Reusing e-waste in civil engineering projects: Lessons learned from implementing circularity

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Summary

Circular Economy (CE) is a relatively established concept in several industries. However, despite the evident necessity to implement CE, it remains underexplored concerning electronic waste (e-waste) and the construction industry. Therefore, the goal of this paper to develop guidelines for the application of CE principles when processing e-waste within the construction industry. This is a gap in literature and practice. Based on a literature study, a theoretical framework has been developed to analyse barriers to CE. This framework was used to reflect on civil engineering projects. Interviews were conducted about the application of CE principles in the projects of the Velsertunnel, Realisationbureau Intelligent Transport Systems (RITS) and the Eerste Heinenoordtunnel. The data from the projects was compared to the literature to provide an understanding of most influencing factors. Three key lessons can be derived from this research. Firstly, the positive attitude towards CE is not widespread within the client organisation and implementation is dependent on the project team. Secondly, there is a lack of use-data about installations, making it impossible to determine their behaviour and durability. Finally, the transition to CE is not defined clearly, which means that contractors and suppliers are hesitant to adopt circularity, as they are unsure whether their efforts will be rewarded.

Key words: Circular Economy, civil engineering, construction industry, e-waste, reuse

1. Introduction

Most economies are nowadays based on a so-called linear economy. In a linear economy, materials are extracted, crafted into products, products are used and after use they are disregarded as waste (Allwood, et al., 2011). Consequently, this leads to a high pressure on the environment and ultimately exhausts our planet (Pomponi & Moncaster, 2017). As an alternative, there is increasing attention for the so-called circular economy (CE). In a Circular Economy (CE) it is tried to close material loops. This means that used products are not disregarded as waste, but remain in the material flow of an economy (Leising, et al., 2018; Geissdoerfer, et al., 2018). CE is defined by the Ellen MacArthur foundation (2013) as: “an industrial system that is restorative or regenerative by intention and design.” More specifically, CE aims for the prevention of waste and for the preservation of the inherent value of products for as long as possible (Geissdoerfer, et al., 2018). Moreover, in a more practical way, CE is often represented in scientific literature as a combination of the terms *Reduce*, *Reuse* and *Recycle* (Kircherr, et al., 2017). The 3R-principle of *Reduce*, *Reuse* and *Recycle*, is a way to apply CE in practice (Huang, et al., 2018) and is rooted in Lansink’s Ladder (Potting, et al., 2016). As Reuse is a main strategy to close material loops for building elements at the end of their lifetime (Van den Berg, 2019), Reuse will be the highest achievable circular goal in this research. By minimising the consumption of raw materials through the conservation of materials within the system, the negative effects on the climate can be mitigated without jeopardising the economic growth and prosperity. Although CE is a fairly new concept within the construction industry (Pomponi & Moncaster, 2017), the Dutch Government is supporting CE and has set the ambition to become fully circular by the year 2050 (Dijksma & Kamp, 2016).

A specific area of concern with regard to waste are electrical installations from renovated or refurbished infrastructure objects, such as tunnels. This specific type of waste is called ‘e-waste’ and includes broken and outdated electric installations and their electronic parts. Because the electronic parts of the installations consist of scarce materials, like metals, these materials may become unavailable when they are dumped instead of reused (PACE, 2019). Furthermore, e-waste is one of the fastest-growing pollution problems worldwide because of the presence of a variety of toxic substances that can contaminate the environment and threaten human health (Kiddee, et al., 2013). Consequently, it is increasingly important to find ways to reuse the scarce materials from e-waste, instead of dumping them on landfills. Nonetheless, the current practice in the Netherlands is that electrical installations, which become obsolete through renovations, are among the least reused materials, as they are mostly recycled conform the EU WEEE Directive. The reason behind this is that e-waste includes a variety of toxic substances which are harmful for humans and the environment, making it more difficult to reuse compared to other materials.

In this paper, we therefore explore how clients in civil engineering infrastructures projects can handle e-waste in keeping with the principles of CE. More specifically, the main research question is: what are the factors that influence the CE and reuse of e-waste? The contribution of this paper is to provide lessons learned that support the transition from the current linear way of handling e-waste, towards a circular way. This paper is structured as follows. In the upcoming section, we describe how we conducted our study. This is the methodology section. In the next section, we present the results of a literature review on potential barriers that limit the application of CE when dealing with e-waste. The fourth section describes our analysis of projects in which e-waste needed to be handled. Among others, we will explain which obstacles to CE were encountered in real-life. Our paper ends with three lessons learned and a conclusion.

2. Methodology

This study adopts a case-study methoology to collect data. A literature study has first been performed. This systematic review provides a foundation for the research topic by reviewing previous studies (Esa, et al., 2017). Secondly, with a theoretical framework as a reference, we analysed three civil engineering projects where some form of CE was applied and e-waste needed to be handled. These projects are the Velsertunnel, RITS project and Eerste Heinenoord Tunnel. At the time of this research, the Velsertunnel and the RITS project were finished and the Eerste Heinenoord Tunnel was in the contract phase. These cases were among the few cases were CE was applied to at least some extent. The first author conducted 12 interviews with people involved in these projects as part of her master thesis project. Interviewees covered the entire supply chain, consisting of the client, contractors, advisors and suppliers/subcontractors of each project. The technical managers provided information about material flows, the specifications of the projects and motivations behind certain choices concerning CE. The contract managers were included in the interviews to elaborate on the relationship between the client and the contractors. The advisors of the three projects provided background information about sustainability and CE and pinpointed the exact moments when and why implementation was successful or not. Moreover, they gave information about what the ideal process could look like and how this ideal situation could be reached. Finally, the contractors and the suppliers provided insights on their relationship with the client and the material flows from their perspective. In addition to the interviews, a document study was also conducted in which we analysed project plans and other documentation, which were used to complement results from the interviews. Preliminary results were discussed among all authors.

With regard to data analysis, each interview was transcribed and the results were open and axial coded. This means that each project was analysed separately and then compared with the other projects in a so-called cross-case analysis. Differences and similarities between the cases were identified and explanations were sought as to why certain choices were made with regard to processing e-waste. Finally, we derived some key lessons learned, from the cross-case, which are presented in this paper.

3. Barriers when applying CE principles to E-waste

In this section, we describe the results of a literature review on CE principles related to e-waste. It will give an overview of the barriers that might be encountered when applying these principles. Although environmental concerns, stricter legislation, social responsibility and competitive pressure (Govindan & Bouzon, 2018) have made it increasingly important to process residual flows according to CE principles (Agrawal, et al., 2015), the actual implementation of CE lags behind at this point in time. The existing literature attributes this to numerous barriers concerning CE. These barriers have been categorised by the researchers into five categories: legislation, attitude, risk, responsibility and technical. These categorized barriers provided a framework for analysing the projects.

3.1. ***Legislation barriers***

The 'legislation' category comprises two main barriers. Firstly, literature states that there is a lack of supportive legislation and regulations for the implementation of CE (Hosseini, et al., 2015; Govindan & Bouzon, 2018). Existing laws are not supportive of CE and not motivating the implementation, meaning that the implementation of CE is considered an added difficulty for organisations (Govindan & Hasanagic, 2018). Secondly, some authors take the extent of legislation further, arguing that existing laws and regulations even prevent CE (Mahpour, 2018; Schamne & Nagalli, 2016; Chinda, 2017). They argue that the current legislation is often too strict concerning safety, which renders the use of recovered materials or products nearly impossible.

3.2. *Attitude barriers*

The second category is the 'attitude' category. Within this category, three barriers have been found. Firstly, many authors mention that other goals and ambitions, such as the management of cost and time, have a higher priority in projects than CE (Mahpour, 2018; Hosseini, et al., 2015; Govindan & Bouzon, 2018; Govindan & Hasanagic, 2018). Because project teams perceive CE as having a lower priority than other requirements, it becomes a complicating factor rather than added value to the project. The second barrier in this category is that users often have an outspoken preference for new rather than recovered products or materials (Mahpour, 2018; Hosseini, et al., 2015; Govindan & Bouzon, 2018; Hosseini, et al., 2014; Govindan & Hasanagic, 2018; Chinda, 2017). Recovered products or materials often have a stigma of being of lower quality than new ones and users often prefer the best available option. This consumer perception and attitude towards CE makes it more difficult to implement it. The final barrier from the 'attitude' category is that the reputation of CE is working against itself. Currently, the less environmentally friendly options of CE, such as recycling, are more appealing than the more environmentally friendly alternatives such as reuse (Hosseini, et al., 2014; Mahpour, 2018; Chinda, 2017). In the past, recycling was emphasized a great deal as being the mostenvironmentally friendly option and it is often still perceived as such. Moreover, recycling does not have high initial costs as, for example reuse, while it could generate a profit for the owner of the materials that are recycled.

3.3. *Risk barriers*

The 'risk' category includes three barriers. Firstly, numerous authors have argued that the quality from recovered materials can be insufficient (Hosseini, et al., 2015; Govindan & Bouzon, 2018; Hosseini, et al., 2014; Govindan & Hasanagic, 2018). It is not always clear what the quality is of recovered materials or products because there is a lack of information and the quality cannot always be determined with a visual inspection. Because of this, the quality can vary among the same sorts of products or materials and therefore pose a risk to the user. Furthermore, another barrier from the 'risk' category includes that there are not enough incentives by the government to make CE appealing for companies (Mahpour, 2018; Govindan & Bouzon, 2018; Hosseini, et al., 2014; Schamne & Nagalli, 2016). That is because CE demands an initial investment and often has higher initial costs. Therefore, without incentives from the government to support companies in taking this risk, CE will not be appealing to the vast majority of construction companies. Finally, the last barrier is that it is unclear in which direction CE will develop (Govindan & Hasanagic, 2018; Mahpour, 2018). The literature provides a great number of paths and definitions of CE and the industry is uncertain about the outcomes of this. It poses a high risk to invest in something without knowing whether it will be valued later on.

3.4. *Responsibility barriers*

The next category, 'responsibility', includes three different barriers. The first 'responsibility' barrier is that there are ownership issues when it comes to reuse (Mahpour, 2018). Often it is the case that the ownership of waste is not specified and when this waste is processed according to CE principles, it retains value and different parties want to participate in collecting the value. Furthermore, another barrier is that organisations do not take their social responsibility and lack support for CE (Mahpour, 2018; Govindan & Bouzon, 2018; Chinda, 2017). They do not have clearly defined goals and visions to move to CE and the government does not provide enough support for this transition. On top of this, the industry does not take their responsibility either, which is the third barrier (Mahpour, 2018; Adams, et al., 2017; Hosseini, et al., 2014; Schamne & Nagalli, 2016; Govindan & Bouzon, 2018; Hosseini, et al., 2015). The reason behind this is that there is a lack of awareness of CE across the construction industry and this results in a lack of producer-based responsibility. The benefits are not articulated enough and therefore the interest in CE is falling behind.

3.5. *Technical barriers*

The final category is the 'technical' category, in which two barriers have been classified. Firstly, the supporting facilities for CE are underdeveloped (Huang, et al., 2018; Mahpour 2018; Hosseini, et al., 2015). Because the market for recovered/salvaged materials is underdeveloped, the promoting of the acceptance and use of recovered materials or products is more difficult (Huang, et al., 2018). Furthermore, the technologies for effective dismantling, collection, sorting and transporting of waste are not in place (Mahpour, 2018; Adams, et al., 2017; Huang, et al., 2018). Besides this, there is need for space to sort and store materials as well as enough skilled manpower to do so (Hosseini, et al., 2015; Adams, et al., 2017). The second barrier from the 'technical' category includes the lack of standards imposed on products and materials (Huang, et al., 2018). As there are no proper guidelines to classify waste, there is limited potential for the implementation of CE in the construction industry.

3.6. *Summary*

Summarising, this review explains the barriers that can limit the application of CE principles when handling e-waste. It appears that the barriers can be categorized into five main categories: legislation, attitude, risk, responsibility and technical barriers. With the barriers in mind, we analysed the projects and derived key lessons learned from them. This is discussed in the next section.

4. Results

This section describes the key lessons learned from the projects that we analysed. In this section we have focused on the three most important lessons learned from the projects analysed. The first case that has been researched, is the Velsertunnel, a bank connection that runs under the North Sea Channel near Velsen. During the renovation, a new ventilation system, fire resistant layer and operating system were installed, and CE was an important project goal. The second case that was researched, is the RITS project. RITS stands for Realisationbureau Intelligent Transport Systems and is a combination of many small projects where the digital transport management and intelligent transport systems on the Dutch national roads were renovated. This includes cameras, traffic control installations, traffic signalling and roadside systems. Within the RITS project, several materials were successfully reused. Finally, the case of the Eerste Heinenoord Tunnel has been included into the research. This project was in the phase of establishing the contract between client and contractor during this research and because of that, it gave insights into the process of how a contract is drawn up and why certain choices concerning CE are made.

4.1. *Key lesson one: project-specific implementations*

The first key lesson that we have derived from the three projects, is that the implementation of CE, and also of e-waste reuse, is often project-specific. It often depends on the project manager and other key project members whether CE is applied to the project or not, and in which form and to which extent. When one of the project members does not support CE or reuse, it could jeopardise the implementation and even prevent it. This implies that the positive attitude towards CE is not always organisation-wide and there are large differences in opinion and implementation because of this. Moreover, because the attitude on CE is not consistent throughout the client organisation, the image that is projected towards the outer world, in particular towards contractors and suppliers, is not consistent as well. This results in uncertainties for, and an unwillingness by, contractors and suppliers to invest in CE. They are not sure if they will be rewarded for their investment and effort.

The most evident lesson taken from this is that the attitude towards CE needs to be positive organisation-wide. Especially decision-makers need to be educated in order to support and stimulate CE and reuse. Moreover, it is even more important to present a consistent and positive image of CE externally, to stimulate the infrastructure sector to invest money and effort into CE. In summary, the role of the client is substantial in the implementation of CE and the reuse of e-waste.

4.2. *Key lesson two: missing data*

A second key lesson that has become evident from the projects analysed, is that there is a great lack of data concerning the installations. Crucial data about the installations is often missing, such as the structure, components or programming of the installations. This data has never been requested upon installation of the electronics, and over the decades, the suppliers have disregarded the data as well. Due to this, great uncertainties arise in the prediction of the behaviour and durability of the installations after reuse. Therefore, neither the client nor the suppliers have access to the data, which is crucial in order to determine the state of the installations. Thus, the reason e-waste is often not reused, is that it is difficult to determine what the state of the installations is and whether it is durable and responsible to reuse it because of this lack of data.

Therefore, the lesson that can be taken from this situation is that it is often unclear what installations and software exactly are installed in assets. Thus, in new projects, data needs to be requested, monitored and updated through Material Passports about purchased installations in order to be able to reuse those in case of a renovation.

4.3. *Key lesson three: the future of CE*

Key lesson number three is that the transition to CE and in particular reuse of e-waste is not defined clearly. Goals and ambitions are often set, but not defined clearly and lack technical boundaries, benchmarks and scientific argumentation. Moreover, as the leading client and innovator in the sector, RWS and possibly other asset owners could lead and pave the way for the others. Until asset owners define a clear path for the CE transition, the market will still be hesitant and will not make decisions or investments regarding CE. The uncertainties about the right path cause the contractors and suppliers to become passive and simply wait for more information to secure their investments.

In sum, from the third key lesson it becomes evident that clients in the civil engineering sector need to invest more time and resources to clearly define their future CE goals to accommodate the market. They also need to make these goals concrete and specific and provide more substantial scientific argumentation. The market is likely to remain passive until they know for certain whether their investments will be rewarded.

5. Conclusion

As the construction industry is a large contributor to the development of e-waste, the implementation of CE in a more substantial way, could help keep the effects on the environment to a minimum and could take care of the social responsibility. The barriers of CE have already been widely discussed in literature, however little of that research is focused on the construction industry and e-waste. As the largest client in the Dutch industry, RWS plays a great role in the implementation of CE in the Netherlands. Hence, this research has aimed to fill out the missing blanks when it comes to CE in the construction industry and e-waste.

The research has pointed out that there are three key lessons that RWS and possibly other asset owners should focus on, which are directly linked to the barriers identified. Firstly, the CE of e-waste currently is project-specific, meaning that in one project reuse could be an important goal, whereas in the other project there is no attention for it at all. The reason behind this is that CE is often not widespread within the organisation and it depends on the project manager whether CE will be implemented or not. This means that benefits of CE are not always being experienced by asset owners/clients, which is a barrier that is recognised in both literature and practice. Secondly, there is a lack of accessible project data about installations, such as the structure, components or programming. Because of this, it is not possible to determine the behaviour and durability of the installations and therefore e-waste cannot be reused in projects without risk. Finally, the third factor that influences the reuse of e-waste is that the transition to CE is not defined clearly, which has been recognised in literature as well as in practice. Goals and ambitions that are set, are not defined clearly and lack technical boundaries, benchmarks and scientific argumentation, causing the market to be hesitant concerning investment in CE innovation.

With the identification of the three key lessons, this research provides new ideas and opportunities for public infrastructure clients to consider or rethink the reuse of e-waste to fulfil their social responsibility and ultimately reduce waste and the need to extract virgin resources.

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