instance, outdated products like old computer technology. The use pattern of a product is especially relevant for the collection phase of the product. It comprises issues like the location, i.e. different locations and effort for collection (individual or institutional use, collection point or individual take back), intensity and duration of use.

2.3 Actors and responsible parties in reverse logistic activities

A distinction of actors in reverse logistics activities can be made between (e.g. Dekker et al. 2004, Fuller & Allen 1995):
- forward supply chain actors,
- specialised reverse chain actors, and
- opportunistic actors.

In particular, responsible parties can be, among others: original equipment manufacturer (OEM), wholesalers or retailers, independent intermediaries, specialised recovery enterprises, third party reverse logistics service providers, and governmental institutions, like municipalities taking care of waste collection.
3 REVERSE LOGISTICS IN CONSTRUCTION

Applying reverse logistics concepts from the manufacturing in the construction industry, one faces numerous difficulties. These difficulties mainly arise from the more complex nature of the forward supply chain as depicted in Figure 1.

In comparison to the products of the manufacturing industry, such as electrical and electronic equipment, the “products” of the construction industry, i.e. civil objects, like houses, bridges or roads, have a long life cycles and are immobile. Due to their size and immobility the recovery of civil objects usually takes place on-site (Dekker et al. 2004). Concluding, reverse logistics operations in the so called reverse supply-chain are more difficult due to the higher number of actors (contractor, supplier, sub-supplier) and materials of different composition, degree of deterioration, and use pattern. An example of different recovery options for C&D waste is depicted in Figure 2.
3.1 Motivation

The motivation for construction companies to participate in reverse logistics is likely the same as in the manufacturing industry. Regarding profit-orientation a reduction of costs for disposal by selective deconstruction and separation of C&D waste can be realized. Additional gains are expected from the resale or recovery of valuable components and materials, for instance deconstructed aluminum framed windows, steel bars, wood, or bricks.


While the first two drivers for reverse logistic tasks focus on economic and legal aspects, the third factor addresses social consideration. It focuses on the fact that an enterprise depends on the “license to operate” issued by the people and institutions in its living environment (cf. section 2). Due to environmental concerns, also construction enterprises face pressure to act according to the principle of sustainability, i.e. waste avoidance and reuse in order to foster resource preservation and emission avoidance. The “green image” gained by environmentally friendly business operations can help to win the favor of the public.

3.2 Characterisation of material and waste flows in the construction industry

When construction materials are classified, it has to be differentiated between constituent parts and components of buildings used for construction and construction waste. According to Kibert, five general component categories of houses can be distinguished (Kibert et al. 2000):

1. manufactured, site-installed commodity products, systems, and components with little or no site processing (e.g. boilers, valves, electrical transformers, doors, windows, lighting, bricks),
2. engineered, off-site fabricated, site-assembled components (e.g. structural steel, precast concrete elements, glulam beams, engineered wood products, wood or metal trusses),
3. off-site processed, site-finished products (cast-in-place concrete, asphalt, aggregates, soil),
4. manufactured, site-processed products (dimensional lumber, drywall, plywood, electrical wiring, insulation, metal and plastic piping, ductwork),
5. manufactured, site-installed, low mass products (paints, sealers, varnishes, glues, mastics).

At the end of the life-cycle of a building, these components represent potentially recoverable materials and parts which are transformed into waste.

Apart from deconstruction this waste also arises during the erection of buildings. These materials can be classified according to the European Waste Catalogue (EWC) (European Commission 2002). The EWC contains a number of different waste descriptions, e.g. for wastes from inorganic chemical processes, waste from the photographic industry as well construction and demolition wastes (including excavated soil from contaminated sites), as exemplarily depicted in Table 1.

Depending on the actors involved in reverse logistics processes in construction, as addressed in the next section, different networks of collection points (supply sources) and recovery facilities or disposal sites (demand points) for C&D waste exist. If third party service providers are authorized with the pick up and recovery or disposal C&D waste, from the viewpoint of this service providers, numerous collection points (construction sites) exist and difficult transport problems, i.e. vehicle routing problems, occur. If the construction operator itself is responsible for the collection and transport of C&D waste to the recovery facility or disposal site against some charge, easy network structures and planning problems occur. However, this situation only occurs for very small deconstruction projects usually processed by small construction enterprises, usually engaged in regional business and contracts with private persons.
Table 1. C&D wastes according to the EWC (European Commission 2002).

<table>
<thead>
<tr>
<th>EWC Code</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>17 01</td>
<td>concrete, bricks, tiles and ceramics</td>
</tr>
<tr>
<td>17 01 01</td>
<td>concrete</td>
</tr>
<tr>
<td>17 01 02</td>
<td>bricks</td>
</tr>
<tr>
<td>17 01 03</td>
<td>tiles and ceramics</td>
</tr>
<tr>
<td>17 01 06</td>
<td>mixtures of, or separate fractions of concrete, bricks, tiles and ceramics</td>
</tr>
<tr>
<td>17 01 07</td>
<td>containing dangerous substances</td>
</tr>
<tr>
<td>17 01 06</td>
<td>mixtures of, or separate fractions of concrete, bricks, tiles and ceramics</td>
</tr>
<tr>
<td>17 02</td>
<td>woods, glass and plastic</td>
</tr>
<tr>
<td>17 02 01</td>
<td>wood</td>
</tr>
<tr>
<td>17 02 02</td>
<td>glass</td>
</tr>
<tr>
<td>17 02 03</td>
<td>glass, plastic and wood containing or contaminated with dangerous substances</td>
</tr>
<tr>
<td>17 03</td>
<td>bituminous mixtures, coal tar and tarred products</td>
</tr>
<tr>
<td>17 03 01</td>
<td>bituminous mixtures containing coal tar</td>
</tr>
<tr>
<td>17 03 02</td>
<td>bituminous mixtures other than those mentioned in 17 03 01</td>
</tr>
<tr>
<td>17 03 03</td>
<td>coal tar and tarred products</td>
</tr>
<tr>
<td>17 04</td>
<td>metals (including their alloys)</td>
</tr>
<tr>
<td>17 04 01</td>
<td>copper, bronze, brass</td>
</tr>
<tr>
<td>17 04 02</td>
<td>aluminum</td>
</tr>
<tr>
<td>17 04 03</td>
<td>lead</td>
</tr>
<tr>
<td>17 04 04</td>
<td>zinc</td>
</tr>
<tr>
<td>17 04 05</td>
<td>iron and steel</td>
</tr>
<tr>
<td>17 04 06</td>
<td>tin</td>
</tr>
<tr>
<td>17 04 07</td>
<td>mixed metals</td>
</tr>
</tbody>
</table>

3.3 Actors and responsibilities for C&D waste management

The responsibility for C&D waste management in deconstruction projects is usually assigned to the general contractor, i.e. the construction enterprise or the responsible sub-contractor. The contractor or sub-contractor has to organize the disposal of waste. Thereby, C&D waste can be sorted on-site and collected in transportable devices, for instance, containers. The aim of the contractor is to reduce disposal costs. This is usually realized by selective deconstruction and high degree of C&D waste separation. After deconstruction and sorting, either the contractor delivers the waste to recovery facilities or disposal sites against a fee or directly contracts with a specialised reverse chain actor, e.g. a recycling company, who picks up the containers of C&D waste on site for money and resells, recovers or disposes the C&D waste itself.

4 CHALLENGES IN THE ORGANISATION OF REVERSE LOGISTIC PROCESSES FOR CONSTRUCTION

Concentrating on the analysis of reverse logistics concerning C&D waste, recovery strategies for C&D waste have already been discussed intensively in literature. This comprises, for instance, research on deconstruction and recovery techniques (e.g. Tam & Tam 2006, Kuo 2006, Thormark 2000) and the use of various building materials and components after recovery (e.g. Rao et al. 2007). Therefore, in the following, the focus is shifted to the organisation of operational logistic tasks, i.e. the collection of C&D waste at the deconstruction site and its transport to recovery facilities or disposal sites. Hereby, the statement of Fleischmanns et al. (2000) (cf. section 2) especially holds true for construction, where common problems occurring are to be found in transportation activities, i.e. inefficient route planning and empty truck loads, so called deadheads.

These problems result from the characteristics of the construction industry, which differs from the manufacturing industry in many points. Among them are the complex and heterogene-
ous structure of the product, the long life time of the product and its immobility, the uncertain and non static waste accumulation in deconstruction projects, as well as the varying locations of construction sites, i.e. varying collection points but only a few recovery facilities and disposal sites as addressed before. Considering these particularities less space of freedom is given in the development of logistic strategies.

In the following, we therefore particularly focus on the influence of the characteristics of the construction industry on:
- actors and responsibilities,
- means of transport, and
- modes of transport.

C&D waste management in deconstruction projects is usually undertaken by the general contractor, i.e. the construction enterprise or the responsible sub-contractor. Accordingly, the contractor or sub-contractor is responsible for the disposal of the waste, as discussed before. This waste can be sorted on-site and collected in, for instance, containers. Either the contractor delivers the waste to recovery facilities or disposal sites for a fee or directly contracts with a specialised reverse chain actor, e.g. a recycling company. This actor picks up the containers or trucks loaded with C&D waste on site and resells, recovers or disposes the C&D waste itself.

Especially for reverse chain actors, the efficient transport of C&D waste is difficult. In contrast to the manufacturing, the location of the deconstruction sites is varying and usually the only accessible way is road transport mode. Hence, trucks with special equipment (for instance, special hangers to safely store deconstructed windows for resale) or container trucks are used. Thereby, also the composition of C&D waste hampers efficient reverse logistic activities. The size and quality of C&D waste is usually not standardised and the waste often contains unexpected hazardous substances. Deadheads cannot be avoided due to the missing planning certainty with respect to the forecast of the amount, place and time of the pick up of goods or collection from the construction sites and usually different role of the actor (a recycling plant usually does not deliver a deconstruction site with recovered components or recycled material). Instead, pick up tours have to be calculated every time an order is made by a contractor and complicated vehicle routing problems occur every time a new order arrives.

5 CONCLUSIONS

The aim of this contribution was to investigate the challenges of the application of reverse logistics to the construction industry. Special focus was put on deconstruction projects and C&D waste. It could be shown that reverse logistic activities also become important in construction, especially with respect to the need of the recovery of C&D waste trying to establish closed loop material loops.

It can be concluded, that the main structural difference between the construction industry and the manufacturing industry regarding take back of products, i.e. waste, does not refer to waste treatment or recovery processes, but to the organisation of the collection and the design of logistic processes from the building site to the recovery facilities due to the special characteristics of the construction industry and its products.

Accordingly, future research has to focus on the logistic processes from the source of origin of C&D waste to the first step down the process chain, i.e. the connection between construction sites or collection points and recycling or recovery facilities.

6 REFERENCES

European Commission 2002. *Consolidated European Waste Catalogue (EWC).*


