Master's Degree Thesis

Closed loop building approach to address sustainability challenge into the future of urban areas

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Abstract: Global urbanization trends and climate changes result in a significant pressure for the future development of urban areas. The construction industry can play a primary role in addressing some of the challenges, but in order to make it happen, the phases of design, construction, use and deconstruction of a building should meet the criteria of sustainability. The closed loop approach can help the construction industry to move in the right direction.

This thesis analyses the closed loop approach to identify its potential contribution in solving the sustainability challenges in urban areas, as well as explores the key aspects helping or hindering the implementation of the approach. The methods used for this research include the framework for strategic sustainable development, case study analysis and interviews with experts in the field.

The research exposed several gaps in the use of the approach moving towards sustainability, mainly due to the fact that a unique and shared definition of it is missing and neither actions nor tools are suggested for a successful implementation of the approach. Main barriers are related to the material choice, flexibility of the design, communication and legislation aspects, work with supply chain and interaction with stakeholders. Nonetheless, most of them are also seen as potential enablers. Recommendations are provided to help overcoming the existing barriers and valorising the key enablers, but a clear definition of the approach is necessary to exploit the potentialities of the closed loop approach.

Keywords: Closed loop approach, sustainability, sustainable building, strategic sustainable development, Cradle to Cradle, barriers, enablers.

Statement of Contribution

The topic of our thesis was brought up from the different interests and backgrounds of our team members. Katya has a background in sustainability and corporate social responsibility management, Martina has done environmental engineering and Silvia's background is ecological agriculture.

The “journey” was started formulating the topic of our work in a way it could be exciting and sufficient for all our group members, followed by sharing our common vision and expectations from the work process. Being interested in sustainable architecture, building design and urban gardening, we managed to put together our differences and we agreed on conduct our thesis with the closed loop approach as our topic.

Katya's working experience in construction industry provided us with an input on how to interpret the closed loop approach applied to buildings. She deliberately gave insights on the different types of approach. Her calmness and verbal communication skills allowed her to contribute on the details of the thesis production. As a good planner and sharp thinker, Martina gave the flow to our work and stimulated discussion and further studies. Her experience in environmental modelling gave us the opportunity to explore the methodology in detail. She contributed to our thesis process with enthusiasm and she took care of the communication between our team and advisors. The experiences on conducting research with case study was provided by Silvia, where she was able to help us to have a track of interviews and build up the case studies. She offered constructive critics into the work. Her critical thinking made us to keep asking to ourselves where we did well our work or not.

The process of the thesis writing was carried out ad a combination of collaborative and individual work. By carrying our group meetings we were able to share our concerns and findings, discuss the points that required common understanding and agreements, as well as distributing the tasks for individual work.

We decided to distribute our thesis work in the following way: Silvia contributed to the detailed overview of the existing sustainability challenge in urban areas, as well as in the construction industry, and the description of case studies. Martina and Katya were working together on data collection and interpretation, which became the baseline for methods, results and recommendations. Together we formulated research questions, contributed to the discussion and formulated proposal for the future work. All the team members contributed on gathering data and interviews. All the findings, "moments of truth", challenges and periods of joy throughout the process made this experience unforgettable and valuable, from gaining new knowledge to personal growth.

Ekaterina Glukhova	Martina Cividini	Silvia Erimasita

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We would like to acknowledge our second supervisor, Cesar Levy Franca, MSLS staff and Karl-Henrik Robèrt on their lectures, support and motivation they gave us. Alexandra Licthenberg, with her precious proofreading, and our fellow MSLS 2015 and shadow group, which helped us along the thesis process. Their support, comments and care helped us to stay focused. We greatly value their friendship.

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Executive Summary

Introduction

Human activities, social and economic development, as well as population growth, increase the concern that the stability of the Earth system could be damaged raising the risk of catastrophes for the current and future societies (Rockström 2009). Human activities contribute to the main drivers that stimulate the change of the Earth climate and the shift towards an unacceptable environment (Millennium Ecosystem Assessment 2005). As in 2050 the urban population is expected to increase by 25% (United Nation 2011), the activities within urban areas contribute to the global challenge and potentially affect the Earth system (Grimm et al. 2002).

Social and ecological problems, surface and atmospheric changes associated with the construction and functioning of cities are profound. The design and the construction of an individual building is likely not to consider the limited capacities of natural resources and still relies on open-loop material system.

The way in which buildings are nowadays designed and used can lead to more issues and challenges instead of playing a positive role in helping to address the existing ones. The phases of design, construction, use and deconstruction of a building should meet criteria of sustainability, and this becomes clearer considering the rapid growth of the building stock due to the increasing urbanization rate (Smit 1992).

Planning of urban areas and the construction industry will play a key role in addressing some of these issues. Nonetheless, there is little attention given to discarding material or to the use of abandoned buildings, and recycling materials have not yet become a common understanding in building practices. Although much effort has been undertaken to develop recycling techniques for construction materials in the past years, the construction and recycling industry, especially in the housing sector, still suffers from a lack of innovation in terms of sustainability. The optimization approach towards closed loop system on material flows in the construction industry has to be developed further (Schultmann and Sunke 2014).

Sustainability and sustainable development

An essential obstacle to move towards a better future is the lack of clarity on what the terms ‘sustainability’ and ‘sustainable development’ mean. As a response to these challenges, there is a significant need for a clearer definition of sustainability that includes both sociological and ecological perspectives.

The definition of sustainability provided by Ny (2006) and Missimer (2013) was considered to be the most comprehensive, as it makes use of a principle-based definition of sustainability that is “science-based, necessary and sufficient for sustainability, general, but concrete enough and distinct” (Ny 2006). Compared to the different definitions found in the literature, the three principles presented by Ny and the following five by Missimer are designed in a way that makes them to be necessary and sufficient to achieve sustainability, general enough to make possible all the activities for society, concrete enough to give directions in actions and non-overlapping or mutually exclusive (Robèrt 2010, 38). Other principles are not yet claiming to do so.

Sustainable buildings and the closed loop approach

At present, the construction industry is still mostly characterized by open loop systems, which create waste from both use and deconstruction stages. Considering the limited dumping capacities, reduced land for landfill, growing urban population and scarcity of natural resources, it is obvious that closed loop material systems have to be considered as one of the solutions for the existing sustainability challenge (Guy and Kibert 2003, 186).

Currently, the closed loop approach in construction industries is not well defined. Different approaches, which are present in the literature, such as selective deconstruction and adaptive reuse are claiming to be closed loop, as well as those mostly related to materials. Nonetheless a closed loop systems with full materials recovery still do not exist at present.

Purpose and research questions

The purpose of this research is to assess the closed loop approach in the construction industry moving towards a sustainable society. The motivation behind this research is to understand how the concept of closed loop can be used to foster strategic sustainable development in the construction industry. In this line, the research questions of this thesis are:

- How, and to what extent, can a closed loop approach to construction help to address sustainability challenges in urban areas?
- What are some key success factors for implementing a closed loop approach in the construction industry?

Methods

Different methods were used to address the outlined research questions with the focus on different case studies in order to see how different closed loop approaches work in real world. The analyses included five different case studies from four countries:

- CEFUR, Sweden
- Venlo City Hall, Netherlands
- Agrodome, Netherlands
- Chobham Manor, UK
- Upcycle House, Denmark

Data collection was achieved by means of desk research and two types of interviews: with experts on the closed loop topic and case studies' project leaders.

The analysis of data in order to find answer to the first research question was done through the five levels of the FSSD (Robèrt et al. 2010, 34). This framework was used to explore gaps and contribution of the closed loop approach in addressing sustainability challenges in urban areas, and to describe the role that it can play in moving towards sustainability.

Regarding the second research question the data analysis was based on coding of the information with its further clustering and identifying the main barriers and enablers.

Results

FSSD Analysis

At the system level, the closed loop concept sufficiently acknowledged the existence of the sustainability challenge and the important role that the construction industry can play in relation to it. However, the concept lacks of a complete system perspective since it does not have a clear description of the social dimension related to sustainability, and there is still not a unique and agreed definition of the closed loop concept.

Due to the lack of a unique and agreed upon definition of the closed loop approach, no universal guidelines for success exist, except for certain suggestions in relation to materials. Finally none of the approaches that claim to be closed loop ones, as they are conceived now, provide concrete indications in terms of social sustainability.

At the strategic level, the closed loop approach does not provide any indication of clear guidance to help practitioners to apply it in order to move towards sustainability. Moreover, it does not suggest specific actions that should be taken or tools in support to its use.

Barriers and Enablers

Based on the interviews and case studies analysis, 141 barriers and 106 enablers were identified and grouped into 10 and 11 clusters, respectively. Almost all the clusters can be seen as both barriers and potential enablers under certain conditions or cases.

The main barriers that are currently hindering the implementation of the approach are related to: flexibility of building design, material choice, work with supply chain, interaction with stakeholders and community, addressing of the social and cultural aspects, sustainable education.

Besides these main categories, additional barriers and enablers that are less frequent were identified, which can still be important in the implementation process.

Discussion

By examining a closed loop approach it was revealed that construction industry misses the common definition of sustainability, which makes it hard to get a system perspective of the concept and thus makes it difficult for practitioners to address the sustainability challenge in construction properly.

Findings about today's construction industry and society on the whole result to the fact that conditions for wider adoption of the closed loops concept are not present yet. This is to a large extent explained by lack of clear definition of sustainable construction and closed loop approach, which makes a concept difficult to understand, as well as lack of clear guidelines defining the closed loop cycle materials, providing explanations on economical benefits of the concept and describing associated strategies.

The research conducted in this work demonstrates how the use of FSSD can advance the closed loop concept. Moreover analysis of all the categories of barriers and enablers provided an opportunity to reveal the main gaps resulting in low application of the concept. Basing on that, some recommendations for filling up the gaps and stimulating of the concept implementation were given.

Relevance of the research

By analysing the closed loop concept in the construction industry it became possible to reveal both its gaps and contributions in addressing the sustainability challenge in urban areas. By defining and analysing key barriers and key enablers of the concept it became possible to reveal common challenges that different players of the construction industry are currently experiencing and to provide recommendations for fulfilment of the existing gaps.

Strengths and Limitation of the research

Various backgrounds and areas of work, as well as different geographical and cultural experiences of the interviewees are considered as strength of the work, as it helped to identify both common gaps and positive shifts currently happening in various areas of the construction industry. Analysis of different case studies also contributed to understanding of the common trends among the different players of the construction industry. However, in order to confirm validity of the results, additional interviews would be helpful, which was challenging due to the time constraints.

Future work

The future research for the closed loops concept can be based on the recommendations of how to address and overcome existing barriers. The main efforts should be aimed at creation of guidelines for the construction professionals and include recommendations for the closed loop cycle materials, advantages of flexible building design and highlighting economic incentives of the concept. Another focus has to be made on fostering of sustainable education and interaction among the stakeholders, as well as changing of the relations within the construction product service system by means of legal enforcement.

Some of the recommendations should be encouraged, while others should work as enforcement tools for the wider adoption of the concept of closed loops in construction. What is evident is that by using one or several recommended actions separately it is hardly possible to achieve any significant improvements for the sustainable construction on the whole and closed loop approach in particular. Real shifts towards wider adoption of the concept on all societal levels become possible only when all of the recommendations start working altogether.

Conclusions

The research has shown that adoption of a closed loop approach in the construction industry can foster the movement towards sustainability, enhancing the awareness of the sustainability challenges. However, there is still not a unique and clear definition on the closed loop approach in the construction. Moreover, conducting an analysis through the FSSD, it was revealed that the concept exhibits several gaps in relation to the definition of global sustainability, especially in regard to the social aspects, as well as guided definition of success, strategic guidelines and associated tools and actions. Altogether it results to the fact that the use of closed loop approach as it is now cannot lead to full sustainability in the socio-ecological system. Nonetheless, basing on the analysis of existing barriers and enablers of the approach recommendations for overcoming of the existing obstacles were provided.

List of abbreviation

5LF: Five Level Framework

ASBP: Alliance for Sustainable Building Products

BRE: Building Research Establishment

C2C: Cradle to Cradle

CE: Communautè Europèenne

CL: Closed Loop

CLMC: Closed Loop Material Cycle

EU: European Union

FSSD: Framework for Strategic Sustainable Development

KPIs: Key Performance Indicators

LCA: Life Cycle Assessment

NGOs: Non Governmental Organizations

OECD: Organization for Economic Co-operation and Development

SPs: Sustainability Principles

UK: United Kingdom

UN: United Nations

WUR: Wageningen University

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1 Introduction

The United Nations indicates that the world's urban population will increase by 2.7 billion between 2010 and 2050 leading to a global population of 9.3 billion (United Nations 2012). Furthermore, the greatest population growth is expected in urban areas and will be concentrated in the cities and towns of the less developed regions (European Environment Agency, 2014).

Human activities, social and economic development, as well as population growth, increase the concern that the stability of the Earth system could be damaged raising the risk of catastrophes for the current and future societies (Rockström 2009). Human activities contribute to the main drivers that stimulate the change of the Earth climate and the shift towards an unacceptable environment (Millennium Ecosystem Assessment 2005). The activities within urban areas contribute to the global challenge and potentially affect the Earth system (Grimm et al. 2002).

Associated with these demographic changes, urban expansion and the demand for resources and energy from urban producers and consumers are transforming Earth's terrestrial ecosystems; and with it, causing the loss of habitat and species, changes in biogeochemistry, and modifying hydrological systems. Whereas urban areas contribute to more than 70% of the total energy demand and are proportionately correlated to the world's carbon dioxide emissions, it is evident that when combined globally, urban areas have the potential to affect the Earth system (Seto and Satterthwaite 2010).

This growing trend, together with global climate change and modern urban lifestyle, will bring different issues to the future of urban areas. As a population centre grows it tends to expand its area and modify the land surfaces using materials that store short-wave radiations. Respectively this will increase the average temperature of the urban area, known as the heat island effect, which will indirectly contribute to air pollution and provide less space for green areas where plants can absorb CO2 and particles (Oke 1973). Moreover the systematic increase of urban population without a sustainable planning approach can lead to the reduction of per capita green space and to the increase of waste and landfill, which will significantly decrease the social well-being of the population (Gidlöf-Gunnarsson et al. 2007, 115).

In urban areas facing these problems, surface and atmospheric changes associated with the construction and functioning of cities are profound. New surface materials, associated with buildings, roads, and other infrastructure, along with changes to the morphology of the surface, alter energy paths, water exchanges and airflow (Grimmond 2007). The design and the construction of an individual building is likely not to consider the limited capacities of natural resources and still relies on open-loop material system. The open loop does not consider the limit of natural resources capacities. The design phase and the construction process are not kept in a circular flow, utilizing instead the open loop system that requires additional materials.

The way in which buildings are nowadays designed and used can lead to more issues and challenges instead of playing a positive role in helping to address the existing ones. The design of the building could help address many of these challenges by being designed to include water catchment, energy retention or generation, food production and so on.

Nowadays, there are many old buildings that are vacant and abandoned. Some of the buildings are deemed in need of being replaced; however, other possibilities for them are not being considered. The phases of design, construction, use and deconstruction of a building should meet criteria of sustainability, and this becomes clearer considering the rapid growth of the building stock due to the increasing urbanization rate (Smit 1992).

Planning of urban areas and the construction industry will play a key role in addressing some of these issues. Different and alternative trends are already present, mostly focused on green architecture. Much of the literature related to the building industry addresses energy saving and resource efficiency. Green buildings incorporate design, construction and operational practice, which result in considerably less negative impact on the environment and society. Furthermore, green buildings must consider design and construction cost, asset value, operating cost and workplace productivity and health (Environmental Protection Agency 2015).

Nowadays, the companies that design and construct new buildings focus mainly on open-loop systems at the building level. Little attention is given to discarding material or to the use of abandoned buildings, and recycling materials has not yet become a common action in building practices. Although much effort has been undertaken to develop recycling techniques for construction materials in the past years, the construction and recycling industry, especially in the housing sector, still suffers from a lack of innovation in terms of sustainability. The optimization approach towards closed loop system on material flows in the construction industry has to be developed further (Schultmann and Sunke 2014).

1.1 Sustainability and sustainable development

An obstacle preventing movement towards a better future that is essential to address is the lack of clarity on what the terms “sustainability” and “sustainable development” mean. In broad terms, sustainable development is defined as a mean by which the global system would satisfy the needs of present generations without undermining the ability of future generations to meet their own needs (World Commission on Environment and Development 1987, 43). Another well-known definition is provided by the Brundtland Report (World Commission on Environment and Development 1987): “*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*”. This definition underlines the long-term aspect of the concept of sustainability and introduces the ethical principle of accomplishing fairness for both the present and future generations (Diesendorf 2000). Furthermore, the Brundtland Report's definition appears to compare “needs” with “wants” and it assumes that economic growth is a necessary part of development. This definition does not explicitly mention the natural environment, but rather focuses on human needs. However, the report as a whole makes clear that “needs” include the conversation about the natural environment.

As a response to these challenges, there is a need for a clearer definition of sustainability that includes all sociological and ecological perspectives. One such definition is based on first-order principles that account for the complexity of the global socio-ecological system and addresses unsustainable practices (Byggeth 2001, 702). Figure 1 below illustrates the four categories of unsustainable practices that frame the sustainability challenges.

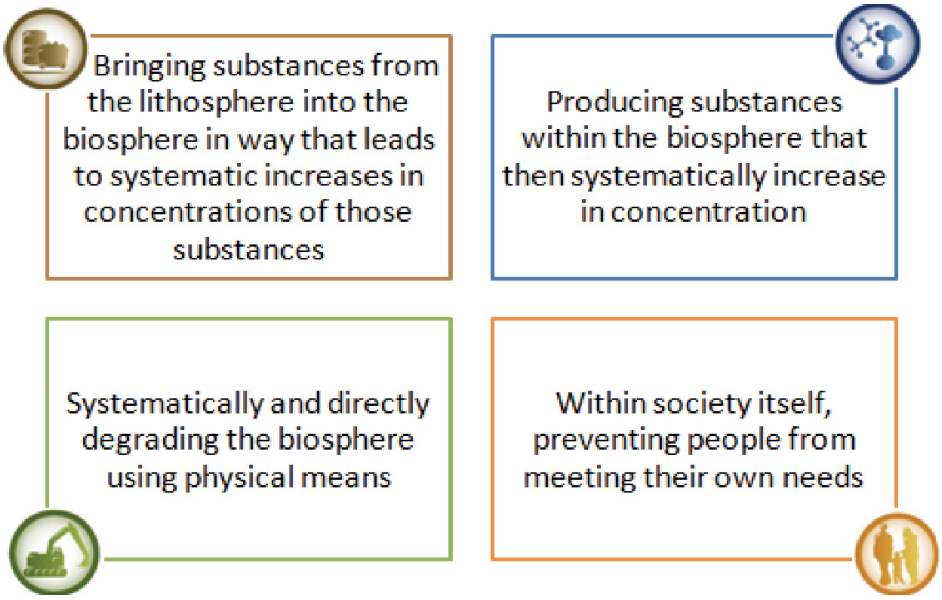

Figure 1: The four categories of unsustainable practices (Robèrt 2010b)

Ny, et al. (2006) state that there are four sustainability principles (SPs) that describe a sustainable society:

"In a sustainable society nature is not subject to systematically increasing

- concentrations of substances extracted from the Earth's crust (SP1);
- concentrations of substances produced by society (SP2);
- degradation by physical means (SP3),

and in that society, people are not subject to condition that systematically undermine their capacity to meet their needs (SP4).

Missimer (2013) refined the fourth principle, as social sustainability is becoming more integrated, and this means that people are not systematically subjected to barriers to:

- Integrity (SP4). This is about not doing direct harm at the individual level; physically, mentally or emotionally. In an organizational context it might refer to working conditions.
- Influence (SP5). This is about being able to participate in shaping social system(s) one is part of and dependent on. At a minimum, this might mean being able to vote on leadership and issues and being able to make one's voice heard.
- Competence (SP6). This is about safeguarding that every individual (and group) has the opportunity to be good at something and develop to become even better. It inckudes the securing of sufficient resources for education and other sources for continuous personal and professional development. This also includes the ability to learn in order to remain adaptable and therefore resilient.
- Impartiality (SP7). This is about people treating each other equally, both between individuals, and between individuals and organizations such as in courts, authorities, etc. It is about acknowledging that all people have the same rights and are of equal worth.

- Meaning (SP8). This is about the reason of being an organization within the system. How does it inspire its members, what does it aim to do and why?

Mitchell *et al*. (1995) in their review of the burgeoning literature on sustainability and sustainable development also identified four other common principles: futurity (concern for future generation), environment (concern to protect the integrity of ecosystem), public participation (concern that individuals can participate in decisions affecting them) and equity (concern for today's disadvantaged people).

Coming to versions more workable for the construction industry, Ortiz (2009) described sustainable development as enhancing quality of life and allowing people to live in a healthy environment and improving social, economic and environmental conditions for present and future generations; while Vollenbroek (2002) stated that sustainable development is a balance between the available technologies, strategies of innovation and the policies of governments. The improving social, economic and environmental indicators of sustainable development are drawing attention to the construction industry.

Berke and Conroy (2000, 23) identify six basic principles of sustainable development retaining the connection to the location, shape, scale, and quality of human settlements within which the process of sustainable development must operate. The principles are:

- land use and development should protect, enhance, and be in harmony with natural systems;
- liveable built environments designed for their inhabitants' uses, offering cohesion, community, and access between land uses;
- a place-based economy that functions within natural systems limits;
- equitable access by all people to important social and economic resources;
- payment by polluters for their adverse effects on the environment;
- responsible regionalism.

Collectively these principles offer a good guide to prioritize actions upon which to base policy, land use, and practical sustainable solutions (Dushenko et al. 2012, 150).

Of all definition mentioned above, it was decided to refer on the definition provided by Ny, (2006) and Missimer (2013) as it is a unifying approach for planning towards sustainability. It is comprehensive because it makes use of a principle-based definition of sustainability that is "science-based, necessary and sufficient for sustainability. It is general but concrete enough and distinct" (Ny 2006). Compared to the different definitions found in the literature, the three principles presented by Ny and the following five by Missimer are designed in a way that makes them to be necessary and sufficient to achieve sustainability, general enough to make possible all the activities for society, concrete enough to give directions in actions and non-overlapping or mutually exclusive (Robèrt 2010, 38). Other principles are not yet claiming to be that.

1.2 Sustainable buildings and closed loop approach

Sustainable buildings as defined by OECD (2003) are buildings that have a minimum impact on the surrounding of the building, natural environment, and bigger perspective. Sustainable

buildings can be described as building practices that aim at basic equity in economic, social and environmental performance (Godfaurd et al. 2004).

Up to now most of the efforts to make building construction more sustainable were merely focused on such aspects as design, materials used considering their ability to efficiently use natural resources such as sun or water (solar panel roofs or closed water management system), or their potentials for avoiding harmful or hazardous emissions. Hence, there is a need to look from a more global perspective, not only the design of a building and its materials have to meet criteria of sustainability, but also the phases of construction, use and deconstruction.

At present, the construction industry is still mostly characterized by open loop systems, which create waste from both use and deconstruction stages. Considering the limited dumping capacities, reduced land for landfill, growing urban population and scarcity of natural resources, it is obvious that closed loop material systems have to be considered as one of the solutions for the existing sustainability challenge (Guy and Kibert 2003, 186).

1.2.1 Closed loop approach

Currently, the closed loop approach in the construction industry is not well defined. Most of the literature focuses on the materials of the building in relation to the closed loop approach. According to Sassi (2008), the principle of closed loop material cycle (CLMC) construction is described as a construction to establish materials and building components that can be recovered from buildings and considerably made from recycled materials naturally or industrially. Furthermore, Anderson et al. (2000) explains that in the early 2000s there were three changes in building industries in Britain. First, the Building Research Establishment (BRE) developed the Environmental Profile System (EPS) for building materials. Later on they also provided a life cycle analysis of the building and at the later stage also incorporated recycled materials into their EPS. Second, design for deconstruction and third, the Landfill Tax was introduced to provide an incentive to reduce waste on site.

Selective deconstruction is an approach considered as closed loop. It is a technique and strategy that explicitly considers the deconstruction process of buildings where both contaminated material and different valuable materials classes can be separated from each other. This method is achieved by partial or complete dismantling of a building in its modules and parts, which can be reused, recovered or disposed (Schultmann and Sunke 2014).

Adaptive reuse, another type of closed loop approach that already presents in the literature, is a process that changes an ineffective item into a new item that can be then used for a different purpose. Sometimes nothing changes, except for the item's use (Australian government 2004). Unlike simple historic conservation, adaptive reuse transforms underused buildings and sites into locations that are economically useful (e.g. the renovation of abandoned warehouses into studio spaces and the use of abandoned parking lots for open-air markets such as farmers' markets).

Kibert (2000), mentioned the concept of a "zero" waste building, which would be in line with the other recycle and reuse closed loop approach mentioned. The concept of "zero" waste building on materials suggested that the construction industries were able to take a lesson from nature, by recycling the materials in a closed loop manner.

Analysis of multiple case studies by Chini and Saleh showed that, aside from their environmental advantages, designing for adaptive reuse and deconstruction add short term economic and possibly environmental costs to the project, but on a bigger scale of the lifecycle of the project, the long term benefits of utilizing those two concepts outweigh any extra initial costs (Chini and Saleh 2009).

Despite the significant advantages provided by selective deconstruction and adaptive reuse, closed loop systems with full materials recovery do not exist at present because of such reasons as lack of technology, poor product design, the lack of sufficient economic incentives, and little knowledge of thermodynamic processes (by considering laws of thermodynamics through a building life cycle, it becomes possible to minimize the losses of materials and energy to the environment. In this way, fewer resources need to be put into the building to keep the human environment inside the building in a desirable state) (Guy and Kibert 2003).

1.3 Purpose and Research Questions

The purpose of this research is to assess the closed loop approach in the construction industry moving towards a sustainable society. The motivation behind this research is to understand how the concept of closed loop can be used to foster strategic sustainable development in the construction industry. In this line, the research questions of this thesis are:

- How, and to what extent, can a closed loop approach to construction help to address sustainability challenges in urban areas?
- What are some key success factors for implementing a closed loop approach in the construction industry?

1.4 Scope and Limitations

Considering the fact that the closed loop approach is a relatively young concept it has a relatively limited scope compared to all the sustainability issues related to the future of urban areas and their planning.

Nonetheless, we were fascinating by the idea of exploring a new concept and its contributions in solving the sustainability issues acting on the construction industry and at the building level.

For this reason, the thesis is concentrated in the area of construction industries trying to use a closed loop approach in their practices. Organizations and companies actively promoting closed loop approaches across Europe were chosen, which enabled a better concept understanding, as well as having a common ground on the research.

The aim of the research is to understand the closed loop approach in the construction industry in order to address the sustainability challenge, as well as to figure out the key success factors for the implementation of the approach. Therefore practitioners and experts working with the closed loop approach were reach out.

The limitation of the topic chosen is clear considering the vastness of the urban planning at large scale. The concept explored only covers a little part of the sustainability challenge, but still can offer great potentialities where it works.

Limitations of the research are related to restriction of areas, organization and companies that are not yet widely practicing the closed loop approach. Moreover, despite the interesting outcomes that it can offer, the relationship between the building level and the spatial planning of the surroundings has not been considered due to limited time.

2 Methods

In this chapter, the design of the research and the methods used to answer the two research questions are described.

2.1 Overall Research Design

We decided to use a qualitative research design since it is appropriate in the exploration of relatively new topics, where lack of validated research or understanding from the researchers is common (Bryman and Bell 2011). It seems useful for our topic since the closed loop approach is a relatively new concept and it is still not widely understood or adopted by practitioners.

In order to shape the process of research, we decided firstly to focus on different case studies, representatives of the functioning of the various types of approach available in the construction industry that claim to be closed loop. The expected outcome of this case study analysis is to find out the practical reality of how the construction industry works applying a closed loop approach. The process of data collection – explained in the next section – evolves around the different case studies considered and around materials collected from expert in the field.

Based on the data collected, we wanted to find out contributions and gaps present in the closed loop approach solving the sustainability issues in urban areas, and the current barriers and enablers for its implementation. The best way to analyse the approach in detail without losing sight of the bigger perspective was through the use of the Framework for Strategic Sustainable Development. The five levels of the FSSD provided us the right space for an in depth analysis of the concept. The identification of the gaps in this way was useful for the further identification of the barriers that are currently hindering the implementation of the closed loop approach.

2.2 Data collection

In order to answer the research questions, it was decided to start by searching for information about how different closed loop approaches work in practice today. For this reason, the focus on different case studies was done. In total, five case studies were analysed, representative of the situation of the currently existing closed loop approaches.

Once the case studies were defined, the data collection was achieved by reviewing websites related to each specific case and reading project book sheets and summaries of the cases found online or provided by experts related to the case studies. Key research topics included ‘closed loop’, ‘building industry’, ‘cradle to cradle (C2C)’, ‘material loop’ and ‘sustainability in urban areas’.

Moreover, a significant part of data collection was made by interviews with specialists related to the different cases or experts in the field and willing to collaborate with the research. A detailed explanation about the interviews is provided in section 3.1.2.

In the following section, an overview of each case study is provided.

2.2.1 Case studies

2.2.1.1 CEFUR, Ronneby Sweden

CEFUR (Centre for Research and Development) is an organisation that works to promote sustainable development within business and society with focus on the Cradle-to-Cradle (C2C) concept. It is based in Ronneby, Sweden. CEFUR's vision is to support companies who want to move towards sustainable development with a focus on C2C (CEFUR 2015).

CEFUR's main focus areas are building construction and architecture. They use adaptive reuse in construction and material selection, which has added value from the environmental perspective. One of the projects that CEFUR is working on is the triangle-shaped Kilen area (figure 2), in Ronneby. The area was an industrial complex and has been recently vacated for new construction as sustainable buildings (CEFUR 2015). Furthermore, together with Ronneby Municipality, CEFUR is building a preschool in Listerby with emphasis on the construction elements and planned with C2C principles. It means that all the construction materials must be free of toxic substances, planning has to be efficient and reduce waste and materials use, as well as having LED lighting, solar panels and hydropower for the energy, warm water from heat recovery and outdoor environment that cares for the biodiversity.

Figure 2: Kilen area, CEFUR, Sweden (CEFUR 2015b)

2.2.1.2 Venlo City Hall, Netherlands

Venlo City Hall (figure 3) is a project applying the C2C concept on design at the building scale. The idea of this project is to translate the C2C inspired building into reality, how the process evolves and benefits society. The Venlo City Hall is designed with the idea to be pleasant for the community, as well as anticipating culture and future innovations (C2C ExpoLAB 2014).

The reason behind the implementation of C2C in Venlo City Hall was simply due to the reduction of the available area in the region of Venlo. Therefore the Municipality decided to find strategies that fit their structural growth. Hence C2C principles are seen as highly innovative and able to bring results in new design, as well as economic benefits to the region.

The dedication of the Municipality and other stakeholders in implementing C2C is considered as an essential instrument to accomplish sustainable development and to maintain the investment in the Venlo region (C2C-Centre 2015).

The project features material cycles, green façade, renewable energy, enhanced water and interior quality. The project has 13,500 m2 of floor area, with 2,000 m2 of office space and 2,026 m2 of green façade. By creating the use of material cycles, the project tends to diminish the loss of raw materials, plus it uses waste to create a new product with environmental value. In terms of the green façade and interior, the project aspires to improve air quality throughout the building without losing the aesthetic perspective. Regarding renewable energy and water quality, it uses solar panels and recycles the wastewater (C2C Center 2015).

Figure 3:Venlo City Hall, the Netherlands (Kraaijvanger 2015)

2.2.1.3 Chobham Manor, UK

Chobham Manor (figure 4) is the first of five neighbourhoods to be created in London's newest urban Park - Queen Elizabeth's Olympic Park. This whole area was revitalized and is a legacy from the London 2012 Summer Olympics. It is part of the Alliance for Sustainable Building Products (ASBP) that focuses on sustainable building products to ensure the transformation of the building is achieved. The vision is not only to provide the owner/tenant with a healthy building with low carbon emissions, but also to promote sustainable development between people, building and nature. Chobham Manor is also trying to encourage policy makers, industry and public to understand the benefit of sustainable building products (ASBP 2015).

Chobham Manor is based on selective deconstruction, one of the closed loop approaches. The project did the following: buildings existing in the area were closely examined in order find materials for reuse (once they were torn down). It is a practical alternative to the conventional design method and it is environmentally friendly. This is an area known to promote an environment that encourages more sustainable behaviour. The building was constructed on the contaminated and reclaimed ground. Also, a construction system with

special foundations is being used so that it can be easily removed at the end of its life span. (Suitebox 2015). Chobham Manor utilized the revolutionary on-ground foundation system of steel pad feet that reduces the cost of complex foundation and reduces the on-site build time significantly (ASBP 2015).

Queen Elizabeth Olympic Park's development is designed with sustainability in focus. It was designed to reduce the impact of new construction and aims at zero carbon buildings, responsible sourcing, the use of low environment impact materials, water efficiency in the building site, waste minimization by reuse and recycle and fostering the biodiversity (Queen Elizabeth Olympic Park 2015).

Figure 4: Chobham Manor, UK. (BSAGA 2015)

2.2.1.4 Agrodome, Netherlands

Agrodome is a non-profit organization, innovation and knowledge centre for bio based building. Agrodome's mission is to promote and facilitate the transition to bio based construction materials. (Capem 2015). Together with Wageningen University (WUR), Agrodome worked on a number of experimental houses built using as much of renewable building materials as possible, with a sustainable design. The project (figure 5) is focused on the use of renewable raw materials and the reduction of the use of primary resources. It is also focused on energy efficiency and on recycling or reuse of other building materials. Besides that, the project investigates various materials that are renewable and can be obtained in short time periods such as vegetable fibres, silica ash, lignin, protein etc., with potential application for construction (Agrodome 2015).

Figure 5: Agrodome, the Netherlands. (Agrodome 2015b)

The concept of sustainability in the Agrodome Project is also taking into account the flexibility of the space. The selected materials must perform to standard building regulations (mechanical, health and safety). Therefore, the selected products are sustainably produced, replaceable, reused or reusable raw materials. The choice of the materials in the building is basically based on price, availability and performance.

2.2.1.5 Upcycle House, Denmark

Upcycle house in Nyborg, Denmark is part of the mini CO2 houses project funded by Realdania Byg, a Danish property management foundation (Meinhold 2013). The mini CO2 houses project built six houses in the Nyborg area. They aim to demonstrate different aspects of CO2 emission reduction in the construction, use and maintenance phases of the houses. The overall mission is to improve the quality of life through the built environment and to promote innovation in the building sector (Kelis 2014).

The Upcycle House (figure 6) project focuses on carbon emission mitigation. The main consideration for carbon emission reduction is through the building materials. During the operation and maintenance phases, there are components of the building that must be replaced, which automatically adds to its total carbon emissions. Ultimately, when the house is demolished at the end of its life, the waste materials sum up into more carbon emissions, especially when disposed of as waste instead of being reused or recycled (Kelis 2014). Therefore the investigation on the use of recycled or upcycled materials makes a lot of sense, as their carbon emissions have already been accounted for.

The Upcycle house project claimed that they succeeded in reducing the CO2 emissions up to 86% compared to the conventional houses. The project conducted a Life Cycle Assessment (LCA) on all materials throughout the entire project. Due to limited financial resources, a special concern has been put on the houses' performance. Thus they were designed with orientation, temperature zones, daylight optimization, shading and natural ventilation in mind (Archdaily 2015).

On the other hand, the project tries to meet the needs of the buyers and the local real estate market trends. When a client considers buying a house, CO2 emission reduction is not the first priority. Instead, a house that is family friendly, easily adapts to change and trends, has appealing aesthetics, and is reasonably priced, is the most desirable one nowadays (Kleis 2014).

Figure 6: Upcycle House, Nyborg, Denmark (Archdaily 2015b).

2.2.2 Interviews

After the initial information research about the selected case studies, the next step was to determine which experts could contribute to our research.

It was agreed to interview two sets of people: the first one made of practitioners strictly related to the case studies (architects, municipality and project leaders), and the second one made of experts on the topic from the academic world. Potential interviewees were chosen based on their contribution to the case study considered or to the closed loop literature reviewed. All the potential interviewees were contacted via email asking for an interview and explaining the project aim and the potential duration of the interview. The list of questions was sent ahead in order to allow the interviewees to be prepared.

The design of the interview questions was varied for each set of interviewees: a general set of questions (Appendix B) was used for interviewing the experts and an adapted list for the people involved in each different case study (Appendix C - the questions were specifically referred to the case on which the interviewee was working on). Both sets were based on the desired outcomes and had a maximum of 10 questions, to make sure all key aspects were covered. An additional list of questions was used in case there was enough time left after the first 10 questions. A total of 6 interviews - with an open-ended structure - were conducted, both with practitioners (4) and with experts (2).

Two of the interviews were conducted in person (CEFUR and Agrodome), three via Skype (Chobham Manor, Upcycle House, expert Appleton) and one via email (expert Sassi). With the permission of the interviewees all the interviews - with the exception of Agrodome, for which the notes were taken only manually due to technical problems with the recording device - were recorded using an iPhone, in order to make the transcription process easier and more transparent.

2.2.3 Transcription

The interviews were recorded with the iPhone and transcribed listening to the records. After the transcription each member of the group checked the work in order to clarify unclear parts and verify the final validity of the transcripts.

2.3 FSSD Analysis

In order to assess whether the closed loop approach helps to address sustainability challenges in urban areas we were looking for a framework able to give us the opportunity to find out what was working well and what not in the approach, without losing sight of the bigger perspective. For this reason, we decided to analyse the collected data through the five levels of the Framework for Strategic Sustainable Development (FSSD). The use of the framework was aimed to the identification of contributions and gaps of the closed loop approach towards a sustainable future.

The FSSD is a conceptual framework focused on sustainability - at the level of the global socio-ecological system - aimed at helping to plan in complex systems. It provides a clear definition of sustainability based on eight different principles scientifically agreed upon, described in chapter 1.1. The framework is designed so as to support the sorting of information and the decision making process, always with the big picture in mind. This helps organizations, communities and society itself to improve their actions towards sustainable development (Broman et al. 2000).

The structure of the FSSD framework consist of five different levels, as could be seen in figure 2:

Figure 7: The five levels of the FSSD

1. The System Level. This first level clarifies the system being talked about, which is the sustainable society including the ecological systems upon which human society

depends. For this reason this level provides all the basic knowledge of the socio-ecological system, relevant to reach the final goal of global sustainability. Thus, it explains the basic functioning of the biosphere - based on natural cycles and laws of thermodynamics - and the characteristics of human society within the biosphere (Robèrt et al. 2010, 34).

2. The Success Level. It provides a clear definition of what success for the system is. Using the FSSD, success is defined as sustainability for the global socio-ecological system, and the eight principles described in chapter 1.1 define what sustainability is. It should be noticed that the principles were generated starting with the idea that in order to be sustainable, society must stop the unsustainable actions currently threatening the socio-ecological system (Robèrt et al. 2010, 38). This means that society must stop: extracting from the lithosphere and producing within the biosphere substances that systematically increase in concentration (SP1 and SP2), systematically and directly degrading the biosphere by physical means (SP3) and preventing people to meet their own needs (SP4 - SP8) (Robèrt et al. 2010, 39).
3. The Strategic Level. This level provides the strategic guidelines that should be followed in order to reach success. The framework introduces here the concept of backcasting from principles, as a "methodology for planning under uncertain circumstances" (Holmberg and Robèrt 2000). The idea of backcasting is to start from a future that is consistent with the eight principles that define sustainability, and generate ideas of actions oriented to reach that principles-based vision of sustainability from where you are today. Since many actions can be brainstormed this way, three prioritization questions are provided to aid in prioritizing the possible actions (Robèrt et al. 2010, 39):
    a. *Does this action proceed in the right direction with respect to the sustainability principles?*
       This question is aimed to make sure that actions are analysed regarding the eight sustainability principles, in order to see if they move in the right direction for all of them.
    b. *Does this action provide a stepping stone for future improvements?*
       The aim of this question is to verify that actions are sufficiently flexible, in order to allow for changes if needed, to avoid dead ends.
    c. *Is this action likely to produce a sufficient return on investment (financial, cultural, political and social) to further catalyse the process?*
       The question has the purpose to understand if the action is able to continue in time and not end due to lack of resources.
4. The Actions Level. It includes all the actions selected using the prioritization questions in order to move towards sustainability (Robèrt et al. 2010, 43).
5. The Tools Level. This last level includes all the tools and concepts able to help moving towards sustainability. Usually the different tools can be classified into i) strategic - if they provide an understanding about the relation between action and strategic guidelines; ii) systems - if they are used to monitor the on-going actions; and iii) capacity tools - if they help people understand more about sustainability (Robèrt et al. 2010, 44).

In order to conduct the FSSD analysis and identify contributions and gaps of the closed loop approach to sustainability, we asked ourselves different questions for each level:

- The System Level: how is the concept related to the sustainability challenge? Does the concept have a clear overview of the socio-ecological system?
- The Success Level: does the concept elaborate on a definition of success (sustainable society)? Does it cover all the SPs? Are there any blind spots, where the concept cannot help users to achieve success in relation to SPs?
- The Strategic Level: does the concept offer any guidelines for prioritizing strategic moves and integrate sustainability into it? Does the concept use a backcasting approach?
- The Actions Level: does the concept suggest actions in line with the strategic guidelines that will help move towards sustainability? Does the concept suggest any specific action for any context?
- The Tools Level: does the concept suggest any complementary tool to help practitioners to move towards sustainability?

2.4 Coding of Information

In order to answer the second research question the focus was made largely on the interviews and the supporting materials provided by the experts on the field. All the material were coded, clustered by meaning, and then divided into barriers and enablers. The process of data coding for the closed loop approach can be divided into four main stages, which are: creating emerging codes, identifying bling spots, clustering of information and definition of barriers and enablers. These steps are explained below.

2.4.1 Creating Emerging Codes

The first stage can be referred to as the creation of a list of "emergent codes". That was done by reviewing all the transcripts of the interviews, case studies, experts' opinions and supporting materials and identifying key ideas, concepts, requirements or actions that were considered significant for the closed loop concept.

2.4.2 Identifying Blind Spots

At the second stage the list of identified "emergent codes" was screened once again in order to identify some "blind spots" or gaps. That was done by creating a smaller list of "a priori" codes derived from the FSSD conceptual framework and research questions.

2.4.3 Clustering of Information

In this phase of data processing the whole list of codes was structured and divided into bigger clusters that combined the codes with similar meaning. Some of the clusters were further collapsed, combined or renamed. This process was done in order to group same concepts expressed with different words by different interviewees or contained in different documents. The following 11 categories were defined:

- flexible building design;
- material choice;
- legislation and regulation;
- social and cultural aspects;
- sustainability education;

- consider market trends;
- work with supply chain;
- set measurable goals;
- interaction with stakeholders and community;
- lack of funding;
- physical material bank.

In the clustering process no distinction was made between codes obtained through interviews with experts on the topic, people related to case studies, or through documents review.

2.4.4 Definition of Barriers and Enablers

At the final stage all the codes within their clusters were divided into two main categories of *barriers* and *enablers.*

A barrier was defined as something that is now present and that is obstructing the implementation of the closed loop approach in the construction industry. Enabler was defined as the opposite - i.e. a factor present right now that is helping and fostering the implementation of the approach.

Each code was assigned to a category of barrier or enabler depending on: 1. the context it was mentioned in; 2. In regard to the answer it provides to the second research question (can a code really be considered as a "*key success factor*" or just the opposite? Does it help moving in the right direction to be financially viable (strategic), in order to achieve social and ecological "success"?).

3 Results

The results obtained using the different methods explained in Chapter 3 are presented in the following sections.

3.1 FSSD Analysis

To help determine how, and to what extent, a closed loop approach to construction can help to address sustainability challenges in urban areas, a structured understanding of the closed loop approach was established and its gaps and contributions to address sustainability challenges in urban areas were explored. The relevant information is categorized into the five levels of the FSSD - system, success, strategic guidelines, actions and tools.

3.1.1 System

Today there is significant knowledge and experience relating to sustainability in the built environment industry. In certain cases building development has successfully addressed human requirements for quality of life, independence, health and community and leisure facilities, while also addressing energy use, water use and disposal, material use and protecting and enhancing the building site's biodiversity.

However, two main problems arise. To make a significant difference in overcoming the sustainability challenge, such comprehensively sustainable approaches have to be clearly defined and adopted on a large scale in mainstream construction industry. Moreover, not only the design of a building and materials itself have to meet criteria of sustainability, but also the phases of construction, use and deconstruction. This is not yet happening.

"The building industry is a very important enabler, and the reason why I say this is that we will always need buildings and we will always be stuck with the bad building. So if we make sure that all the buildings that we make are material safe… and that we can use in another way a building that we don't use anymore, it's an enabler in creating a new economy and a new society." (Appleton 2015).

Adopting a closed loop thinking enhances the awareness of the sustainability challenges and the comprehension of how the socio ecological system functions. However, there is not a unique and clear definition of the concept, but different approaches - selective deconstruction, adaptive reuse, C2C - trying to build on the closed loop thinking in different ways. The C2C approach seems the closest to a closed loop definition, but still it misses something: "*C2C is a design philosophy, where theory comes from. Setting the rules that all the building should be C2C designed is a very good starting point but if you don't find a business model behind… the difference between closed loop and C2C design. C2C has the ambition to be closed loop but it doesn't have to be. All those smart manufactures of C2C products don't take them back, where closed loop design means also that you promise what will happen after the first person has used it."* (Appleton 2015).

Besides this, the concept lacks a complete systems perspective since it often does not have a clear description of the social dimension related to sustainability. Moreover, up to now the construction industry is still mostly characterized by open loop material systems, generating

waste from both use and deconstruction stages and it has not yet adopted a unique and agreed definition of the concept of closed loop.

There is still a significant difference between the largely one-off built solutions - that can be regarded as good practice in terms of sustainable design and mainstream construction - despite the signs of a public that is beginning to become involved and is willing to generate more sustainable solutions.

3.1.2 Success

Regarding sustainability, the built environment could be said to have two main spheres of influence. One of them is related to the use and exploitation of natural resources (SP1 - SP3) while the second one is related to the social dimension (SP4 - SP8).

Firstly, building design impacts resource use for constructing and operating buildings, such as energy, water and materials (SP1 and SP3) and pollution including carbon dioxide emissions (SP2). Also the design of settlements influences how land is used and how much and how efficiently it is used. This in turn impacts on the availability and suitability of land for natural habitats and local biodiversity (SP3); energy consumption associated with travel (SP1); water availability (SP1); food availability; drainage and flood risks (SP3); and other environmental phenomena.

The closed loop approach, as the name suggests, emphasizes the need to move away from a traditional linear way of thinking in the construction industry, based on the take - make - waste model for resource use. Due to the lack of a unique agreed upon definition of the approach, no universal guidelines for success exist, except for certain suggestions in relation to materials. They should be kept in two different cycles: one is for biological nutrients and the other for technical ones, where biological nutrients are non-toxic and biodegradable substances (EMF 2013, 26) while technical ones are durable materials that can be reused or recycled/upcycled (Braungart and McDonough 2002).

The closed loop approach is primarily aimed to protect the environment by reducing the consumption of natural resources and closing the material flows, but this is not sufficient to achieve the complete socio-ecological sustainability, especially if it is limited to single building level and not extended through a comprehensive urban planning process. Moreover, the different types of closed loop approaches operate in different ways also regarding the materials, e.g. through selective deconstruction materials are kept in the loop being moved from one place to another and reused, while through adaptive reuse the building itself is not dismantled after the end of its primary function, but it is used for a different purpose.

The second sphere of influence is on the social structures, community cohesion and human health and well-being – physical, mental and emotional - which can be affected by both settlement and individual building designs (SP4 - SP8).

Besides being focused on environmental sustainability, the closed loop approach as it is conceived now does not provide concrete indications in terms of social sustainability, apart from improvements at materials and energy levels which can improve the well-being of people who live in and around the building considered.

3.1.3 Strategic Guidelines

Closed loop approach in construction is already present as a concept, moreover, there are best practices examples in the construction sector, including buildings and even areas made up in accordance with closed loop concept. In spite of this, there still is a significant gap between specific projects' implementation and mass public adoption of the concept. This is, to large extent, caused by the fact that changes in attitudes at a societal scale happen slowly. To this effect, education and interaction are becoming critical aspects in raising awareness and increasing understanding between people and gaining community consensus. "*Some people have been forced to have C2C education and learn this material bank, because their supervisors say that they have to do it, but they start [to] want it themselves and it starts to roll in.*" (Apelman 2015).

Apart from the social aspect and public adoption there are also barriers at legal and economic levels. Good practices without clear measurable achievements are not enough to gain consensus from politicians and they cannot provide a solid basis for formulating legislation.

In order to overcome the existing barriers, specific guidelines on implementation of the closed loop concept in the construction industry have to be developed. Such guidelines do not exist yet, which might lead to various challenges in the building construction process, when it comes to decision-making in specific situations.

3.1.4 Actions

The FSSD analysis revealed that the closed loop approach also does not indicate any concrete actions to be taken. It can be said, that, rather than defining actions to be put in practice, closed loop approach seems to be more focused on the materials aspect, related strategies and design flexibility.

Actions promoting public adoption of CL concept and thus its wider implementation have to be enforced rather than simply encouraged. However, both encouragement and enforcement actions are essential; they can work together and can be divided into the following dimensions:

- informing, guiding and raising awareness among designers, builders, clients, community and other stakeholder groups;
- identifying economic benefits for building owners and occupiers;
- forming the basis for legislation aimed at limiting the use of non-closed loop materials and fostering the projects built in accordance with CL concepts (Sassi 2009).

3.1.5 Tools

Due to the lack of a clear definition of success and no strategic guidelines for a successful implementation, the closed loop approach does not provide any tools to support its use.

3.2 Barriers and Enablers

In this section the barriers and enablers discovered through the interviews and the reviews of the supporting material are described. Since this research is focused on the key success

factors for the implementation of the closed loop approach, the barriers and enablers mentioned the most are explored in more detail, followed by a short description of additional barriers and enablers less mentioned.

3.2.1 Barriers

After analysing the interviews and case studies totally 141 barriers were identified. After grouping the barriers into bigger clusters, there were 10 main categories of barriers identified, presented in Figure 8:

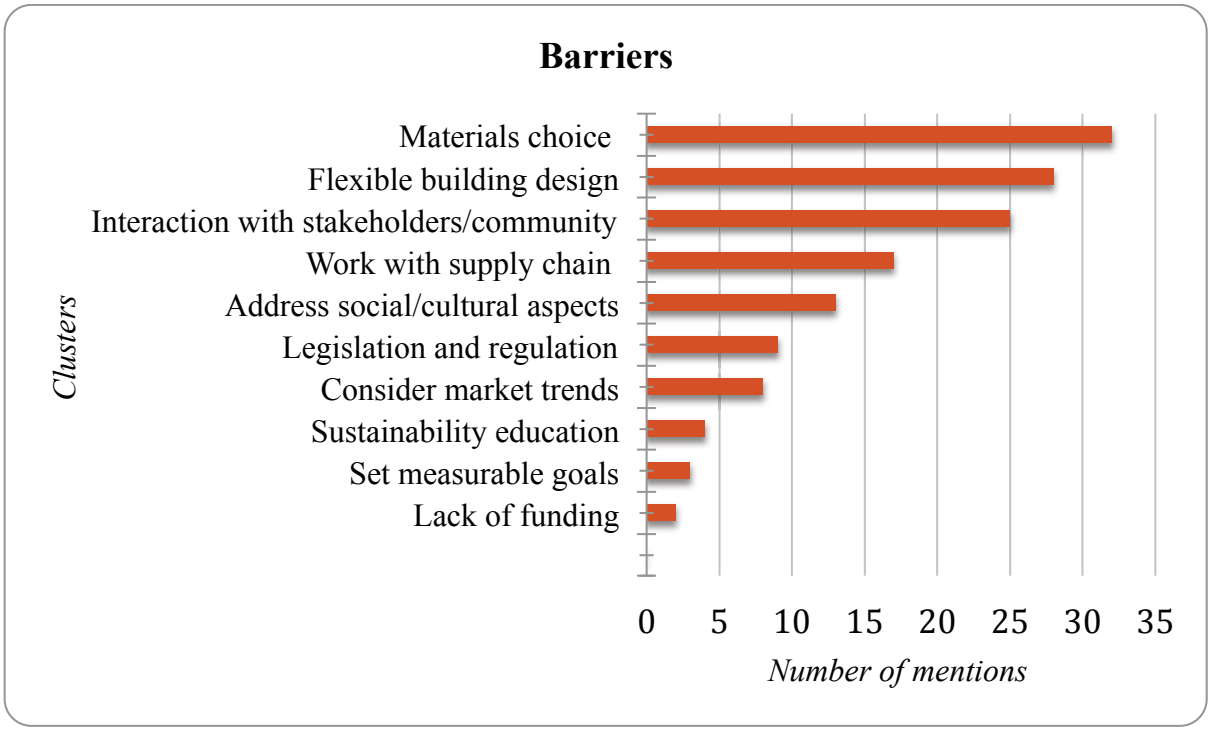

Figure 8: Barriers in the implementation of the closed loop approach

3.2.1.1 Key Barriers

Flexible building design

Flexible building design is an important condition for minimisation of buildings' environmental impact at the end of their life cycle, as it allows the designers to partly dismantle buildings for reuse in another function, thus minimising waste and providing the opportunity for materials reuse, while simultaneously saving time and cost for future construction. *"Flexible design is a big part of everything…, as buildings do change and they need changes. Some years we want a pre-school, then we need a school and then we need a retirement home and we want to be able to change its purpose without so much reconstruction"* (Apelman 2015).

"This is why it makes very good sense to investigate the use of recycled or upcycled building materials, as they have already 'paid off' their carbon emission price, or to introduce an adaptive and flexible building system, which enables alterations and changes in a house,

without destroying the construction and adding new materials in the process" (Sondermark 2015).

But, in spite of the evident benefits, flexible design is considered as a barrier at the current stage. The associated difficulties are caused by the fact that existing buildings have not been designed for dismantling, by the lack of tools for deconstruction as well as the possibility of building components' recertification, and regulations on economic and environmental benefits.

"In the building environment, at least in the Netherlands, most organizations don't know if they will still use the building in 10 years, they don't know it they will exist in 10 years. Now we need more flexible buildings, you have to be able to adjust the building, move it, reuse the materials… If we don't do it, at the end we will not have any materials. So that is the biggest advantage." (Appleton 2015).

Material choice

The choice of the "right" materials, those that are not harmful for the human health and the environment, can be easily separated from each other, as well as its contaminated parts is a critical aspect for a closed loop building. The value of the materials can be kept only in case the building is made in a special demountable way. Otherwise material value is lost for the future construction. The ways how to make building designers more conscious about the material choice is still have to be figured out in a large scale.

"*The materials that we have are the ones that we have to use for all the generations after us as well, but right now we are actually using it as if they are regenerative… Also if you use a material that is very valuable and very expensive, but you design the product in a way that you cannot use it after a certain time, then it has a very low value of use.*" (Appleton 2015).

Material choice process is also complicated by public negative perception, considering that reused materials can be sub-standard, that's why reasons for not using recycled materials are very often impaired by lack of clear information and guidance. Legislation also does not often work towards legally promoting materials re-certification, which results into lack of reused materials use in the mainstream construction.

"*It matters that you choose the right materials and it also matters that you try to find materials that have already been in use before…. But it is very hard to find recycled materials in Denmark, as if you use building materials without CE mark upon it – you have a hard time getting your warranties, making your contract... It is sad, because you lose what you can call "a common sense"…We have to learn to change the buildings in a way that saves as many materials as possible, so that we don't have to destroy a lot of things to make a change, even though it is based on fashion [aesthetic] desires.*" (Sondermark 2015).

Work with supply chain

Most of the businesses nowadays don't want to disrupt their supply chain, even if they understand all the advantages of the closed loop approach. Construction industry is not an exception from this, yet unsustainable, trend. As change of the relations within the supply chain, as well as product-service system, requires re-distribution of the roles within the chain,

most of the suppliers try to avoid additional responsibilities for taking back and utilization of the materials at the end of the building's life cycle.

"*If you redesign the chain, the supply chain, the function of actors will change. Maybe some of the people will get an extra function and there will be more decentralized logistic… If you design the system, the product design will follow. But you can't do this alone, you have to work with your suppliers and their suppliers and make agreements with them... about what will happen after the first loop and the second and etc...We need transformation within company and within the value chain…, but this is a challenge*." (Appleton 2015).

Interaction with stakeholders/community

In spite communication with the stakeholders is considered as one of the fundamental aspects in promotion of the closed loop approach, it is something in what most of the closed loop practitioners haven't succeed yet. "*We haven't really succeeded in working with community. People here in Ronneby know so very little about what we do. We have quite a lot of articles in newspapers...,but people still don't know anything about it. They don't connect it together"* (Apelman 2015).

Experts on the closed loop approach, as well as sustainability practitioners on the whole are interested in the aspects of "selective deconstruction", "material bank" and "reuse of materials". Nonetheless the majority of the general public still have very insufficient knowledge about the closed loop concept, as well as generally on sustainability. *"The concrete industry in the UK is a multi-billion pound sector. They don't want what we are doing [flexible buildings] and it is a big problem. That's the thing, it's a constant communication and re-education of the construction, it's really difficult."* (Baker 2015).

Addressing social/cultural aspects

Changes at the societal level always take time. The same is true for the concept of sustainability as a whole and for the closed loop approach in particular. *"We are doing this since 2010 and it's not long [it will take a long time] to change the mindset of whole organization with thousands of people employed" (Apelman 2015).* The same is true for the concepts of sustainability in general and closed loop in particular to gain general acceptance.

A new approach to building construction and the acceptance of more innovative technologies, such as adaptive reuse and selective deconstruction, into mainstream practice can happen only when these ideas have gained sufficient support and a good general level of awareness has been attained.

"We have already compromised that planet a lot, so we need to restore it. I think that is the same with cultural diversity. We need to let other people be different. Even if someone else finds something beautiful maybe I'll find it ugly! And we need all of that. It is the joy of life. The same with ideas to try not to have one solution that fits all because all situations are a little bit different." (Apelman 2015).

3.2.1.2 Additional Barriers

Legislation and regulation

"*Planning permission is always a problem and if you are doing what we are calling "flexible building" to get permission it takes you 6 months to sometimes a year.*" (Baker 2015).

The current legislation system is considered as a barrier due to the lack of legal incentives provided to building constructors using closed loop approaches (ex. reduction of the taxation base) and lack of barriers for those avoiding implementation of the closed loops.

"*But you could also imagine that you get some regulation from the state. If you, for instance, put into the building code some regulations that state some limits on the carbon footprint, then maybe you would force the building industry simply to get out and get some recycled stuff simply because that would be the only way that they could reduce their carbon footprint*." (Sondermark 2015).

Sustainability education

Education plays one of the central roles in this process of shift from "single best practices" towards "public adoption" of closed loop approach. "*Motivating people to change and adopt a more sustainable way of life has to be done by making sustainability understandable as a principle and comprehensible in respect of the associated dangers and the benefits it brings.*" (Apelman 2015).

One way the perception towards reused materials might be changed is to educate people as to the potential benefits of reusing materials – that they are often cheaper, whilst still being of high quality: "*The main challenge at the moment is trying to educate the construction industry that closed loop construction and reusable parts is an advantage for them.*" (Baker 2015).

Consider market trends

For wider promotion of the closed loop approach the business model behind it has to be considered. To make a concept adopted by significant market players, their commercial needs have to be addressed; otherwise return on investment becomes more difficult. "*Our basic philosophy is about the creation of flexible large buildings, but looking more into commercial applications, like restaurants and shops….They would have a need to have this particular building system that they can use….Many companies today don't think about things like sustainability or closed loops, because they have their primary commercial needs...And that is one of the few ways how we can get these things to start moving - to have commercial applications that need to be addressed…"*(Baker 2015). At the moment there's still observed lack of commercial reasons to be addressed by concepts such as closed loop.

Lack of interaction between the practitioners from the construction industry and business community results in lack of awareness on the concept, as well as misalignment of commercial reasons and closed loop building requirements. "*We also work a lot with the businesses by bringing awareness into the business world. And that is also a little bit special for a small place like this, because businesses don't even have a sustainability plan, as the bigger business usually have one*." (Apelman 2015).

Set measurable goals

By analysing interviews and business cases, it is evident that the setting of clear measurable goals is critical for achieving success in project realization. In each individual case specific goals have to be set. Nonetheless development of strategic guidelines on closed loop approach, which would analyse possible benefits and outcomes for different types of materials and strategies in clear KPI terms, would make the whole process more understandable for designers, developers and clients.

"*Goal-setting is at the heart of any C2C work... In order to identify a truly beneficial intention, goals have to be measurable. Goals can be set at different levels and applied to various topics.*" (Scheelhaase et al. 2012).

"*We have the sustainability program, every time that we make a project we make a very specific sustainability program with measurable goals in a way that we can look what we have actually done. And we are still trying to figure out what is a measurable goal actually! It is not so easy.*" (Apelman 2015).

Lack of funding

At the moment such closed loop strategies as design for deconstruction are considered to be more expensive in terms of capital cost. In many cases end building users find it hard to justify such a building's higher initial cost, particularly if they cannot see how they will benefit from a building that is designed to be demountable in the future. More ecologically minded clients may see that the future benefits of minimising waste and maximising the use of the reused materials within the building are worth the potential extra cost. "*Traditional projects would need more financing, depending on the cost of waste in future and the need to adapt the building, the extra costs could be offset in future*." (Sassi 2015). However, for clients to take this view they need to be aware of the issues and benefits involved.

3.2.2 Enablers

A total of 106 enablers were identified through the review of the interviews and the supporting material. They were classified into 11 categories according to common themes. These categories are presented in Figure 9, based on the number of codes that they contain.

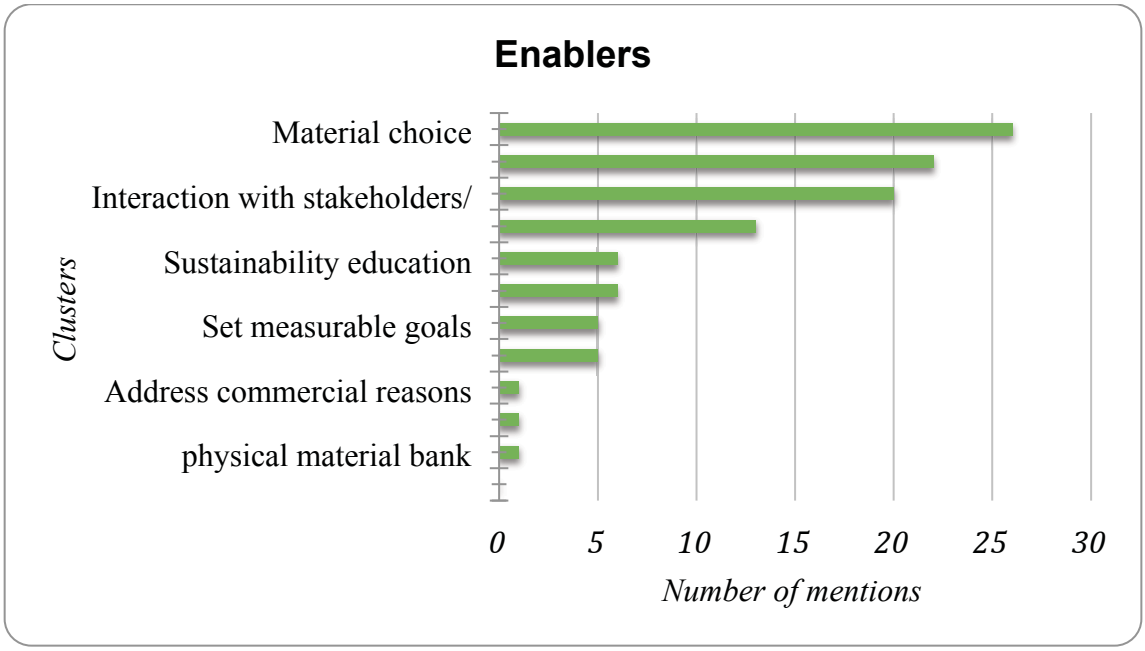

Figure 9: Enablers in the implementation of the closed loop approach

3.2.2.1 Key Enablers

Material choice

The choice of the right material can play the role of enabler in at least two different ways right now.

First, knowing the value of the materials used in the process can foster the change of the business model behind the implementation of the approach. *"We try to distinguish between all the different values. So you have material, component and product value. And every loop in which products are used, this value changes. ...in the current system in which we work producers always try to minimize the material use in order to make it cheaper, but in the end you ended up with bad product. You have to look at the material that made the product and the business model behind will change."* (Appleton 2015).

A second aspect of the material choice that can facilitate the implementation of the process is the use of materials or products that failed the original production purpose. An example can be the case of Upcycle House in Denmark, where windows from failed production were used in the project instead of producing new ones. Besides being positive from an environmental point of view - generating less CO2 emissions - this offers also the possibility of speeding up the process because of the use of something already present instead of relying on the production of something new (Sondermark 2015).

Flexible building design

Flexible building design is stated as the biggest current barrier for the implementation of a closed loop approach, but it is also one of the most promising enablers, and it starts working in this direction in some cases.

The flexible design is the basic requirement in order to make possible a design for deconstruction, reconstruction and reuse in different locations or situations, and the design of large and flexible buildings is the main design philosophy guiding the realization of the Chobham Manor in London, UK (Baker 2015).

This approach starts working nowadays and it seems promising especially for applications in the commercial sphere more than in the public one, because of the specific needs of increasing or reducing the commercial area following the market (Baker 2015).

Moreover, a successful example for the private sphere is the Upcycle House project in Denmark, focused on the idea of having an adaptive and flexible building system able to easily adapt to the changing needs of people living there, and besides, this bringing positive value to the environment through the reduction of the CO2 emission due to the use of upcycled materials (Sondermark 2015).

Interaction with stakeholders / community

Considering the desires of the stakeholders leads to a more collaborative and co-creative environment, as it is clear especially in the successful case of CEFUR, Ronneby. *"And then they were here in a workshop, all together at the same time and we encouraged them to talk to each other, learn from each other and then develop their own thing and then, instead of choosing one, we displayed all three of them for the public to come and see and have opinions around. Because we had all of these amazing ideas. ... for two weeks we had exhibitions here and we invited a lot of school children and NGOs and stuff and everyone could come. It was open both during daytime and evening time. And we had posters all on that walls where everyone can come and put something. It was a way to make a stakeholders analysis in a public setting."* (Apelman 2015). Also if the process is still before the implementation phase, the design and the visioning were successfully completed thanks to the opening of the stage also to other people than architects and designers. Thinking outside the box and considering all the different ideas seems to be a basic requirement in order to reach consensus starting from the initial phases of the process (Sondermark 2015).

Moreover, in order to get more and more people involved in the process of implementation of a closed loop approach, a good way is to show examples during the different steps of the process (Appleton 2015). This can be achieved doing smaller steps and showing results step by step, in order to make people understand the real value of what is happening. *"We need to create more examples. Turntoo tries to make small steps so people are not scared of making big changes, and every small steps you can show cases. You just show what works. And then you move more. ... But people need to see the results in between. You cannot do steps too big."* (Appleton 2015).

Work with supply chain

Working with the entire supply chain is something that can help speed up the implementation of the closed loop approach, thanks to the interaction with people involved at different levels. "*We want to work with the construction supply chain to integrate these opportunities into regular practice and build a more sustainable future.*" (Allwood and Tingley 2014).

Working to make it possible is the guiding philosophy of Turntoo, an enabler organization for closed loop systems, working specifically for customers in redesigning their propositions

and processes, mostly, but not uniquely in the building environment. Designing a closed loop means considering also what will happen after the first use, and there should be an agreement on that (Appleton 2015). *"If you really want to truly design a closed loop you have to take into account all the supply chain with all the different actors."* (Appleton 2015).

Sustainability education

Education on sustainability seems to be one of the most promising enablers for the application of the closed loop approach. As stated in the case of CEFUR, Ronneby, this is what they are currently doing to reach out to people who do not know about this, or who just do not give it the right value: *"We work on quite different things. We educate children in school, they have C2C and some kind of environmental education, extracurricular things and that is either more traditional sustainability approach or C2C thing, that they choose. And it is one way to reach part of the community that is not really interested"* (Apelman 2015). The education might include information on closed loop system, building materials, but also sustainability in general and sustainability challenge in order to first sensitize people and then give them the basic insight on the approach.

This education process, fostered from the beginning, is now starting to live by itself: *"more people actually also want education on the material bank – how does it work. … Some people have been forced to have C2C education and learn this material bank, because their superiors say that they have to do it, but it's more now they actually want it themselves and it starts to roll their in [it starts to happen]."* (Apelman 2015).

"*It is all about education*." (Baker 2015).

3.2.2.2 Additional Enablers

Legislation and regulation

In certain cases, municipalities have already moved the first steps towards the adoption of a closed loop approach at a wider level than just the building one. This is the case for example of Ronneby, where "*it goes a little bit other way round since the politicians already decided that all buildings have to be C2C. We have this general sustainability planning. … The politicians already have kind of decided it for all the buildings and we do not have to decide it for every building separately."* (Apelman 2015). And this is of course a positive enabler in order to make successful the implementation of each type of closed loop approach, since there is something stated by legislation that has to be followed, as in the case of the Upcycle House, where they *"try to stay within the existing regulations and codes"* (Sondermark 2015) in order not to have to require extra permission or similar.

"In the building industry legislative instruments are the most effective." (Sassi 2015).

Set measurable goals

Experts indicate the clear definition of the needs as something essential for a successful implementation of the process: "*they should try to specify what they want in terms of needs, instead of specify the characteristic of the buildings, materials, design… you have to let the designer do its work and you as user have just to specify what your wish and needs are. Now people try to specify technical details also if it is not their expertise. What Bremen did was to*

say: we have this number of people that need to work here, we have this piece of land, we want to use what is already here, we prefer to work with local suppliers, we have to stay here for 20 years, etc… that is the right thing to say! so then the designer can work." (Appleton 2015).

A successful example of the use of KPIs is the work done for the City Hall of Venlo, Netherlands, where a clear and agreed roadmap, stating the steps to be followed, worked as a plus for the implementation of the project: "*These concrete goals can be captured in a roadmap, which can be used as a tool for stimulating employees to get creative and search for ways to achieve these goals.*" (Scheelhaase et al. 2012).

Social and cultural aspects

Considering and valorising the social aspects and the social diversity is often considered one of the key focus areas for the implementation of a closed loop approach, based on the use of C2C principles, as it can bring in more values and more ideas for the implementation of the approach. *"We can build something that brings us more values. I think that's the same with cultural diversity. We need to let other people be different because we need all of that. It is more fun and more resilient. Even if someone else finds something beautiful maybe I'll find it ugly! Because we are different! And we need all of that. It is the joy of life."* (Apelman 2015).

Besides this, considering the social and cultural diversity and exploiting the full potential in it - changing the role of the different people in the process - can also foster the re-designing of society. *"By designing a better place for people to live and to work, you actually enable them to fit in better in the balance that we have between human and nature."* (Appleton 2015).

Consider market trends

Related to the action of regulations in order to foster the use of the approach, listening to the market can play a positive role, as stated by one expert interviewed. *"You see, people are quite easy to complain about reasons for not to do something. The 'government should do the first step'. But actually, legislation will follow the practice. So if we do what we do, they will follow with the market demand. Is very hard for the government to prescribe to work in a closed loop system. The point is to listen to the market in order to find where are the blocks and then after that go and change the law."* (Appleton 2015).

Funding

In some cases government funding has already started supporting the implementation of the closed loop approach in the building industry. An example could be the case of Chobham Manor, UK, where they have fostered the collaboration with universities and big construction companies: *"... we got government funding to develop this further, and what government funding allowed us to do was to work with Cambridge University, big building companies, ASBP, so we started working with them and to look at the sustainable issues, and the sustainability of what we are doing"* (Baker 2015).

Physical material bank

The presence of a physical material bank - as a physical place where safe materials can be stored and used if necessary, or as a building itself intended as material sources for the future

- is something that can help to a great extent the successful implementation of the closed loop approach, but it is not yet well known and accepted (Apelman 2015). The successful cases existing right now are related to C2C implementation (Scheelhaase et al. 2012).

4 Discussion

This section provides a discussion of the key findings as well as some recommendations related to the two research questions. Moreover, a reflection on the strengths and limitations of the research is provided, indicating also areas where future work could generate improvements.

4.1 Key Findings and Interpretation of Results

4.1.1 Contributions and Gaps of the Approach Regarding Sustainability

The research used an intersystem analysis in order to form the link between the closed loop approaches with sustainability challenge. Through the lens of FSSD, the system boundaries were portrayed and the success and the strategic guidelines are examined. The FSSD gave us a comprehensive framework to analyse closed loop approach in a systematic way to lead into a deeper understanding, and it was concrete and general enough.

In this research, the system boundaries are focused on how the construction industry relies on different approaches of the closed loop concept and how it can influence the related system. The contribution of the closed loop approach for sustainable development has been shown in practices. However, there are gaps along the application that are not leading towards full sustainability. The definition of closed loop is not widely recognized in the building industry as well as within society. The lack of understanding and knowledge on the closed loop approach might cause the user to apply it in ways that will end up leading to the degradation of sustainable living. Although the approach itself can sustain environmental welfare and economic performance, overall it does not address in full all sustainability issues.

As it was described in the previous chapter, the building industry has addressed some of the sustainability issues. However other problems remain. The comprehensive approach still needs to be defined and adopted on a bigger scale. It is context specific and it takes a little consideration for encompassing system such as society. By not yet having sufficient understanding on sustainable construction and on the closed loop approach - which is relatively new and not widely spread - practitioners are not provided with a systems perspective. This might lead them or society to not address the sustainability challenge properly. This can create a complication for both internal and external collaboration within the building industry.

On the success level, the closed loop approach was evaluated by using sustainability principles. There is no robust vision for success including definition of sustainability. The concept has no definition of success while covering all of the aspect involved within the system boundaries. Due to the lack of knowledge of the practitioners and the complexity of the closed loop approach, the success is not defined and there are misalignments with the sustainability principles such as the social principles (SP_4-SP_8). Nevertheless, in this case, there are no visible results yet since the approach is relatively new and its economic benefits in certain projects are not really perceived so far. Most of the case studies reported have achieved carbon footprint reduction through the use of sustainable materials. But there is no

clear evidence whether the closed loop approach is meant to only account for environmental benefits over the life cycle of the building, or if it also attempts to take into account sustainability's social aspects apart from improving the wellbeing of the inhabitants as well the community surrounding the building.

Additionally, the FSSD analysis emphasized the gaps that contribute to a lack of guidance in the implementation of the approach. The strategic level revealed the nonexistence of guidelines. Thus the existing barriers cannot be tackled in a strategic way - there is no support for stakeholders dealing with the barriers to properly handle the decision making process. Therefore, specific guidelines on the closed loop concept in the building industry have to be developed. In order to define a strategic framework for the implementation of the closed loop approach, the three prioritization questions explained in section (TOT) are used. Having a definition of success for the closed loop approach, this could be used to specify the right direction; however no unique and clear definition of the approach itself or of its success is present. Therefore, stepping-stone actions are required firstly to create a definition of success, which is in compliance with the sustainable principles. Moreover, strategic guidelines have also to be developed.

Required actions and tools are also missing. The closed loop approach is focused on the materials aspect of the construction, but not really on any clear strategy on what comes next. Based on the interviews during the research, deployed actions are mainly focused on how to close the loop on the material elements and how to reduce the costs. Apparently such actions are quite difficult to achieve since more knowledge is required among the stakeholders involved, as well as higher financial and time investments. Therefore it is important to actively promote the closed loop approach in order to achieve its wider implementation. Moreover, there are no unique and agreed upon tools to be used, whereas each approach has its unique and it has different primary focus. This leads to different perspective and experiences among practitioners.

For this reason, it is essential to integrate the FSSD in the closed loop approach. Clear definition and guidelines on the closed loop approach are required to help the construction industry move toward sustainability. The FSSD will assist the closed loop approach with guidance and strategic moves in an effective and efficient way. Thus this concept would benefit from a more relevant purpose, and would not be longer perceived as a confusing concept, making it easier for practitioners to engage and apply it in the construction industry. A framework for the implementation of the concept is needed.

The framework might include:

1. A general definition of closed loop approach that is easy, robust and concrete enough to be understandable for the construction industry and society as a whole.
2. A platform enabling the participation among stakeholders. An example can be an information center where all participants can share their experiences and resources through each phase of the approach. The information center would combine the multiple layers of business, practices and researchers into a compelling display. Another example could be to organize dynamic incentives and prizes related to closed loop approach practices in addressing the sustainability challenge. This platform would create the space for all the stakeholders to build the consensus across the organization involved.

3. A model providing insight into the practitioner's viewpoint and indications about the use of closed loop approach that helps to identify the gaps and opportunities. Examples can be the definition of a roadmap for planning or of a marketing strategy.
4. A step-by-step process of site selection (spatial planning) where the building has to be built. The process might include specific objectives and cost comparison in order to be aligned with sustainability principles and business perspectives.
5. A waste management module. It could be based on the waste management hierarchy provided by EU legislation (European Commission 2015) which requires the management of waste without harming environment and society and specify how to prepare for re-using the waste or dispose it.
6. An intervention in a public and private sectors in order to improve some aspect of the approaches and to provide the practitioners with monitoring implementation of the approach.

Moreover, in order to get this framework accepted, the government could be more active promoting it in the society and it could allocate a certain budget effectively in the construction industry. There should be a balance based on knowledge spread among the society, investment amount, and time to benefit.

The only concept that nowadays provides an overview with guidelines, actions and tools that are relevant to the closed loop approach is C2C. There is a structured framework on how to use the C2C and the upcycled approaches, material lists and certification, which are being used by practitioners. However, it is not widely spread among the construction industry. Moreover, the C2C concept, as it is defined, covers only a little part of the sustainability challenge, and moving on in time it seems that it is trying to enlarge its scope considering more and more aspects. Thus by keep focusing on new items, the risk that the concept might lack consideration of the older ones exist. Finally, it is necessary to mention that the C2C concept, besides providing guidelines and actions suggested, does not say anything about the materials use phase – e.g. materials that should not be used - in order to be compliant with the sustainability principles.

4.1.2 Barriers and Enablers for the implementation of the approach in the construction industry

The research of the key success factors for the implementation of the approach and the opponent barriers revealed a total of 141 barriers and 106 enablers, classified respectively in 10 and 11 categories.

However, looking at the categories level, the difference between barriers and enablers is less significant, because all the categories defined as barriers could also play the role of enablers under certain circumstances. This is shown in the figure 10. This outcome suggests that there are no single most critical barriers or enablers, but it's actually the different combination of them that favours or hampers the implementation of the closed loop approach.

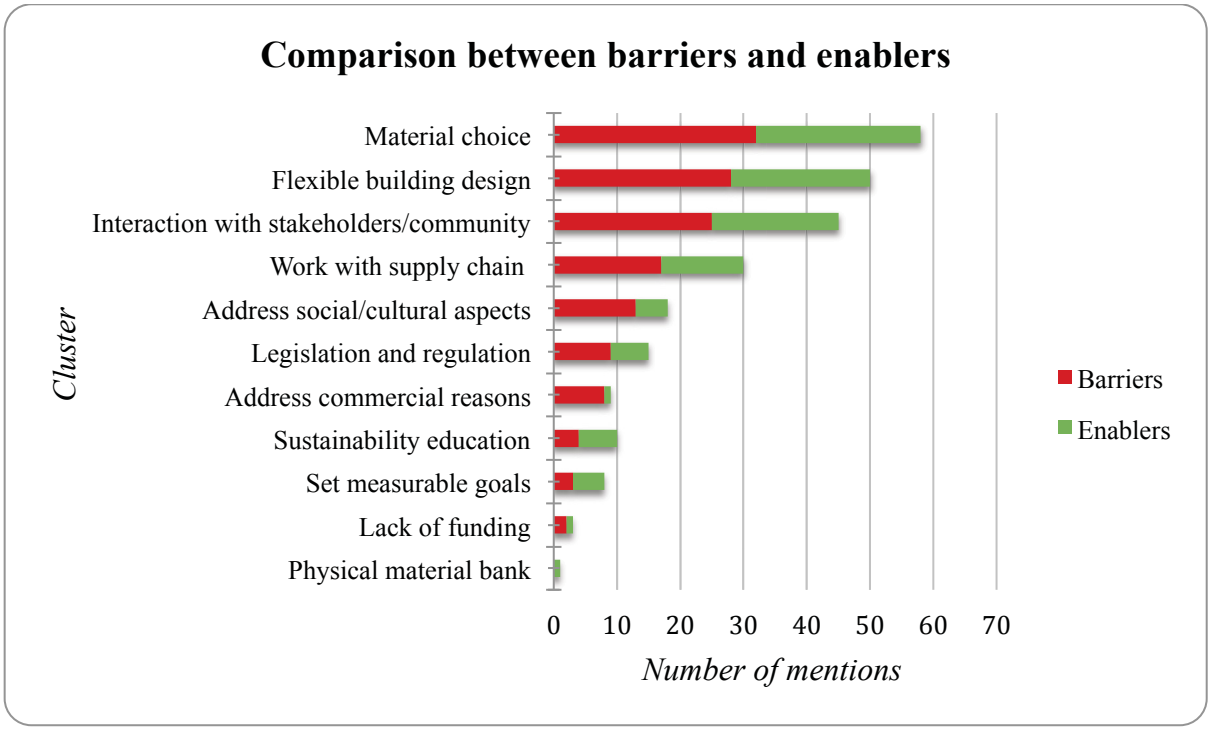

Figure 10: Comparison between barriers and enablers

Material choice

The choice of the right material is seen both as the biggest barrier and the biggest enabler for the implementation of the closed loop approach. The additional value of using recycled materials or eco-materials is clear. A growing trend is to use materials or production waste that failed the original purpose of production. Anyway, a problem that can turn this into a barrier is that people sometimes perceive materials that have been already used in a negative way, thinking that they cannot satisfy the modern standard requirements (Tingley 2012, 25). Most of the time, though, this fear is unfounded, because there are a lot of requirements that should be satisfied in order to use recycled materials, and this slows down the process (Sondermark 2015).

Regarding the use of renewable raw materials or eco materials, a successful example is the case of Agrodome, where some of the materials used are organic foam concrete, anhydrite, flax and fir. Thus, an increasing education on the use of recycled product or new types of eco-materials is needed in the construction industry, because their use is still perceived as something leading to a growing initial cost, despite the large benefits that they can actually provide at later stages. Using valuable materials can turn in being cheaper than using low cost materials if the long-term plan is to deconstruct the building and change it's function or shape. Using cheaper materials can lead to savings on short-term period, but when the long-term vision is to make possible a deconstruction and reuse, the economical savings coming from the use of valuable and durable materials is significant (Appleton 2015).

Moreover, all the indications provided are mostly related to materials that should be used, without mentioning the materials which use should be avoided in order to be compliant with the SPs.

Physical material bank

In relation to the choice of the right material, the presence of a physical materials bank can be considered an enabler because it is something that - if present - can concretely help the practitioners to select safe materials for their closed loop construction; and it can also be considered a reference place where materials from deconstruction can be placed waiting for another use. Therefore, a complete and spread knowledge about the concept of material bank is still not so common.

Flexible building design

Flexible building design, also known as design for deconstruction, 'is arguably the most important green design strategy for achieving material sustainability through closing the materials loop" (Kestner and Webster 2010). It also enables the future reuse and recycling of building elements (Sassi 2009). This, in combination with the potential energy savings, makes design for deconstruction a very important sustainability strategy for future buildings. Designing buildings so that they can easily be deconstructed makes the benefits more accessible and financially attractive. Facilitating deconstruction through building design reduces the time, and therefore the cost of deconstruction, and makes it possible to extract pure materials that can be reused or recycled or disposed of at cheaper disposal rates. (Kibert 2000). But despite its significant advantages and high potential for the building industry, for dismantling and reusing and recycling materials, design for deconstruction still remains mostly untapped. Thus at the current stage it is still considered as a barrier due to lack of application in the industry.

Another aspect lacking in this category is the relation between flexibility of the building design and the spatial planning. A backcasting approach from a sustainable future, with its land use that safe guard space for vital ecosystems, is needed and it should be put in relation with the construction of new buildings. Flexible buildings guarantee the possibility to be deconstructed, moved and reused in another location and with another purpose, however, the planning and construction phases should avoid risks for forthcoming urban sprawl and assure effective transportation, biodiversity maintenance, relation with community, etc. Therefore it is important to consider the relation between the effective construction of buildings and an accurate planning also of the surroundings.

Interaction with stakeholders and community

Interaction with stakeholders and community is another category that is almost balanced between barriers and enablers (25 vs. 20). More and more organizations and individuals in sustainable construction begin to understand that interaction with stakeholders and community is a great enabler in the promotion of sustainable building concepts and spreading the knowledge about sustainable materials. *"We involve the community around this area to get to know each other on what we are doing. We have expositions, discussion evenings. So far, they are quite interested on these projects. They came here and asking questions and some students from the university even doing the internship"* (Agrodome 2015).

It has been proven that the interaction and involvement of people in a way in which they can play for real an active role in the implementation of the process, is growing, and it leads to positive improvements in sustainable construction concepts, such as the closed loop approach. A multi-stakeholders cooperation before the starting of the process of construction

– or at least at the initial steps - can guarantee that all the interests are considered. Moreover, it can facilitate the compliance with the social sustainability principles, because people, being involved in the process, can express their needs and make sure that they are effectively satisfied.

The fact that the community interaction aspect is still mentioned mostly in a negative way is caused by the fact that most of the people, who are out of the "sustainability community" are mostly not interested and unaware of the existing sustainable concepts in construction. Thus they cannot estimate the advantages of recyclable materials and closed loop buildings in comparison with conventional materials and traditional buildings. Therefore their motivation for living in a "healthy house" turns out to be quite low too.

"*How we get the materials and convince people involved is the biggest challenge for us. It is not easy to tell to the people that are used with doing the same thing for years then we ask them to have new thing*." (Agrodome 2015). Moreover, in communicating the benefits of the closed loop approach and of the use of safe materials that allow a flexible design, no information related to the compliance with the social principles is provided. Hence, it is desirable to involve all the different stakeholders from the beginning of the process, in order to raise awareness in a spontaneous and practical way, giving them the space to interact and contribute to the process.

Address social and cultural aspects

One of the reasons explaining the lack of community interest towards sustainable construction lays deeper in societal and cultural aspects, because any change in the way society thinks and acts takes time. The same is true for the concepts of sustainability in general and closed loop in construction in particular - time is required for it to gain general acceptance. The acceptance of new ideas related to sustainability into mainstream practice can only occur once these ideas have gained sufficient support and a good general level of awareness has been attained. Furthermore, understanding the concept and the need for action to achieve sustainability involves some unpalatable facts that may be difficult to understand (Sassi 2009). Understanding the problems and accepting that action should be taken does not imply that action will be taken. The investment in taking actions has to be weighed against other priorities. When it comes to actively following one's interests, it appears sustainability is not a priority in many people's minds. Moreover, it should not be seen as negatively affecting the personal interests of individuals, as the less change is perceived as affecting what is currently valued, the more likely it is to be accepted (Tingley 2012).

People's unawareness combined with "societal resistance" towards new less familiar trends results in the fact that, for example, "peoples' perception towards materials that have already been used can be quite negative, taking a view that second-hand materials might be substandard"(Tingley 2012). The reasons for not using more recycled/reused materials are 'often exacerbated by prejudice and lack of clear information and clear guidance'. (Gorgolewski 2006, 490).

Sustainability education

One way in which this perception might be changed is to provide education on sustainability and sustainable construction trends. Even though education on the matter is still not widely

spread, in certain cases (e.g. CEFUR, Ronneby) it already plays a positive role in the creation of shared knowledge about problems and on the approaches to be used.

Motivating people to change and adopt a more sustainable way of life has to be done by making sustainability understandable as a principle and comprehensible in respect to the associated risks and the benefits it brings (Sassi 2009). Education plays one of the central roles in this process of shift from "single best practices" towards "public adoption" of the closed loop approach. Despite this, no information about the sustainability principles – neither ecological nor social – is generally provided.

Legislation and regulation

Legislation is one of the essential elements required to engender action, particularly when action is required within a limited time frame (Sassi 2009). In spite of this fact, it remains one of the major barriers to deconstruction/designing for deconstruction, as it still provides very few legal incentives (ex. reduction of the taxation base) for builders and designers applying the closed loop approach. There is also a lack of barriers for those insisting on unsustainable practices in construction. The use of an assessment system would enable the identification of building materials and systems that are non-closed loop, to form the basis for developing take-back schemes or tax disincentives to reduce their use and avoid the environmental impacts associated with them (Sassi 2009). But that is not happening yet.

Consider market trends

In relation to the legislation, considering the market trends is one of the emerging enablers that hopefully will gain strength in the future, but as now it is still far from that. Listening to the market can potentially play a positive role because it can allow finding the bottlenecks to the implementation of the approach, especially regarding areas where legislation is not effective yet. From another point of view, the use of a closed loop approach in commercial buildings enables its flexible use, especially given the need for enlarging or reducing the space in relation to the present commercial activity. However, right now it's still difficult to find commercial activities willing to change the structure of their working space using an innovative approach as the closed loop one, probably due to the strong relationship with their suppliers, and to the difficulty in changing their habits. That's why it is mostly considered as a barrier at the moment.

Work with supply chain

Connected with the difficulties encountered in changing habits of people, working with supply chain is still mostly considered as a limitation to the use of the approach. This is because in the construction industry usually the relationship that a builder establishes with all its suppliers is strong and long lasting; therefore, making new agreements and changing the role people play in the chain is a challenge. Even when the benefits of the approach are recognized, still people resist in adopting it. Considering the design for deconstruction for example, in many countries where deconstruction is being considered as an alternative to demolition, there is a lack of a supply and demand chain for reused materials (Guy & Shell, 2006). Development of such a system or the growth of second-hand materials shops would enable deconstruction to become a more appealing option for contractors (Odom 2003). However, the process is long and still challenging.

Set measurable goals

The setting of measurable goals and the creation of KPIs has proven to be a concrete way to stimulate people and foster the action overcoming obstacles, such as the slow changes related to the supply chain (Allwood and Tingley 2014). It is clear, for example, considering the successful case of the city hall in Venlo, that set quantifiable and concrete goals increases the clarity of the final aim of the project and leads to a more concrete and systematic way of operating. However, there are still deficiencies in some cases. For example, the building designers sometimes still lack a system of quantifiable targets for designing buildings that would result in minimal waste. The lack of quantifiable measures and targets makes it difficult to assess the success of a comprehensive waste minimisation strategy, which takes into account the end of life of a building, and to encourage improvements (Sassi 2009).

Lack of funding

The approach being quite new and not clearly defined, an initial financial investment that might be a little bit more than what is required for a normal project, is something that still is required for a successful implementation (Appleton 2015). This is because the investment is going into the definition of a new process, and not into the creation of a new product. However, the payback time is not so long (if the business case proves successful) due to the savings in the oncoming phases of the process. Anyway, this is not always seen as the best way to proceed, and more attention and funding are given to different problems perceived as more urgent. In fact, as stated in Sassi (2009, 43) the area of design for deconstruction, recycling, reuse and closed loop material cycle construction is suffering from a lack of attention, at least partially due to the increasing alarm related to global warming that effectively attracts attention and funding for other research areas (Sassi 2009, 43).

4.2 Recommendations

Considering the different categories explained in section 4.1, we created a list of recommendations in order to help practitioners overcoming the existing barriers and applying successfully the closed loop approach. These recommendations are discussed in the following. They are created using our knowledge on the topic and considering the different considerations made by the interviewees or found in the literature. Anyway, they are not tested nor approved by experts. Follow that, one of the next steps would be to discuss their viability and change them accordingly with experts suggestions.

Addressing the barriers related to materials choice and flexible building design

As it has already been mentioned several times throughout this work, the closed loop concept lacks specific definition and criteria, which can make it less applicable for practitioners. It also leads to the fact that the closed loop approach is very often mixed up with such concepts as “C2C” or “circular economy”.

In order to make the closed loop approach more understandable and more easily applicable, the criteria for closed loop buildings could be developed into guidelines and made available for building designers and builders. The guidelines might include a definition of the closed loop concept, description of the related strategies, building materials and recovery methods, defined by the Sustainability Principles.

The materials bank concept can help to quantify the amount of closed loop cycle materials included in a building versus non-closed loop cycle materials destined for landfill. This information could be used to assess the waste liability associated with specific building designs, including materials waste and disposal costs over the building life and at its disposal phase. In their simplest form the criteria could be employed as a design or building checklist. The application of the criteria could be facilitated by assessing typical construction systems using the closed loop building criteria and making the assessment results available to building professionals. This would enable them to make informed choices about which materials and building systems to use. The assessment system could also be used by clients in order to assess building design, suggest changes or make an informed choice (Sassi 2009).

Development and implementation of the guidelines should be a collaborative work of construction practitioners and experts on the closed loop concept. Construction associations and unions can become a working ground for the regular meetings of the professionals from the construction industry. Government representatives have to be included in the working groups as well for further promotion of the developed guidelines and to make them into regulations to be followed by the whole industry.

Besides the creation of these guidelines, another important aspect that should be considered in order to overcome the existing problems related to the building flexibility, is the lack of consideration of the relationship between the effective building construction and the land planning of the areas. Besides being flexible, buildings should also be properly located in their area and surrounding, in a way that does not jeopardize the biodiversity and the community. The needs of people should be considered and biodiversity should not be damaged – or even better if improved – by the presence of the construction. This is possible due to a correct integration of the land planning and buildings construction/re-construction.

Addressing the barriers related to social / cultural aspects, sustainable education and interaction with stakeholders

Education on closed loop and active popularization of the concept is the main and most effective way of influencing public perception and attitude, which can finally result in wider adoption of the concept. It should be considered as a baseline element in raising the public awareness and encouragement for builders to design differently. If and when the benefits of closed loops are outlined and demonstrated clearly, by using various means of communication for different target audiences, then evident reasons for the adoption of the approach will flourish. Moreover, the benefits should be measurable whether financially or in terms of social and environmental advantages.

By fostering communication and interaction among people, a wider range of various stakeholders can be introduced and involved in the closed loop building concept. Finding the right way of communication for different audiences, or, “speaking their language” is an essential consideration. Series of professional case studies on closed loop construction can become a good communication instrument for designers and architects. Public exhibitions of the buildings constructed in accordance to the closed loop concept, with emphasis on social aspects and improvement of life quality conditions can become a good tool for working with the general public. NGOs and Municipalities can be also considered as a ground for regular meetings of working groups, which would bring together politicians, private construction businesses, regulators and environmental organizations’ representatives. Similarly, local

Municipalities can provide space in their buildings for exhibitions, where construction companies and bureaus can demonstrate their projects to both the public and professionals.

The creation of working groups to foster the multi-stakeholders collaboration is a powerful idea to make sure that all the needs of the stakeholders involved are considered, in respect to the social sustainability principles.

Addressing barriers related to work with supply chain

Changing of the roles within the product service system, which is mentioned by most of the experts as one of the biggest current challenge for the closed loop construction, can become one of the main enablers for wider adoption of the concept.

Responsibility for taking back the materials and their inventory at the end of the building's life cycle, selling them, storing for future use, recycling or, as a last, disposal, should be transferred to the manufacturer. By doing so, "it will be no longer in a manufacturer's interest to make inseparable elements of different waste classifications, when they are responsible for taking the products back and paying for their disposal. It is now in their interest to consider how the products are dealt with at the end of their useful life." (Tingley 2012, 27).

Development of chains of second-hand materials shops can become another solution, which can foster change of the relations within the supply-demand chain. In this way, contractors will be able to approach building deconstruction and taking responsibility for materials not as a challenge, but as an additional source of profit.

As manufacturers often consider taking back their products/materials as an additional challenge/cost and, thus, unwilling to take responsibility for it, the change of the roles within the product service system should be fostered by the legislation.

Addressing barriers related to legislation and lack of governmental funding

Criteria, formulated in the guidelines for closed loop buildings and closed loop cycle materials can be used to formulate legally binding standards. The use of the assessment system would also enable the identification of non-closed loop cycle building materials and systems and form the basis for developing take-back schemes or tax disincentives to reduce their use and/or environmental impacts associated with their use. This in combination with the continuously rising Landfill Tax could encourage more waste conscious designs (Sassi 2009).

Addressing barriers related to market trends

Closed loop building projects are likely to have a higher initial cost both in terms of design time and therefore cost and construction price (Appleton 2015). However, for example, deconstruction can be a viable removal technique that is not necessarily more expensive. Whilst it is normally a more time consuming process, and will therefore incur higher labour costs, the salvaged materials can be sold which generally offsets the higher labour costs; reusing and recycling materials rather than taking them to landfill will also result in savings by minimising landfill costs, which can be very high in some areas (Tingley 2012). To maximise the economic advantage of building using closed loops, a cost function related to the assessment system could be developed. Even though the economic context of the building

industry is not static, a cost function that identifies the closed loop cycle materials and elements that can be easily and cost-effectively integrated into buildings would encourage a wider adoption of such principles in practice (Sassi 2009).

By developing guidelines, which would clearly show the connection of the closed loop approach in construction with economic benefits from using the approach can become another good incentive. Analyses of different case studies can be included in order to demonstrate financial investments and returns at each stage of the building's life. That can be included for discussion with the professionals already working in groups discussing flexible building design and materials choice aspects.

Some of the recommendations should be encouraged, while others work as enforcement tools for the wider adoption of the concept of closed loops in construction. What is evident is that by using one or several recommended actions separately it is hardly possible to achieve any significant improvements for sustainable construction as a whole and for the closed loop approach in particular. Real shifts towards wider adoption of the concept at all societal levels becomes possible only when all of the recommendations start working together and building upon each other.

4.3 Strengths and Limitations of this Work

The closed loop approach is a relatively new concept in the construction industry, which is not yet globally perceived in the industry. While providing an opportunity for addressing sustainability challenge in the construction industry from a new perspective, the lack of research on the topic can create confusion about how the different practitioner perceive the approach, biasing the result.

Lack of a clear definition of closed loops in the construction, as well as missing concept guidelines and associated actions and tools, were revealed by applying FSSD. Analysis of different case studies also contributed to understanding of the common trends among the different players of the construction industry. However, in order to increase validity of the results, a larger number of interviews would be helpful, which was challenging due to the time constraints. Moreover, the data collection was held using a qualitative method that involved semi structured interviews, which required an in-depth, time-consuming analysis.

The scope of this research was mainly in Western European countries, where experts researching on closed loop approach use were interviewed. Various backgrounds and areas of work, as well as different geographical locations of the interviewees are considered as strength of the work, as it helped to identify both common gaps and positive shifts in various areas of the construction industry. Interviewing practitioners and experts enriched this work with a combination of practical and theoretical data. This provided valuable insights that allowed analysing the approach from different perspectives. At the same time information based on personal opinion might pose the risk of misinterpretation of the closed loop approach as a whole.

4.4 Future work

This research was mostly related to analysis of the different types of closed loop approaches existing as now. The analysis was started with the idea to examine two different types of the

approach, but during the research process there were found more approaches for comparison. For this purpose the case studies representing different approaches were analysed. For future research, it would be valuable to take a more wide perspective and – through the review of more case studies - analyse how the implementation process of each approach differs in different parts of the world. In this way it will be possible to have a clear overview on how each different approach contributes to solving the sustainability challenge and to see if barriers and enablers are different depending on where the approach is implemented.

Furthermore, having discovered the importance of collaboration between multiple suppliers in the supply chain, it will be useful to conduct deeper analysis on which parts of the chain are the most proactive or reticent in the adoption of the approach.

Further research can be based on the recommendations how to address and overcome existing barriers. The main efforts should be aimed at creation of the guidelines for the construction professionals and include recommendations for the closed loop cycle materials, advantages of flexible building design and highlighting economic incentives of the concept. Moreover, efforts could be undertaken to further elaborate on the education of the construction industry and on the integration of the social perspective in the closed loop approach. Emphasis can be put on examining consumer behaviour and preferences, as well as, needs of stakeholders in order to get the better way to involve them since the first stages of the process of implementation of the approach.

5 Conclusions

The purpose of this work was to analyse the contribution of the closed loop approach in the construction industry to address sustainability challenge into the future of urban areas and to highlight the key factors supporting or hindering the successful implementation of this approach.

The research has shown that adopting a closed loop thinking in the construction industry can actually foster the movement towards sustainability, enhancing the awareness of the sustainability challenges and being an enabler in creating a new economy and a new society. However, there is still not a unique and clear definition of what the closed loop approach is.

Moreover, by conducting an analysis through the five levels of the Framework for Strategic Sustainable Development (FSSD), it was found out that the closed loop concept exhibits several gaps in relation to the definition of global sustainability, especially in regard to the social aspects, that are not clearly addressed in any way. Without a clear definition of the closed loop approach, it is difficult to have a shared understanding for both practitioners and experts and general public. It is therefore impossible to have an agreed upon and guided definition neither on success in relation to the socio-ecological sustainability, nor on strategic guidelines. For these reasons, the use of closed loop approach as it is cannot lead to full sustainability in the socio-ecological system.

Regarding the research of the key success factors for the implementation of the approach, the identified barriers exceed the number of enablers. Nonetheless, almost all the barriers can be turned into enablers, which suggests that there is no single most important barrier or enabler, but it is the combination of both that influences the implementation of the approach. Recommendations for overcoming the existing barriers and supporting the construction industry in the implementation of the approach were offered within this work.

There is an urgent need for a clear and agreed framework for the closed loop approach that makes clear to practitioners and users the advantages in its application for the future development of urban areas. The creation of strategic guidelines for a successful and more standardized implementation of the closed loop approach, as the next step, will offer guidance on how to strengthen the potentialities and overcome the existing challenges.

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Appendices

A. List of experts interviewed

Company	Country	Industry	Name	Position
Agrodome	Netherlands	The Green Deal biobased building	Sissy Verspeek	Member of Agrodome foundation
Agrodome	Netherlnds	The Green Deal biobased building	Fred van der Burgh	Board member of Agrodome foundation
CEFUR	Sweden	Centre for Research and Development	Lisa Apelman	Project Manager
Chobham Manor	United Kingdom	Residential development	Jon Baker	Marketing manager
Real Dania		Member-based philanthropic organization that supports projects in the built environment	Jørgen Søndermark	Project Leader
Turntoo	Netherlands	Circular economy solutions and services	Debbie Appleton	Project manager
Individual expert	United kingdom	Expert on closed loop approach	Paola Sassi	Program Leader and Senior Lecturer at Oxford University

B. Questions for experts on closed loop approach

1. In your opinion, what is building's contribution to sustainability challenge in urban areas?
2. What is your understanding and feeling about closed loop approach in the construction industry? Will it gain more appreciation in the future?
3. What are the main incentives/advantages in using this building approach? What is the added value?
4. What are some of the key challenges with the implementation of such projects?
5. What, from your point of view, are the requirements/ recommendations that could help accelerate the implementation of such projects?
6. Do these types of projects usually require additional permissions/ approvals from authorities?
7. What's the community attitude towards these projects? How is it perceived? What are the most and least appreciated aspects?
8. What role do such projects play in the social, environmental and economic development of urban areas?
9. Do these type of projects require additional financing? If yes, do these additional spendings defray expenses at a later stage?

C. Questionnaire sample for people related to case studies

1. What is the design philosophy behind this project?
2. In your opinion, which role do buildings play in sustainability challenges?
3. What are your understanding and feeling about of closed loop approach in the construction industry? In which way do you think this project can be seen as a closed loop?
4. What are the main incentives/advantages in using this building approach? What is the added value?
5. What are some of the key challenges you coped with when dealing with the implementation of the project?
6. What, from your point of view, are the requirements/ recommendations that could help accelerate the implementation of this projects?
7. Does this type of projects require additional permissions / approvals from other authorities?
8. What's the community attitude towards this project? How is the project perceived, in your opinion? What are the most and least appreciated aspects?
9. What role do this projects play in the social, environmental and economic development of a municipality?
10. Do this project require additional financing? If yes, do these additional spendings defray expenses at a later stage?

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