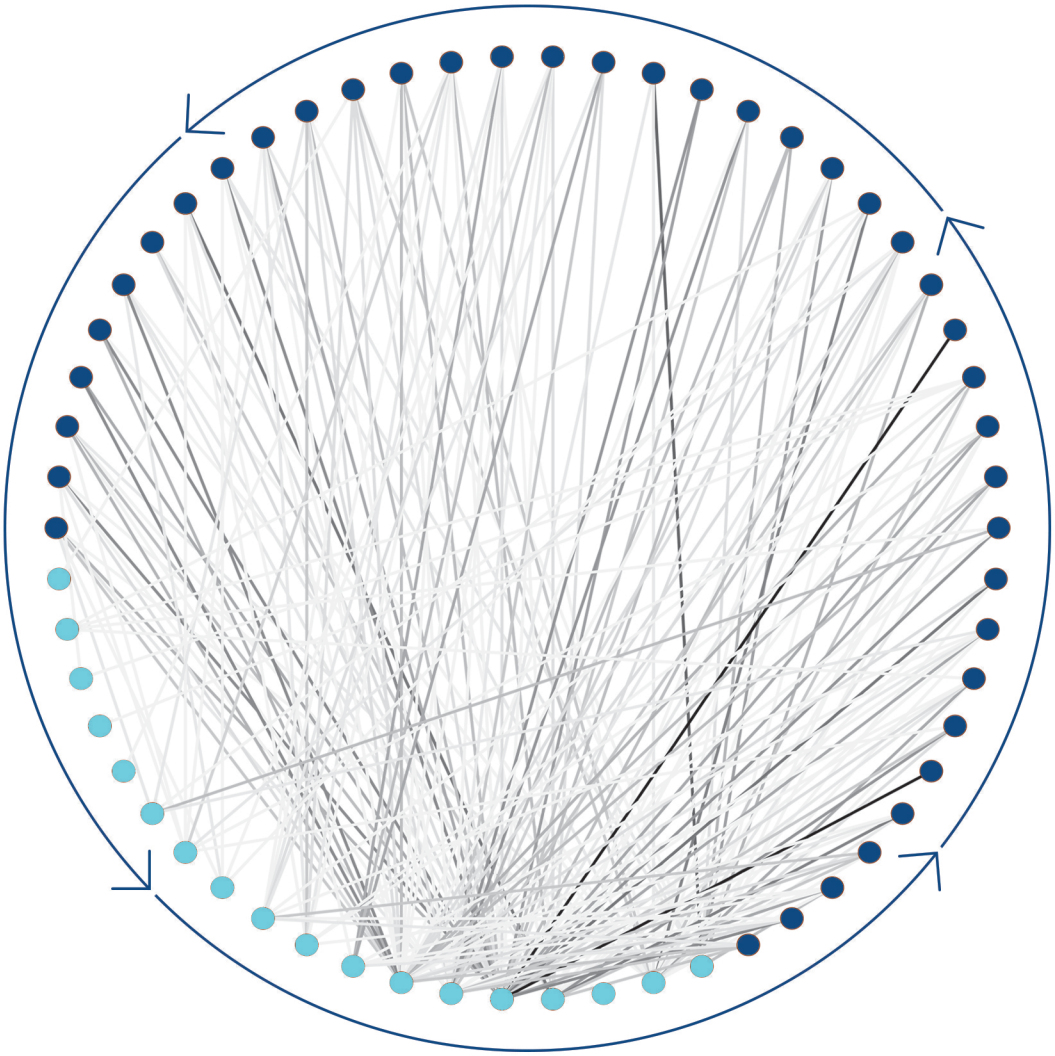
Change towards the Circular Economy: eliminating inertia in supply chains

A concrete case of stony materials supply chain in The Netherlands



Uroš Bukvić

Master Thesis

11.06.2018

TU Delft

BRBS Recycling
Brancheverenging
Breken en Sorteren

- Intentionally left blank -

Change towards a Circular Economy: Eliminating inertia in supply chains

A concrete case of stony materials supply chain in the Netherlands

Author

Name: Uroš Bukvić

Student number: 4625838

E-mail: *uros89@gmail.com*

Graduation Thesis

University: Delft University of Technology

Faculty: Civil Engineering and Geosciences (CiTG)

Master track: Construction Management and Engineering (CME)

Course(s): CME 2001 Master Thesis Preparation and CME 2000 Master Thesis

Committee

Chair: Prof.dr.ir M.J.C.M (Marcel) Hertogh
Civil Engineering and Geosciences
Materials, Mechanics & Design (3Md)
Integral Design and Management

Supervisor: Dr. D.F.J (Daan) Schraven
Civil Engineering and Geosciences
Materials, Mechanics & Design (3Md)
Integral Design and Management

Supervisor: Dr. F. (Francesco) Di Maio
Civil Engineering and Geosciences
Engineering structures
Resources & Recycling

External supervisor: P. (Peter) Broere
BRBS

Front page design: Ivan (batica) Avdić

- Intentionally left blank -

Preface

Thesis, as the grand finale of attaining a Master of Science degree, is in itself a major challenge from personal, scientific and organizational viewpoints. Therefore, it is crucial to focus it around a topic that intrinsically motivates you. I was lucky enough to achieve just that.

My first contact with the notion of circular economy was when I saw a poster in the faculty corridor, which, in a broad sense, called for research of circularity in the construction sector. I immediately got intrinsically interested in the idea and its promise of a prosperous and sustainable future. The poster led me to Daan, and that represents the beginning of the one-year long journey, which is coming to an end with me writing this preface.

And what a journey that was! Circular economy is a novel way of thinking, without much supportive research or literature, nor a precise formulation. In the case of my research, this translated to a (very) long period of figuring out just what it is and narrowing down the scope of research to follow. This was a particularly challenging period for me, but, thankfully, I had Daan and Peter to guide me through it and help me set up the initial research approach. Considering the ambiguity of the notion of circular economy, this approach changed twice fundamentally. First time it occurred because of the failed ratification of the Concrete Agreement (Betonakkoord) just before the kick-off of my research, which lead to observation of, and focusing on, inertia. The second time it was after the results from the first part of research made it clear that a different approach is needed in the second part than it was planned. Both of these implied complete overhaul of the research process. However, with the whole thesis committee behind me, the changes were implemented that turned these setbacks into opportunities and lead to the research that is before you. The research that I am particularly proud of.

Summing it up, after a year of dedication, 18 interviews across the Netherlands, more than a 1000 kilometers of driving and numerous challenges and uncertainties, the whole process of compiling this thesis proved to be a unique learning experience for me. From a professional and scientific side, I became an expert in a novel and emerging field of circular economy and mastered techniques and methods of conducting a scientific research. In addition, from a personal side I have learned to cope with long-lasting uncertainties and to persevere. Furthermore, I have perfected my soft and organizational skills.

I would like to thank Peter and BRBS for providing me with an inexhaustible source of information, advices and support from the very conception of this thesis. Simply put, without them this thesis would not have come to existence. I can only hope that I managed to live up to their expectations and that the thesis will prove to be useful for them.

Another irreplaceable screw in the machinery that coughed up this thesis is my committee. They were there during the whole process, making sure that the best way is chosen on every junction on the road leading to this moment. Supportive, understanding, positive, patient and selflessly providing guidance in times of my doubts and ever insightful, willing and critical in general. Therefore, thank you Marcel, Daan and Francesco for bearing with me on this amazing journey. I hope that I have returned at least a bit of what you have given to me.

Dear reader, you are now embarking on a (troublesome, ☺) journey through this thesis. I hope that you will enjoy.

Stay circular!

In Delft, 01.06.2018

- Intentionally left blank -

Samenvatting

Probleem

Het lineaire model is tegenwoordig heersende in de economie van de mensheid. Het wordt als vanzelf sprekend gezien dat grondstoffen en energie oneindig, makkelijk en goedkoop beschikbaar zijn. Deze benadering van take-make-dispose gaat er bovendien van uit dat de vervuiling en afval dat uitgestoten wordt het ecosysteem van de aarde niet in gevaar brengt. Echter, door de bewezen klimaatverandering, het uitsterven van dier- en plantsoorten en de volatiliteit van de wereldmarkt is het snel duidelijk geworden dat deze aanname gewoonweg niet waar is. De natuurlijke koppeling tussen de economische groei, de beperkte middelen en degradatie van de aarde is op lange termijn overduidelijk niet duurzaam. Het is een kwestie van tijd voor het punt is bereikt waarop terugkeren niet mogelijk is. Verandering is daarom dringend nodig!

Als reactie op deze bedreigingen tegen de mensheid is er een nieuwe manier van benadering in de economie opkomende – Circulaire Economie. Het belooft, onder het mom van de eliminatie van afval en de realisatie van de volle economische potentie van materialen en producten, economische groei los te zien van de beperkende grondstoffen en verslechtering van de aarde. Eenvoudig gezegd, circulaire economie doelt op het sluiten van de cirkel door de recirculatie van end-of-life materialen en producten in de productieketen. Behalve dat circulaire economie alle negatieve bijzaken van het lineaire model tegen gaat komt het ook met een behoorlijk aantal voordelen. Één van die voorbeelden is dat het zorgt voor 12% meer economische groei en 4% meer banen in vergelijking met het lineaire scenario. Een ander voorbeeld is dat het een extra netto winst van 0,9 triljoen euro en kosten besparing van $630 biljoen op EU niveau. Het bereiken van circulariteit wordt daarom meer en meer gezien als de manier waarop we een welvarend en duurzame toekomst kunnen garanderen. Dit wordt erkend door meerdere autoriteiten, actieplannen en beleid op (inter)nationaal niveau die circulaire economie bevatten. China heeft circulaire economie al opgenomen in hun wetgeving in 2008. Op Europees niveau is er een actieplan met als doel het opnemen van circulaire economie. In Nederland heeft de overheid een breed programma geïntroduceerd dat streeft naar 100% circulariteit in 2050 met als opstap 50% in 2030. The rage omtrent circulariteit, de voordelen dat het met zich meebrengt en de talrijke actieplannen en beleidsvormen die ermee te maken hebben impliceren dat er aanzienlijk wat acties als doelstelling hebben circulariteit te introduceren in de productieketen. Dit is echter niet het geval. Het lijkt momenteel te leiden naar *obervatie van inertie* (”de neiging om niks te doen of onveranderlijk te blijven”) in de productieketen als het de verandering naar circulariteit betreft. Om de verandering naar circulariteit mogelijk te maken verdiept dit onderzoek zich verder in de intertie van de productieketen. Om dat te bereiken is de volgende hoofdvraag geformuleerd:

”Wat zijn de onderliggende redenen voor inertie in de productieketen in relatie tot de verandering naar circulariteit?”

Als er wordt gekeken naar de constructie industrie in Nederland wordt er op dit moment 95% van al het materiaal gerecycled. Echter worden de meeste van deze materialen gerecycled tot het laagste functionele niveau, in de bijna verzadigde grond-, weg- en waterbouw (GWW) sector is dit funderingsmateriaal. De constructie sector is in Nederland daarom niet circulair. De betreffende sector draagt bij aan 4,8% van de Nederlandse economie en is verantwoordelijk voor 50% van de grondstoffen, 40% van het energieverbruik en 40% van de vervuiling. Hiermee is het duidelijk dat er significante voordelen gehaald kunnen worden als er een verandering naar circulariteit wordt gemaakt. Als er een stapje verder wordt gezet en wordt erkend dat beton een van de grootst uitdagende materialen voor recirculatie is dan wordt het belang van de stenen materialen Construction and Demolition Waste (CDW) stroom duidelijk. Het draagt voor 65% bij aan het CWD, dat zich vertaalt in 26% van de totale vervuiling dat wordt verwekt in Nederland. Dit impliceert dat een verandering in circulariteit zal resulteren in beduidende voordelen. Als de behoefte voor de integratie in productieketens in rekening wordt genomen, is, zoals voorgesteld door het concept van circulaire

economie, het belangrijk om te kijken naar de productieketen van stenen materialen. Het hierboven benoemd probleem wordt geobserveerd in een concreet voorbeeld in de productieketen van stenen materialen. Dit betreft de enige actie die streeft naar een verandering richting de circulariteit en dat de gehele productieketen bevat, het vrijwillige Betonakkoord. Deze is echter nog wel in ontwikkeling, met verschillende mislukte ratificaties gedurende de afgelopen drie jaar, dat duidt naar het bestaan van de inertie in de productieketen van stenen materialen.

Circulaire economie is opkomend en in ontwikkeling. Er is daarom nog geen algemeen aanvaard en alles omvattende definitie dat het precies formuleert. Hierdoor zijn verschillende interpretaties van circulaire economie mogelijk wat de verandering naar circulariteit een uitdaging maakt. Volgens de theorie van *algemene relativiteit* is er geen unieke en ultieme realiteit maar een wijd geaccepteerde perceptie ervan. De actoren in de productieketens hebben een verschillende perceptie van circulariteit die op een lijn ligt met hun strategische (lineaire) interesses, dit leidt tot een vaag beeld van begrip van circulaire economie dat effectief de realisatie ervan verhindert. Het fenomeen van *diffusie van verantwoordelijkheid* is niet duidelijk toegekend. Er kan daarom worden gesteld dat de verschillen in perceptie van de actoren in de productieketen en het fenomeen van diffusie van verantwoordelijkheid onderliggende redenen zijn voor de inertie in de productieketen. Om dit te bevestigen en om de andere onderliggende redenen te ontdekken is dit onderzoek gefocust op de percepties van verantwoordelijkheden die de actoren in de productieketen nodig hebben voor de verandering naar circulariteit.

Benadering

Een onderzoeksmethodologie is gevormd dat streeft naar het vastleggen en analyseren van percepties van verantwoordelijkheden voor de verandering naar circulariteit. Hierbij is de benadering van *systems thinking* geïmplementeerd. Deze benadering erkend het belang van sociale aspecten in de integratie van de productieketen, zoals het geval bij circulaire economie.De kern van de benadering is de *Social Network Analysis (SNA)*. Met behulp van SNA kunnen de relaties tussen verschillende partijen inzichtelijk gemaakt worden. De methodologie bestaat uit drie delen. Het eerste deel legt de perceptie op de veranderingen die nodig zijn voor een verandering richting circulariteit vast met behulp van semigestructureerd interviews met de branche organisaties. In het tweede deel komen de percepties van de individuele bedrijven die verantwoordelijk en belangrijk zijn voor de verandering naar circulariteit naar voren. Deze worden in kaart gebracht en geanalyseerd op drie niveaus: Het individueel bedrijf, de branche organisatie en de productieketen. De methodologie is daarom zelf ook circulair, beginnend en eindigend bij de branche organisaties. De methodologie is toegepast in een concreet voorbeeld van inertie in de productieketen van stenen materialen met betrekking tot het maken van een verandering richting circulariteit. In totaal worden 18 interviews en een validatiemeeting afgenomen.

Conclusie

Een discussie concludeert dat de bevindingen van de analyse van de productieketen van stenen materialen toepasbaar zijn op andere productieketens. De volgende conclusie is daarom toepasbaar voor de productieketens in het algemeen.

Vanuit de analyse van de productieketen van stenen materialen was het duidelijk dat er grote verschillen zijn in de percepties tussen actoren van de productieketen op elk niveau van de analyse. De meting van het verschil in perceptie toont aan dat er aanzienlijke verschillen in percepties op de verantwoordelijkheid tussen bedrijven van dezelfde branche, tussen de branches en tussen de branches en de productieketen als een geheel zijn. Verder werden er maar vijf (van de 40) veranderingen gezien als nodig voor het bereiken van circulariteit door meer dan één actor. Bovendien zijn de percepties op het belang van nodige veranderingen ook behoorlijk gevarieerd tussen de actoren van elk niveau. Daarbij zijn alle bevindingen herkend en gevalideerd door de branche organisaties. De verschillen in percepties als onderliggende reden

voor inertie in betrekking tot een verandering richting circulariteit zijn hierbij bevestigd op elk niveau in de productieketen.

Vanuit de applicatie van de onderzoeksmethodologie naar de productieketen van stenen materialen komen de volgende observaties betreffende het fenomeen van diffusie van verantwoordelijkheden naar voren. Allereerst, op het niveau van de productieketen, 73% van de verantwoordelijkheid wordt toegekend buiten de productieketen, de overheid wordt gezien als hoofd verantwoordelijke actor met 32% van de toegekende verantwoordelijkheid. Als gevolg, maar 27% van de verantwoordelijkheden bleven in de productieketen. De betonfabrikanten werden gezien als meest verantwoordelijke partij in de productieketen van stenen materialen met 10% toegekende verantwoordelijkheid. Het volgt dat bijna drie keer meer verantwoordelijkheid wordt toegekend aan partijen buiten de productieketen van stenen materialen dan aan partijen in de productieketen zelf. De meest verantwoordelijke partij in de productieketen krijgt minder dan drie keer de verantwoordelijkheid toegewezen dan de partij buiten de productieketen. Ten tweede kan uit de grafieken van de SNA duidelijk "verantwoordelijkheids eilanden" herkend worden rond de partijen buiten de productieketen op alle niveaus van de analyses. Dit laat zien dat verantwoordelijkheden worden neergelegd bij partijen buiten de productieketen. Ten derde, de verantwoordelijkheid voor drie (van de 40) van de veranderingen die als nodig werden gezien was gekend aan een specifieke branche terwijl de verantwoordelijkheid voor de overige 37 was toegekend op het niveau van de productieketen. Als laatste, alle bevindingen zijn herkend en gevalideerd door de branche organisaties. Het fenomeen van diffusie van verantwoordelijkheden is daarom bevestigd als een onderliggende reden voor inertie in de productieketen in relatie tot de verandering naar circulariteit.

Verdere uitleg van de verkregen resultaten en observaties van de validatiemeeting met de branche organisatie laat fier andere redenen van onderliggende verschillen in percepties en diffusie van verantwoordelijkheden zien in de productieketen:

- Gebrek aan stimulans voor de bedrijven in de productieketen om een verandering richting circulariteit te maken.
- Hoge risico's en onzekerheid worden geimpliceerd door een verandering naar circulariteit
- Gebrek aan gemeenschappelijke interesses tussen bedrijven in de productiekten
- Tegenstrijdige percepties op alle niveaus in de productieketen en tussen de productieketen en de overheid.

- Intentionally left blank -

Abstract

Problem

Linear model is currently ruling over the economy of humankind. It takes as a given that raw materials and energy are infinitely, easily and cheaply available. Furthermore, this take-make-dispose approach assumes that the pollution and waste that stem out of it are not endangering the Earth's ecosystem. However, with the evidence of climate change, extinction of species and volatility of markets around the globe, it is rapidly becoming clear that these assumptions are simply not true. This innate coupling of economic growth with resource constraints and degradation of the Earth is clearly not sustainable in the long run, and it is only a question of time when a point of no return is reached. Therefore, there is urgency for making a change!

As a response to these threats to humankind, a new approach to economy is emerging – Circular Economy. It promises decoupling of economic advancement from resource constraints and deterioration of the Earth with its maxim of elimination of waste and realization of full economic potential of materials and products. Simply put, the notion of circular economy aims at closing the loops by recirculating end-of-life materials and products back into their supply chains. Besides battling off the negativities of the linear economic model, it also entails numerous additional benefits. For example, 12% more economic growth and 4% more jobs in comparison to linear scenario, 0.9 trillion euro of additional net benefit and US$630 billion of cost savings on the level of the EU. Therefore, achieving circularity is increasingly seen as the way to go in order to ensure a prosperous and sustainable future. This is recognized in the numerous policies, action plans and legislations on (inter)national level that encompass the notion of circular economy. China has incorporated it into the legislative system in 2008. On the level of EU there is an action plan which has a goal of incorporating the notion of circular economy. In the Netherlands, a government wide program was introduced that aims at achieving 100% circularity in 2050, with the stepping-stone of 50% in 2030. The hype surrounding circularity, benefits that it entails and numerous action plans and policies related to it imply that there would be a considerable number of actions aiming at introducing it to supply chains. However, this is not the case, which leads to observation of inertia (*"a tendency to do nothing or to remain unchanged"*) in supply chains in relation to making the change towards circularity. In order to enable the change towards circularity, the research focused on further exploration of inertia in supply chains is needed. In order to achieve that, the main research question is formulated as:

"What are the underlying reasons for inertia in supply chains in relation to the change towards circularity?"

Focusing on the construction sector in the Netherlands, more than 95% of materials are recycled today. However, most of these materials are recycled to the lower functional level into the almost-saturated civil engineering sector as foundation materials. Therefore, the construction sector in the Netherlands is not circular. Knowing that it contributes 4.8% of added value to the Dutch economy and that it is responsible for 50% of used raw materials, 40% of energy consumption and 40% of generated waste, it is clear that there are significant benefits to be gained if a change towards circularity is made. Diving even deeper, and acknowledging the concrete as the most challenging material for recirculation, the relevance of the stony materials Construction and Demolition Waste (CDW) stream becomes apparent. It constitutes 65% of CDW, which translates to 26% of total waste generation in the Netherlands, implying that a change towards circularity will result in significant benefits. Taking into account the need for integration of supply chains, as proposed by the notion of circular economy, it is of interest to further look into the stony materials supply chain. The above-formulated problem is observed in a concrete case of the stony materials supply chain. Namely, the only action aiming at a change towards circularity and encompassing the whole supply chain is the voluntary Concrete Agreement. However, it is still in development with multiple failed ratifications over the past three years, which points to existence of inertia in the stony materials supply chain.

The field of circular economy is novel and in development. Therefore, there is no widely accepted and all-encompassing definition that precisely formulates it. This allows for different interpretations of what the notion of circular economy encompasses, which poses a challenge for making a change towards circularity. Namely, according to theory of general relativity, there is no unique and ultimate reality but rather the (widely) accepted perception of reality. The actors within supply chains have different perceptions of circularity, in line with their strategic (linear) interests, which results in a blurry picture of the notion of circular economy and effectively hinders its realization. Phenomenon of diffusion of responsibility entails that individual actor is less likely to take action if he is part of a larger group in which responsibilities are not clearly assigned. Therefore, it is argued that differences in perceptions of actors in supply chains and phenomenon of diffusion of responsibility are the underlying reasons for inertia in supply chains. In order to confirm this and to uncover further underlying reasons a research focused on perceptions on responsibility for making a change towards circularity of the actors in supply chains is needed.

Approach

Research methodology that aims at capturing and analyzing perceptions on responsibility for changing to circularity, while incorporating the systems thinking approach, as entailed by the notion of circular economy, and acknowledges the importance of social aspects for the needed integration of supply chains was formulated. Social Network Analysis (SNA) approach, which at relations between multiple sets of entities, rather than focusing on the single entity, sits at its core. Methodology consists of three distinct part. First part captures the perceptions on the changes that are needed for making a change towards circularity by semi-structured interviews with the branch organizations. In the second part, perceptions of individual companies on responsibility for, and importance of, the changes from the first part are extracted and analyzed on the three levels: individual company, branch organization and supply chain. In the final, third, part key observations and findings are validated in a meeting with branch organizations. Therefore, the methodology is in itself circular, starting and ending with the branch organizations. This methodology was applied to the stony materials supply chain as the concrete case of inertia in regard to making a change towards circularity. In total, eighteen interviews and a validation meeting were conducted.

Conclusions

A discussion concluded that the findings from the analysis of the stony materials supply chain are applicable to other supply chains. Therefore, the following conclusions are valid for supply chains in general.

From the analysis of the stony materials supply chain it was clear that there are large differences in perceptions between actors in the supply chain on every level of analysis. Namely, measure of difference of perceptions showed that there are considerable differences of perceptions on responsibility in-between companies from the same branch, in-between branches, as well as between branches and the supply chain as a whole. Furthermore, only five (out of forty) changes were perceived as needed for achieving circularity by more than one actor. Moreover, perceptions on importance of needed changes also varied significantly between the actors on every level. In addition, all of the findings were recognized and validated by branch organizations. Therefore, differences in perceptions are confirmed on every level of supply chain as the underlying reason for inertia in regard to a change towards circularity.

From the application of research methodology to the stony materials supply chain stemmed the following observations supporting the existence of diffusion of responsibility phenomenon. First, on all levels of analysis most of responsibility was assigned to actors outside the supply chain. On the level of supply chain 73% of responsibility is assigned to outside the supply chain, with government perceived as the most responsible actor with some 32% of assigned responsibility. Consequently, only 27% of responsibility remained within the supply chain. The concrete producers perceived as the most responsible actor within the stony materials supply chain with 10% of assigned responsibility. It follows that almost three times more responsibility is assigned to actors outside the stony materials supply chain than it is to the actors

within the supply chain. Furthermore, the most responsible actor in the supply chain is perceived to be more than three times less responsible than the most responsible actor outside the supply chain. Second, the graphs stemming from the SNA clearly identify large "responsibility islands" around outside actors on all levels of analysis. This shows that responsibility is concentrated around the actors that are not part of the stony materials supply chain. Third, responsibility for only three (out of forty) perceived needed changes was attributed to a specific branch, while the responsibility for remaining thirty-seven was delegated to the level of supply chain. Fourth, all of the findings were recognized and validated by the branch organizations. Therefore, the phenomenon of diffusion of responsibility is confirmed as the underlying reason for inertia in supply chains in relation to a change to circularity.

Further exploration of the obtained results and observations from the validation meeting with branch organizations uncovered the following four reasons underlying differences in perceptions and diffusion of responsibility in supply chains:

- Lack of incentives for the companies in supply chains to make a change towards circularity
- High risks and uncertainties implied by a change to circularity
- Lack of mutual interests between companies in the supply chain
- Clashes of perceptions on all levels in supply chain, and between the supply chain and government

Table of contents

List of figures

List of tables

List of abbreviations

Ban – Banks
BO – Branch Organization
CC – Construction Company
CDW – Construction and Demolition Waste
Con – Contractor
CP – Concrete Producers
DC – Demolition Companies
Des – Designer
EU – European Union
Gov – Government
IC – Innovative Company
Ind – Industry
Inv – Investor
IP – Independent Party
LoW – List of Waste
PAP – Primary Aggregates Producers
RB – Regulatory Body
RC – Recycling Companies
SC – Supply Chain
Sci – Science
SNA – Social Network Analysis

1 Introduction

Current economic practices presuppose that raw materials and energy are abundantly, easily and cheaply available. Furthermore, it is assumed that the pollution and waste as the outputs of the economic activity are not endangering the world we live in (Storm, 2011). These assumptions characterize the economic model that is in use today – the linear economic model. It is best described with the "take, make, dispose" approach. Raw materials are taken from the Earth, made into intended products and after they serve the intended purpose, their disposal takes place (Florin, 2014). Simply put, inputs of this model are energy and raw materials, and the outputs are waste and pollution. Although assumptions underlying the linear economic model were applicable when it first emerged, it is clear that nowadays this is not the case (Sauvé, Bernard, & Sloan, 2016). Generation of waste, pollution and other negative externalities cannot be ignored any more, as they evidently represent a burden for our planet. In addition, raw materials and energy sources are becoming scarce and unevenly distributed throughout the world, which leads to high supply risks and dependence on import, geopolitical situation and markets across the world (Ellen MacArthur Foundation, 2015b). The effects of these negativities are best evidenced by climate change, extinction of species, air pollution and volatility of energy and raw materials markets (Dobbs, Oppenheim, Thompson, Brinkman, & Zornes, 2011; Keeble, 1988; Speth & Zinn, 2008). It follows that the linear economic model couples the economic growth with resource constraints and degradation of the Earth. This, already excessive, degradation of the Earth, in combination with the projected exponential rise of world population in the coming years shows that the current system is not sustainable and that it is only a question of time when the point of no return is reached. Therefore, there is a need for a new, fundamentally different approach.

As a response to negative effects of the linear economic model, a new economic approach is emerging – circular economy. It promises decoupling of economic growth from resource constraints and degradation of the Earth (Ellen MacArthur Foundation, 2015a). Its main notion is elimination of waste and realization of full economic potential of products and materials by reuse throughout multiple life cycles (Ellen MacArthur Foundation, McKinsey Center for Business and Environment, & SUN, 2015). Another important aspect is elimination of "structural" waste, which encompass the time during which the asset is not used for the intended function because of the ownership (Ellen MacArthur Foundation, 2015b). In other words, the notion of circular economy promotes use of the function when needed, rather than ownership of the asset that provides that function. Furthermore, it promotes the use of renewable energy sources and insists that prices reflect real costs (Ellen MacArthur Foundation, 2015b). In addition, it argues for looking at the bigger picture by applying the systems thinking approach and closing the materials loops on the level of supply chains (Ellen MacArthur Foundation, 2015a). It also entails that collaboration, transparency and trust within the supply chains are essential for achieving its goals (Ellen MacArthur Foundation, 2015a). The notion of circular economy is graphically represented in Figure 1, with the prolonging of structure's life cycle by conducting quality maintenance being the preferred choice for the treatment of end-of-life materials, and recycling the last, but still in line with the notion of circular economy, choice of treatment of materials and products.

Besides eliminating the negative effects of the linear economic model, the notion of circular economy entails many other benefits. For example, in a circular scenario the economic growth is projected to reach 27% in 2050, which is almost double of the 15% expected in the business as usual scenario (Ellen MacArthur Foundation, 2015a). Furthermore, it will result in 70% greenhouse gas emissions reduction, 4% more jobs (Wijkman & Skånberg, 2015), 0.9 trillion euros of additional net benefit (Ellen MacArthur Foundation et al., 2015) and US$630 billion of cost savings (Ellen MacArthur Foundation, 2015a), at the level of the EU.

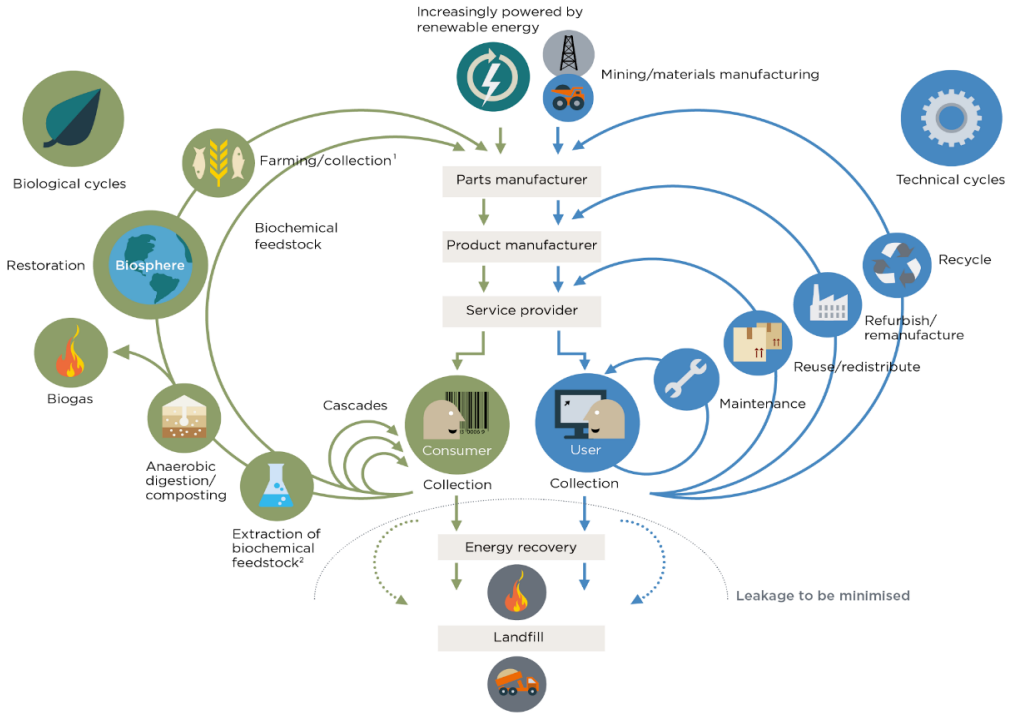


Figure 1: Circular economy – "Butterfly" diagram (Ellen MacArthur Foundation et al., 2015)

Circular economy is acknowledged worldwide as the road that needs to be taken in order to ensure prosperous and sustainable future. This is supported by numerous legislations, policies and action plans on (inter)national level that endorse the notion of circular economy (Ghisellini, Cialani, & Ulgiati, 2016). For example, in China the notion of circular economy is part of legislative system since 2008 (CCICED, 2008). Furthermore, on the level of the EU there is a newly instituted action plan promoting circularity (European Commission, 2015; McDowall et al., 2017), and, within the Netherlands, a government wide program with the goal of achieving 100% circularity in 2050, with a stepping-stone of reaching 50% in 2030, is in place (The Ministry of Infrastructure and the Environment, 2016).

Focus is turned to the construction sector in the Netherlands, where more than 95% of materials are recycled (ABN AMRO & Circle Economy, 2015). However, these materials are mostly down-cycled into the civil engineering sector as base materials for roads (Rijkswaterstaat & National Institute for Public Health and the Environment, 2015). Down-cycling is not in accordance with the notion of circular economy, which is further supported with the saturation of the secondary materials market in the civil engineering sector (ABN AMRO & Circle Economy, 2015) that is occurring because materials from the civil engineering sector can be fully up-cycled and there are less and less structures built within it. Therefore, the construction sector in the Netherlands cannot be considered circular. It is responsible for 50% of used raw materials, 40% of energy consumption, 40% of generated waste, 35% of CO2 emissions, 30% of water consumption, 4.5% of used primary energy, 5% of greenhouse emissions and 20% of total goods transportation in the Netherlands (ABN AMRO & Circle Economy, 2015; BAM & ARUP, 2017; The Ministry of Infrastructure and the Environment, 2016). And, together with the contribution of 4,8% of added value to the Dutch economy in 2013, it is clear that application of circular approach in the construction sector would yield significant benefits (ABN AMRO & Circle Economy, 2015).

The circular approach implies closing material loops. Within the construction sector, concrete is the most challenging material for recirculation because of the following reasons. First, it is the most used construction material worldwide (Lippiatt & Ahmad, 2004; Marinković, Radonjanin, Malešev, & Ignjatović, 2010), with only the consumption of water being larger (Rangan, 2008). Second, the concrete is challenging for up-cycling because of its monolithic structure. Third, it is problematic to formulate a design that enables reuse

on a product level while keeping one of the most valued ability of concrete – to conform to (almost) any shape it is poured into.

Achieving circularity entails elimination of waste. According to the European List of Waste (LoW) end-of-life concrete is part of the stony materials waste stream (European Commission, 2000; Ministerie van VROM, 2001), which is part of the Construction and Demolition Waste (CDW) stream on a more general level. CDW stream is the largest by volume on both the level of EU (European Commission, 2016b) and the Netherlands (CBS, PBI, & Wageningen UR, 2017b), contributing around, respectively, 33% (European Commission, 2016a) and 40% (CBS, PBI, & Wageningen UR, 2017a) to the total generation of waste, with the projection of the rise in the coming years (Ministerie van Infrastructuur en Milieu, 2014). In the Netherlands, the biggest part of CDW is the stony materials stream, with the share of 65% (Mulders, 2013), which translates to 26% of total waste generation. Around 93% of stony materials is down-cycled into the base materials (Mulders, 2013). Furthermore, most of materials within it (concrete, masonry, gypsum, ceramics) are processed together as rubble. Therefore, the processing of stony materials CDW stream in the Netherlands is not in accordance with the notion of circular economy, with the promise of considerable benefits if the change towards circularity is made.

The notion of circular economy implies applying systems thinking approach in order to take all of the relevant aspects into the account and grasp the bigger picture. Furthermore, it stresses the importance of integration of supply chains. Therefore, taking into account the above postulated deliberation, it is of interest for this research to further analyze the stony materials supply chain.

Note to the reader: a more elaborate exploration regarding the inception and background information about the problem that is tackled in this thesis can be found in Appendix A of this thesis.

1.1 Problem statement

As postulated above, the notion of circular economy is emerging in order to combat the negativities of the linear economic model and secure a prosperous and sustainable future. It proposes to achieve that by recirculating end of life materials and products back into their supply chains. The notion of circular economy is gaining momentum throughout the world, with numerous new policies, legislations and action plans that are being introduced on different levels of authority worldwide. In addition, it promises further economic, environmental and social benefits. However, the field of circular economy is novel and developing, which implies that there is no widely accepted and all-encompassing definition that precisely formulates it (Adams, Osmani, Thorpe, & Thornback, 2017; Murray, Skene, & Haynes, 2017). This ambiguity of the term allows for different interpretations, effectively posing a challenge for implementation of circular practices (Cossu & Williams, 2015; Preston, 2012). Furthermore, the notion of circular economy is even more ambiguous when applied to the lower levels, such as national economic level or supply chain level. Namely, unique specificities dictate the precise formulation of the notion of circular economy for each case.

Following from the Einstein's theory of general relativity is the notion that everything is relative (Einstein, 1905). In other words, there is no unique and ultimate reality, but rather the (accepted) perception of reality. In order for something to be considered the reality, all (or most of the) actors that are affected by it have to perceive it in a same way. It is the same with the move towards circularity in the supply chains. The ambiguity of the notion of circular economy implies that different actors from the supply chain have different interpretations of it, in line with their strategic interests. Consequently, these differing perceptions of the notion of circular economy hinder its realization. This is supported by Banerjee (2012) who argued that there are some inherent problems with making a move towards circularity, and pinpointed the obvious disproportion between the small number of actions aimed at boosting circularity and the immense attention that the notion of circular economy is attracting internationally. In other words, considering the global hype

surrounding the notion of circular economy, it is expected that there would be a large number of circular actions reflecting that. However, this is not the case. This is further backed by Papachristos (2014) who analyzed circular practices of recycling and reusing on the supply chain level and concluded that there is inertia in supply chains when it comes to doing it.

Following the already pinpointed relevance of the stony materials supply chain in the Netherlands, it is used as a showcase for the state of inertia within supply chains. Namely, the only circular initiative encompassing this supply chain is the Concrete Agreement. However, this agreement, although in development for three years, failed to be accepted and implemented (MVO Nederland, 2016). Furthermore, there were several attempts of all of the actors from the stony materials supply chain signing it, but they were not successful (MVO Nederland, 2016). On the other hand, there is a great hype surrounding the notion of circular economy and urgency to make the move towards circularity within the supply chain. This hints at the existence of inertia in the stony materials supply chain in the Netherlands.

The socio-psychological phenomenon of diffusion of responsibility argues that an individual entity is less likely to take responsibility for an action if there are other members of the same group in which the responsibilities are not clearly assigned (Guerin, 2011). Following from the notion of circular economy is the importance of integration of supply chains. Therefore, the supply chains can be considered as groups and the actors within them as individuals. Taking into account the different perceptions on circularity of the actors within supply chains, it is clear that the responsibilities within them cannot be clearly assigned. This is simply because different perceptions of circularity entail different perception of changes that will lead to achieving circularity. Consequently, it is argued that diffusion of responsibility is present within the supply chains and that it is a possible cause for inertia within them. This is supported with the concrete case of the stony materials supply chain. Namely, during the initial exploratory interviews with the representative of the recycling companies branch organization (BRBS), the interviewee pinpointed ambiguity of the notion of circular economy, differences in perceptions of the actors in the supply chain and lack of a clear picture on what is to be achieved and by whom as the main issues underlying the above observed state of inertia (Broere, 2017). Therefore, it is of interest to further research the perceptions of responsibilities within the supply chains.

Summing it all up, although circularity promises numerous benefits and sustainable future, there are some inherent problems that are blocking its implementation. These are reflected in the supply chains in the form of inertia. From the ambiguity of the term "circular economy", it follows that numerous perceptions of its meaning are present. With the argument that perceptions define the reality, it is clear that these differing perceptions constitute a blurry reality, which effectively hinders the change towards circularity. Furthermore, these imply that there is a diffusion of responsibility within the supply chains, which might be the underlying reason for the observed state of inertia. A concrete case in which the problem above is observed is the stony materials supply chain in the Netherlands.

Novelty of the circular approach entails that there is relatively little scientific research conducted up until now and that the scientific literature is relatively scarce. Although in the past few years this is rapidly changing with the momentum that the circular approach is gaining, there is a great need for further research dealing with the notion of circular economy on all levels, which is pinpointed in the recent relevant literature (Elia, Gnoni, & Tornese, 2017; Ellen MacArthur Foundation & Granta Design, 2015; Geng, Sarkis, Ulgiati, & Zhang, 2013; Ghisellini et al., 2016; Mendoza, Sharmina, Gallego-Schmid, Heyes, & Azapagic, 2017; Tisserant et al., 2017). Research is needed in order to provide clear definition of the circular economy on every level; analyze specific supply chains and provide them with the path towards circularity; and develop circular economy indicators and methodologies that will both assess the current state of circularity in the supply chains, and enable boosting, tracking of, and reacting on the process of implementation of the notion of circular economy (Di Maio, Rem, Baldé, & Polder, 2017; Nasir, Genovese, Acquaye, Koh, & Yamoah,

2017). Therefore, the problem postulated above falls into the academic domain which is recognized as in need of further research.

1.2 Goal and purpose

Based on the introductory part and the problem statement above, the goal of this thesis is to find out the underlying causes for the observed inertia in supply chains related to the change towards circularity by developing a methodology that will analyze the perceptions of the actors within the supply chains and applying it to the stony materials supply chain.

From an academic viewpoint, this research will contribute to demystifying the notion of circular economy on both the general and the level of the stony materials supply chain. Furthermore, it will result in a methodology that will provide an understanding of inertia that is present in supply chains when the change towards circularity is considered.

From the viewpoint of the industry, on a general level, it will spur a change towards circularity and provide understanding of the problems underlying inertia. Zooming in to the stony materials supply chain, it will provide insights about perceptions of circularity on the levels of individual actors, branches and the supply chain as a whole.

1.3 Research question(s)

Based on the formulations of the goal and purpose, and the problem statement, the research questions and sub-questions are formulated as follows:

"What are the underlying reasons for inertia in supply chains in relation to the change towards circularity?"

1. "How is inertia manifested in the stony materials supply chain?"
2. "How to capture and analyze the perceptions of actors in the supply chain?"
3. "What are the underlying reasons for inertia in relation to the change towards circularity in the stony materials supply chain?"
4. "How do the underlying reasons for inertia in the stony materials supply chain translate to other supply chains?"

1.4 Research design

In order to enable answering the research question and sub-questions the following research design is formulated. First, there is a need for further exploration of the concrete case of the stony materials supply chain and the notion of inertia that was observed. Second, in order to enable further research a methodology is formulated that will gather and investigate perceptions of the actors within the supply chain. Third, this methodology is put to practice for the stony materials supply chain, with the output of actors' perceptions of responsibilities. Furthermore, these results are discussed and the implications for the state of inertia on the level of the stony materials supply chain are postulated. Fourth, a discussion is carried out, focusing on the translation of the implications for the stony materials supply chain level to the level of supply chains in general. In the end, conclusions are drawn, generalizing the findings to the level of supply chains. This research design is depicted in Figure 2.

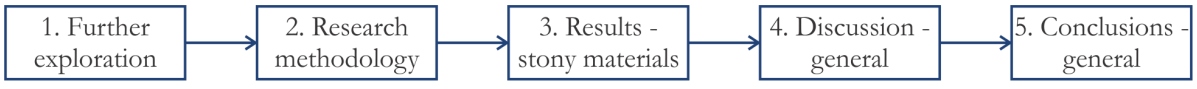


Figure 2: Research design

1.5 Thesis outline

In support of the formulated research design, the thesis is structured as follows. First, Chapter 2 encompasses a literature review focusing on the notion of inertia and the real-life example of it – the Concrete Agreement and the stony materials supply chain, providing an answer to the first research sub-question (*"How is inertia manifested in the stony materials supply chain?"*). Second, in Chapter 3, a new research methodology is postulated that allows for capturing and analyzing the perceptions of the actors within a supply chain, which answers the second research sub-question (*"How to capture and analyze the perceptions of actors in the supply chain?"*). Third, the stony materials supply chain is analyzed with the use of the newly formulated methodology and the results are postulated and discussed in Chapter 4. In turn, this gives the answer to the research sub-question number three, which was formulated as *"What are the underlying reasons for inertia in relation to the change towards circularity in the stony materials supply chain?"*. Fourth, in Chapter 5, discussion focusing around the translation of implications of the results for the stony materials supply chain to the general level of supply chains is carried out. Here, an answer to the fourth research sub-question is provided (*"How do the reasons for inertia in the stony materials supply chain translate to the general level of supply chains?"*). Last, but not least, Chapter 6 draws conclusions regarding the inertia on a more general level of supply chains and effectively answers the main research question, which was formulated as *"What are the underlying reasons for inertia in supply chains in relation to the change towards circularity?"*.

2 Literature review

This chapter provides an answer to the first research sub-question that was formulated as: *"How is inertia manifested in the stony materials supply chain?"*. Following from Chapter 1.4 (Research design), this chapter further explores the Concrete Agreement and its context, with the focus on the inertia that was observed in the stony materials supply chain in regard to it. In addition, it discusses the possible causes for this inertia in order to determine the scope of research methodology that is formulated in the next chapter. First, the Concrete Agreement and its context are explored. Second, the stony materials supply chain is looked into and the relevant actors within it are identified. Third, the notion of inertia is explained and related to the situation in the stony materials supply chain in regard to the Concrete Agreement. In addition, possible causes underlying observed inertia in the stony materials supply chain are discussed.

2.1 The Concrete Agreement

In the recent years Dutch government introduced voluntary agreements as an important policy instrument (Cagno, Trianni, Abeelen, Worrell, & Miggiano, 2015). For example, the Green Deals approach, introduced in 2011 (Greendeals.nl, 2017b), which encompasses initiative for making mutual agreements or covenants under private law between a coalition of companies, civil society organizations and local and regional government with the goal of stimulating green growth and resolving social issues (Greendeals.nl, 2017a). Although government is one of the signing parties, its role within Green Deals is a supportive one, and not that of an enforcer (Salo, 2016). Up until now, a total of 217 Green Deals have been signed, with more than 50 related to the construction sector (Greendeals.nl, 2017c). Lead by these examples, actors in the concrete supply chain has recognized this opportunity and, in 2015, decided to formulate a new voluntary agreement – The Concrete Agreement (Betonakkoord) (MVO Nederland, 2016).

The Concrete Agreement aims at securing sustainable growth and strengthening of the concrete supply chain. It focuses on four main areas: CO2 reduction, circular economy, natural capital and social capital. Within the circular economy it defines seven goals that aim at achieving 100% circularity in 2030 (MVO Nederland, 2016). These are:

1. Enabling 100% concrete materials flow in the supply chain by 2030.
2. Ensuring the quality of recycled concrete waste that will enable all fractions to be reused in the concrete industry in 2030.
3. Adjusting norms and regulations by 2020 to allow meeting of the goals.
4. Using minimum 5% of secondary materials in all concrete products in 2018.
5. Continuous increasing this amount over the years.
6. Assessing environmental performance of buildings.
7. Applying R-ladder to each new building built by producers.

The concrete agreement states that it encompasses the concrete supply chain. However, as postulated in the introductory part, end-of-life concrete is part of the stony materials CDW stream. In addition, 87% of stony materials are not separated, but processed and reused together as rubble (Mulders, 2013). Therefore, the Concrete Agreement embodies all actors in the stony materials supply chain. Consequently, it is as relevant for the stony materials supply chain as it is for the concrete supply chain. This is supported by participation of the actors from the stony materials supply chain in conceptualization of the Concrete Agreement. In the next part the stony materials supply chain is further analyzed and the relevant actors within it are identified.

2.2 Stony materials supply chain

Following from the notion of circular economy, integration of supply chains is essential for successful closure of material loops (Ellen MacArthur Foundation, 2015a). Enabling free flow of information and knowledge between the actors in the supply chain is crucial. This also entails a change in the mindset of actors, as well as different relations between them, implying more social interactions. Current outlook at the data as a strategic asset, which leads to unavailability of important data (Lake & Crowther, 2013), has to transition to a "data as a common good" perspective. This is particularly observable in the construction sector, where a specific engineering knowledge is what separates the two companies in the market (Broere, 2017). In order to achieve this, cooperation between actors needs to be focused on joint long-term goals, mutual trust and transparency. In the language of the theory of organizational structure, this translates to a switch from the current "market" relations between the actors to the "network" ones, which entails long-term cooperation between the actors motivated by matching interests. (Jones, Hesterly, & Borgatti, 1997).

Initial exploration of the stony materials supply chain was conducted through a series of interviews with the representative of the recycling companies' branch organization (BRBS). Figure 3 summarizes the findings, which are based on (Broere, 2017), and serves as a guideline through the following reasoning. The journey of the stony materials through the supply chain starts when a demolition company is tasked with demolition of a structure. Demolished materials are then put on market M1, where on the other end are recycling companies. Considering the relative cheapness of stony materials, and the fact that demolition companies need to get rid of them because of the landfill ban, usually the demolition company pays to the recycling company for taking the stony materials. In the best case today, recycling companies will take materials for free, depending on the cleanliness and composition of those materials. Demolition companies have the option of sorting (S) or pretreating (T) the materials and, therefore, attaining a better deal with the recyclers. Therefore the market M1 determines the way in which the demolishers will conduct the demolition and if and how they will sort and treat the CDW materials, and the stony materials within them. Market M1 also determines the amount of CDW materials that are imported and exported. If not already sorted, the stony materials are then sorted and further processed by the recycling companies and placed on market M2, where producers are looking for raw materials. Producers have a choice between the secondary and primary raw materials, which implies that the primary aggregates are competing with the stony materials for their place under the sun of the market M2. Market M2 also dictates the level of sorting and processing that is applied by the recycling companies. That is, whether they are put on the market as rubble, as separate materials or as a combination of these two. Market M2 also determines which treatment process (P1, P2, P3) the recycling companies apply. For different uses, a different level of cleanliness and quality is needed. As already postulated, today, the most of the stony materials (95%) is recycled into the road base materials, with some 3% going back to the concrete industry and 2% being used for the construction of embankments.

Based on the material flow approach above, demolition companies (DC), recycling companies (RC), (concrete) producers (CP) and primary aggregates producers (PAP) are identified as the key actors within the stony materials supply chain. Currently, the level of cooperation between them is below par, with knowledge and information sharing virtually nonexistent (Broere, 2017). This is contrary to one of the main principles of circular economy, postulated above, – supply chain integration.

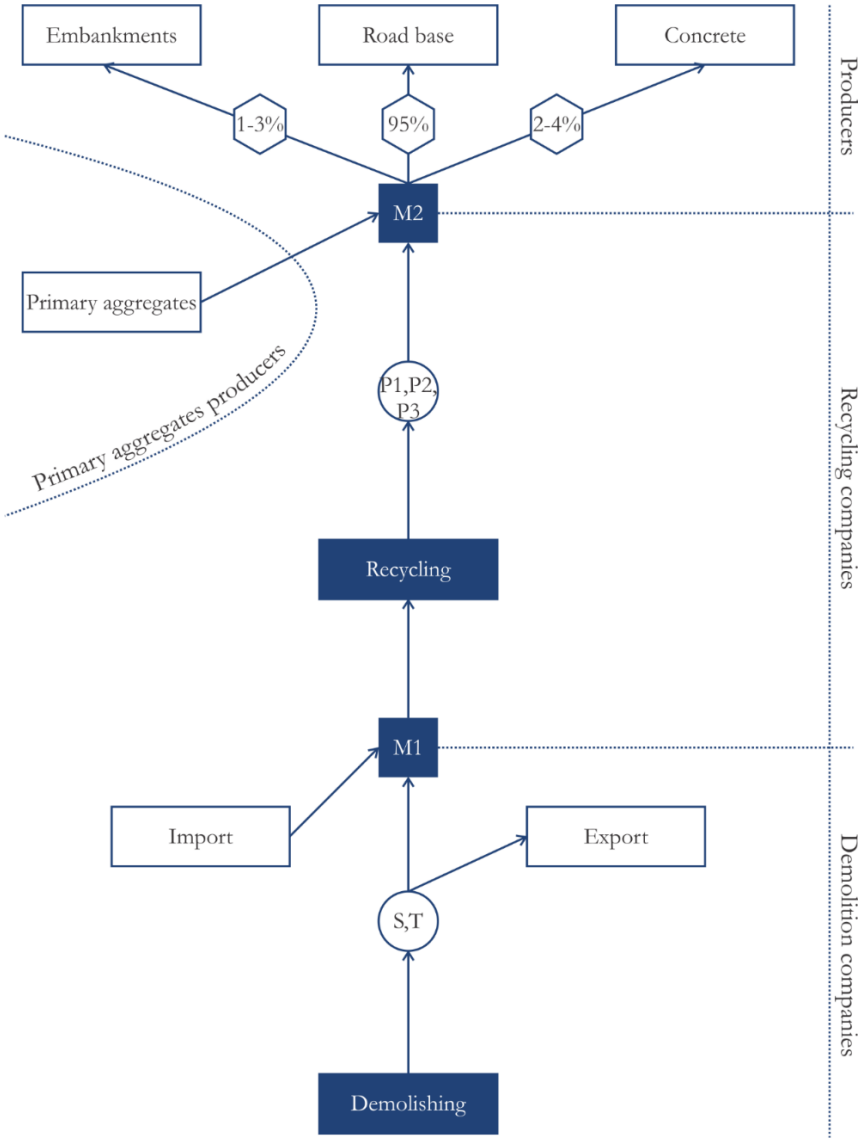


Figure 3: Stony materials supply chain

With the concrete agreement and the stony materials formulated and described, the next part focuses on the notion of inertia.

2.3 Inertia in the stony materials supply chain

Considering the hype around the notion of circular economy, its (inter)national recognition and the benefits it promises to yield, as postulated in Chapter 1 (Introduction), it is expected that there are numerous circular initiatives and actions in the Netherlands encapsulating the stony materials supply chain. However, there is only one initiative on the level of the whole supply chain – the Concrete Agreement. As already stated in Chapter 2.1 (The Concrete Agreement), it encapsulates all of the actors from the stony materials supply chain. Furthermore, it ensures their commitment because of its voluntary nature. Therefore, it is completely in line and supportive of the notion of circular economy. However, when the process of its conception, formulation and acceptance by the participants is scanned it is clear that there are some underlying issues that are interfering with it. Namely, formulation of the Concrete Agreement started in late 2015 (MVO Nederland, 2016). When it was completed, it was scheduled for ratification by participants multiple times during the 2017 (MVO Nederland, 2016). However, this ratification never occurred, which resulted in significant delays in its initial timeline. During the course of the attempted ratifications, it also significantly

changed in rigidity and content in order to accommodate differing interests and perceptions of the participants. In its current form, it represents more of an ambition document, than an actionable plan that was envisaged in the beginning (Broere, 2017; MVO Nederland, 2016). In addition, process of its formulation is perceived as unfair and opportunistic by some of the actors from the supply chain (Broere, 2017). Therefore, besides the benefits and sustainable future that follow with the implementation of the notion of circular economy, the actors within the stony materials supply chain remain passive when it comes to making the change to circularity. This passivity corresponds to the term of inertia. The term *inertia* comes from the Latin word *inert* which means *"lacking the ability or strength to move"* and it is defined as *"a tendency to do nothing or to remain unchanged"* (Stevenson, 2010). Therefore, it is observed that the inertia is present in the stony materials supply chain when it comes to the change towards circularity.

2.4 Discussion – possible causes for the inertia in the stony materials supply chain

The goal of this part is to provide input for the next chapter in which research methodology that will enable answering the research (sub)question(s) is formulated. Namely, it is of interest to determine which aspects are to be analyzed and which data is to be gathered. This is accomplished by a discussion focusing at identifying the possible reasons for the inertia in the stony materials supply chain.

As already postulated in Chapter 1.1 (Problem statement), the notion of circular economy is not strictly defined. Therefore, the actors within supply chains have different interpretations of it, in line with their strategic interests. On the other hand, based on the theory of general relativity, there is no unique reality, but rather the perceived one. In other words, the reality represents common ground in perceptions of the actors. With the perceptions about circularity widely varied, it follows that the circular reality is a blurry picture. This disables changing towards circularity. Therefore, further research should focus on perceptions of the actors in the supply chains.

The phenomenon of diffusion of responsibility is defined and described in Chapter 1.1 (Problem statement). Furthermore, it is shown that conditions for its occurrence are present in supply chains in connection to implementation of the notion of circular economy. Diffusion of responsibility implies that different perceptions of the actors on responsibility for the change towards circularity can prevent it from happening. In other words, actors have different perceptions on responsibility for the changes that will result in circularity. Therefore, analyzing perceptions of actors in supply chains on responsibility for actions resulting in circularity is of particular interest.

Summing it up, it is argued that differences in perceptions, especially those on responsibility, between the actors in supply chains are hindering change towards circularity and causing the inertia in the supply chains.

3 Research methodology

In this part a research methodology is devised that enables analysis of perceptions of the actors in supply chains, answering the second research sub-question (*"How to capture and analyze the perceptions of actors in the supply chain?"*). Following from Chapter 2, the goal of this research methodology is provide the means of gathering and analyzing perceptions of the actors in supply chains on the notion of circular economy and the responsibilities for its implementation.

First of all, in order to harvest perceptions of responsibility, there has to be something to be responsible for. Considering that perceptions on the meaning of circular economy should also be collected, the research is divided into two parts. The first providing perceptions on the notion of circular economy and serving as the base for the second which captures the perceptions on responsibilities for the change towards circularity.

Responsibilities are assigned to actions. Therefore, it is decided that the first part should focus on the changes that the actors within the supply chain perceive as needed for achieving circularity. Changes encompass multitude of information. They propose an action with the goal of altering the current state to the perceived needed one, and in that way they also provide insights about the notion of circular economy and the current state within the observed supply chain. It is also of interest to analyze the perceptions on the priority of those changes.

Based on deliberation above, this chapter is structured as follows. First, a choice is made on the data analysis approach that can accommodate all specificities of the problem at hand and yield wanted results. Second, methodology capturing and analyzing the perceived needed changes is devised. Third, using the results of the first part as input, methodology enabling gathering and investigation of perceptions on responsibilities for the perceived needed changes and importance of those changes is formulated. In the end, a validation procedure is postulated.

3.1 Choice of data analysis approach

In this part, a research approach is chosen that will be used for analysis of data in research methodology. Its goal is to provide results that are needed for successfully answering formulated research question(s).

First, the notion of circular economy implies the use of systems thinking approach. System thinking acknowledges and analyzes dynamical complexities of our world by taking a step back and looking at the system as a whole, rather than at only a small detached part (Senge, 1990). Therefore, the approach has to have the ability of assessing supply chain as a whole, but also enable "zooming in" to the levels of individual actors. Second, as stated in Chapter 2.2 (Stony materials supply chain), one of the main principles of circular economy states the need for integration of supply chains. This implies more social interactions between the actors in the supply chain. Furthermore, in theory of organizational structures this translates to a switch from the current "market" to "network" relations, which entails long-term cooperation between the actors motivated by matching interests. In addition, the goal is to capture perceptions of the actors, which entails cognitive data analysis. Moreover, the approach should allow for the ambiguity of the notion of circular economy. Summing it up, there is a need for an approach that can assess a supply chain both as a whole and on the lower levels of abstraction, such as branches or individual companies. Furthermore, it should appreciate supply chains as social networks, with relations of responsibility as connections between them.

Based on deliberation above there is but one approach that conforms to all of the stated criteria – the Social Network Analysis (SNA) approach. In the following part, the SNA is defined and discussed, and its fitness for purpose for this research is supported.

3.1.1 Social Network Analysis

Network perspective, which is embedded in the SNA approach, looks at any system as a set of interrelated actors (Scott, 2017). The notion of social structure is formulated as *"relatively prolonged and stable pattern of interpersonal relations"* (Freeman, Romney, & Freeman, 1987). Combining these two, *"the social network consists of a finite set or sets of actors and the relation or relations defined on them"* (Wasserman & Faust, 1994).

SNA is a research method that focuses on relations between actors within a predefined system (Wasserman & Faust, 1994). View of the SNA is that social environment can be expressed as patterns of regularities in relationships among interacting units. It applies systems thinking approach, as it takes a step back and analyze a set of entities and relations between them, rather than solely focusing on one individual. Within the SNA approach, these relations among entities, as well as the patterns and implications of these relations are captured and analyzed.

Following are expressions from the SNA vocabulary and their definitions that are needed for further development of research methodology:

- *Actor* is a discrete individual, corporate or collective social unit, which does not necessarily have the ability to "act" (Scott, 2017).
- *Dyad* consists of a pair of actors and the possible tie(s) between them. On a more general level, there is a *subgroup*, which represents any subset of actors and all ties among them (Wasserman & Faust, 1994).
- *Group* encompasses a finite set of actors who for conceptual, theoretical or empirical reasons are treated as a finite set of individuals on which network measurements are made (Wasserman & Faust, 1994).
- Network data set can include two types of variables (De Nooy, Mrvar, & Batagelj, 2011):
    - *Structural variables*, which measure ties of a specific kind between pairs of actors.
    - *Composition variables*, representing measurements of actors' attributes, defined at the level of individual actors.
- *Mode* is a distinct set of entities on which the structural variables are measured (Wasserman & Faust, 1994).
- *One-mode* networks are those with structural variables measured on a single set of actors. Consequently, network data set that contains two sets of actors is called a *two-mode* network (Wasserman & Faust, 1994). Special case of two-mode networks are *affiliation* networks. Instead of two sets of actors, they consist of one set of actors and another set of events or attributes (Borgatti & Halgin, 2011).
- *Island* represents a maximal connected subnetwork such that values of selected property inside island are larger than values of that island's neighbors (Batagelj, 2009).

Considering that the goal of this research is to capture perceptions on responsibility for the needed changes, it is clear that the resulting network will be a two-mode affiliation network. It consists from one set of actors that are perceived as responsible and a set of "events", that is, changes. The relation between them that is analyzed is that of responsibility. Actor X *is responsible* for change Y. Therefore, the following part deals with affiliation networks in more detail.

Affiliation networks, also called membership networks (Breiger, 1974, 1990) or hypernetworks (McPherson, 1982), are non-dyadic, two-mode networks in which entities from one set are related to each other through their joint affiliation with entities from the other set, rather than through ties in-between them (Wasserman & Faust, 1994). In other words, specificity of affiliation network is that the relations are not possible between entities from the same set. In this case, "membership" translates to "responsibility". An important

property of affiliation networks is *duality* (De Nooy et al., 2011). Duality of affiliation networks implies two additional perspectives that can be taken when analyzing them (Wasserman & Faust, 1994). One perception acknowledges links between the actors as a consequence of their affiliation with the same attributes, while the other identifies relations between the attributes by analyzing the actors that are their members (Breiger, 1974). Within this research it translates to relations between perceived responsible actors, based on their joint responsibility for changes on one hand, and relations between the changes identified from the same responsible actors on the other. Therefore, affiliation networks define relations in three ways (Scott, 2017):

1. Relations between actors and attributes/events.
2. Ties between actors determined by their affiliation (responsibility) with (for) the same attribute (change).
3. Ties between attributes (changes) established by the same actors affiliated (responsible) with (for) them.

Affiliation matrix captures the relations between two sets of entities, M and N. Therefore, it is a non-square, non-symmetric matrix with M rows and N columns, except in special case of equal number of entities in both sets, when it is square. It is represented as $A=[a_{ij}]$, where the element a_{ij} defines the relation (affiliation) between the entity i from set M and entity j from set N.

Summing it up, it is clear that the SNA approach fits perfectly within the scope of research. With the data analysis methodology selected, it is known which data is to be captured in the data gathering parts of the research methodology. Therefore, in the following part of this chapter, research methodology is fully developed.

3.2 Scope

First, a general scope of research has to be set. For this research this translates to identifying actors within the supply chain that is analyzed. An example of this can be observed in Chapter 2.2 (Stony materials supply chain), where four main actors in the stony materials supply chain were identified (demolition companies (DC), recycling companies (RC), primary aggregates producers (PAP) and concrete producers (CP)). Focusing on the SNA approach to data analysis, it is of importance to scope the two sets of entities, in line with the previous chapter. One set encapsulates the perceived needed changes, which are determined in the part one of this research, and it is completely fixed as such. The other consists of actors that are perceived as responsible for those changes. Considering that actors outside of the supply chain can be perceived as responsible as well, this set is not fixed. That is, it will be allowed to state whomever is perceived as responsible.

3.3 Part 1 – perceived needed changes

The goal of this part is to capture the perceptions of actors from the supply chain on the changes that are needed in order for the notion of circular economy to be successfully implemented. Furthermore, it aims at providing additional insights about the notion of circular economy and its state of affairs in the observed supply chain.

For this part of research, interviewing, as knowledge and information harvesting tool, is chosen as the perfect method for capturing the needed data. Current, high level of frenzy surrounding the notion of circular economy implies that relevant actors within the observed supply chain possess high level of knowledge on the subject and that they are willing to share it. Following is the formulation of the interview process that will result in the above postulated needed results.

3.3.1 Interview design

Following is the deliberation on the interview design. It is based on four important aspects: type of interview, choice of interviewees, formulation of questions and organizational aspects. The outcome is the interview process that will be used in part one of this research methodology.

First, a choice has to be made as to which interview type is the best fit for the problem at hand. Possible choices are open, semi-structured and structured interview types. Open interview type entails free-flowing and open conversation, which would allow for biased answers and a possibility of missing to capture the needed data (DiCicco-Bloom & Crabtree, 2006). Structured interview type, on the opposite end, encompasses a fully predetermined and directed approach, which is a good fit if the complete knowledge about the topic is available and if the data that is to be gathered is precisely determined (Turner III & Daniel, 2010). As already stated, circular economy is not strictly defined even on a general level. Not to mention the supply chain level with its specificities. Therefore, the structured interview type, because of its rigidity, is not a good choice. The only option left is the semi-structured type, which combines the best from both other types (Cohen & Crabtree, 2006). It consists from the questions that provide the general guideline for the interview, while remaining flexible as to how "deep and broad" the conversation will go. This approach allows for unbiased responses from the interviewees and at the same time gathering of desired data. Guiding questions ensure that all of the aimed-for areas are covered on one hand, while enabling the space for the interview to develop itself on the other. Therefore, the semi-structured interview type is selected for this part of the research.

Second, sound choice of interviewees is instrumental for ensuring the validity and relevance of the acquired data. Every actor that was determined as part of the analyzed supply chain should be interviewed. It is of importance here to relate the term actor to the actual situation. Namely, the actor refers to the branches, and not to the individual companies. Therefore, a representative from each of the branches should be interviewed. Furthermore, interviewees should be aware of circular developments in their branch, as well as knowledgeable about the notion of circular economy. Taking all of this into account, the choice falls on branch organizations. The reason for this is that they are representing the interests of all of the individual companies that are their members and are, therefore, well informed about the circular developments within the supply chain. Furthermore, they are also knowledgeable about the notion of circular economy.

Third, formulation of the questions that will guide the interviews is central to gathering all of the needed data. Based on the aim of this part of research they are divided into three groups: introduction, supply chain level and branch level. Introduction group has a goal of providing insights about the interviewee and his/her organization/company. Grasping the perception of the notion of circular economy and the needed changes for its implementation within the supply chain as a whole is the goal of the supply chain level group. And, the branch level group aims at capturing the specificities within branches themselves related to the notion of circular economy. The questions are formulated as follows:

Introduction

- What is your company about?
- What is your role within it?
- What is your view on the notion of circular economy? Do you see benefits in becoming 100% circular?

Supply chain level

- What are the criteria that need to be met in order for the supply chain to be considered 100% circular?

- What are the changes that need to occur within the supply chain in order to achieve circularity along these criteria?

Branch level

- What are the perceived needed changes within the companies in your branch for becoming more circular?
- Do you see any changes in the role of the companies from your branch in the market as a consequence of becoming more circular?

These questions represent a guideline for the flow of the interview. They identify the changes that are perceived as needed. Here, first observations can be made about the two arguments about the causes for inertia in the supply chains. Namely, difference in perception is checked by analyzing the number of changes that is recognized by more than one actor. And the diffusion of responsibility by looking into whether the most of changes are perceived at the level of the supply chain or at the level of one of the branches. These are not conclusive, but rather just pointing the probable direction of the supply chain. In addition, these questions provide overview of the perception of the current state of circularity in the supply chain, as well as perceived future developments.

Fourth, organizational aspects need to be carefully crafted, as not to hinder the relevance or validity of information captured. Semi-structured interviews allow for some degree of freedom in the flow of the conversation. Consequently, it is important to ensure that the answers from the interviewees are clear and unambiguous. Therefore, interviewees will be encouraged to further discuss every question up to the point where it is unequivocally clear what is meant by their answers. Relevance of the gathered data depends on having the same level playing field for all interviewees (Turner III & Daniel, 2010). Furthermore, perceptions are easily biased. Therefore, it is decided that there would be no discussion about the notion of circular economy prior to the interviews, and to keep a neutral stance during the interviews. Considering the qualitative nature of the information that are to be captured in these interviews, it is essential to provide an overview of data processing that leads to the final outcome, the perceived needed changes. Therefore, the interviews will be, first, recorded and then transcribed, followed by the approval of transcripts by the interviewees. From there, interview summaries will be extracted, and, in the end, a list of perceived needed changes will be formulated.

With the interviews set up as postulated above, gathering of relevant data in part one of research methodology is ensured. The output of this part of methodology is the list of changes that are perceived as needed for implementation of the notion of circular economy, together with the interviews summaries and transcripts.

3.4 Part 2 – differences in perceptions

Second part of research has a goal of capturing the perceptions of the actors in the stony materials supply chain on responsibility for the perceived needed changes that are gathered in the first part of this research. Furthermore, it has an objective of providing a clearer picture on the perception of the notion of circular economy within the stony materials supply chain by identifying the perceived rank of the changes. First, the data gathering procedure is formulated. After that, the process of data analysis is defined. The outcome is a fully formulated research methodology.

3.4.1 Data gathering – interviews

As already stated, the aim of this part of research is twofold – capturing perceptions of the actors from the supply chain about the responsibility for the perceived needed changes and about the ranking of the changes in terms of importance for implementation of the notion of circular economy. Considering that the needed

data is strictly defined, based on deliberation for the choice of interview type in the first part of research, structured interviews are chosen as the tool for data gathering. Input for the second part of research was provided by the branch organizations in the first part. Branch organizations represent the interest of all of their members, and therefore, their perceptions fluctuate around the mean perception of the companies within the branches. Based on this, it is decided that the companies from the branches will be interviewed in this part.

First, deciding on the number of actors that are to be interviewed, as well as the choice of interviewees is of essence. Theoretically, the higher the number of perceptions captured, the better the results. However, there are two limitations to that in this case. First, considering novelty and vagueness of the notion of circular economy in the stony materials supply chain, branches consist of companies with different levels of awareness and adoption of circular practices. On one hand, there are companies that are advanced and innovative when it comes to the circular economy - the frontrunners, and on the other hand those that are more traditional and conservative, that are lagging behind. The frontrunners are dealing with the circular approach on a regular basis, and consequently, they are knowledgeable about it and about the circular developments in the supply chain. Therefore, it is of interest to interview these, advanced, companies in order to capture the current advances in the supply chain. The second limitation is of a practical nature. Simply, considering that this research is done for a master thesis, the time available for conducting this research is limited. In addition, the number of interviewees per branch should be equal, in order to get relevant and comparable data on branch level. Therefore, it is decided that four companies, advanced and innovative when it comes to the circular economy, are to be interviewed per branch. As already stated, branch organizations represent the interests of their members. It follows that they have unique knowledge about the branch and the companies within it. Therefore, identification of frontrunners is done in cooperation with them. Namely, each branch organization is asked to produce a list of companies from their branch that are innovative and advanced in terms of circularity. From these lists, in a random manner, four companies per branch are selected. If one of those companies refuse, or is unable to, participate, it is replaced with another one from the lists, chosen again in a random manner.

Considering that the goal of these interviews is to capture perceptions of the companies, special care should be taken as not to influence these perceptions prior and during the interviews. In order to achieve that, changes are noted on cards and presented to the interviewees. These cards consist of two parts. The first provides the short description of the change, while the other a more elaborate one. These descriptions are based on the description of the perceived needed changes, formulated in the first part of research. The interviewees are instructed to first go through the short description, and then, if they are not clear on the meaning of the change in question, to proceed to the more elaborate one. If, after reading the more detailed description, they are still not clear on what is meant, only then, they are provided with a further oral explanation by the interviewer. By applying this approach the need for interaction of the interviewer and interviewee is minimal, and consequently, the possibility of biasing the answers is minimalized. In addition, the use of cards triggers the interviewees' engagement, as they demand physical manipulation.

The interview process is divided into two stages. In the first, the interviewees are presented with the stack of cards containing changes and asked to state one responsible actor for each of the changes. They are instructed to draw cards one by one and to state their answer, leaving the already drawn cards on the table. As already postulated, the set of responsible actors is not strictly defined, and therefore all answers are valid and accepted. If an actor outside of the scope of the supply chain that is analyzed is stated, it is assigned to the category "other" and it is noted exactly which actor it is. There is a possibility of different actors using different names for the responsible actors that are in essence the same. For example, depending on the context, a construction company and a contractor may be named as two different actors, when in essence they encapsulate the same meaning. As the interviews progress, a picture of what is meant by which actor becomes clearer, enabling the corrections of the interviewer on the exact name that is noted. These

corrections are applied only after discussion and explicit agreement of the interviewee during the interview. There is also a possibility that some of the interviewees do not agree with some of the perceived changes. Moreover, there could be a last minute cancelation of one of the interviewees, without the possibility of organizing another interview with a new company. Furthermore, it is possible that one of the branch organizations fails to produce a list with four companies In that case, they cannot be expected to give a perception on who is responsible for that change. In other words, a blank answer is recorded. In order to counter these potential issues a normalization procedure is devised. This procedure is postulated in Chapter 3.4.2.2 (Perceptions of responsibility – the SNA approach). Considering that the SNA approach is to be taken with the analysis of this data, the data gathering should facilitate making of the affiliation matrix. In order to allow for that, the answers will be recorder in a table (matrix) with the rows representing perceived needed changes and columns the perceived responsible actors. The cells represent the responsibility of the actor (columns) for the change (rows). Considering that the interview process entails that only one actor can be stated per change, the actor is either responsible or not responsible for a certain change. Therefore, the scores in the table are either 1, if the responsibility for the change is assigned to that actor, or 0, if it is not.

In the second stage the actors are asked to rank the ten changes that are in their opinion the most important. This part is second for two reasons. First, the interviewees are left with all of the cards describing changes in front of them at the end of the first stage, which makes it easier to address them all at once. Second, being acquainted with each of the changes in the first stage implies that the interviewees are knowledgeable about all of the changes and that they are able to prioritize the ten most important ones.

The outputs of data gathering are tables capturing each interviewee's perception on the responsible actors from the perceived needed changes and the perceived rankings of the changes.

3.4.2 Data analysis and results

Previous chapter defined the procedure of data gathering that will yield two data sets – one encompassing perceptions of the responsibility for the perceived changes, and the other capturing perceived ranking of the changes. This part formulates a method of data analysis that will enable answering of the formulated (sub)research questions. As with the two sets of data, there are two separate data analyses. First, analysis of the rankings of changes is formulated, followed by the analysis of the perceived responsible actors.

3.4.2.1 Ranking of changes

In the first part of research, each interviewee has selected ten changes that he perceived as the most important and ranked them from 1 to 10, where 1 means the most important and 10 the least important. Further analysis is conducted on two levels – branch and supply chain level. There is also the level of individual actors within the branch. However, this level is not of interest for further analysis in this case.

First, rankings of changes are aggregated on the branch level. This aggregation consists of counts of how many times have each change been ranked in total and for every point of scale (1-10). Then, the changes are sorted. First sorting filter is the total number of times that the change was ranked. The more times the change was ranked the higher it is placed in the list. Considering that there might be changes that were ranked the same amount of times, the second filter is introduced. The second filter looks at the amount of rankings per point of scale of importance (1-10) for every change. For example, if two changes have been ranked the same number of times, then the amount of times they were ranked as the first most important one is compared. If this is also the same, then the number of rankings as the second most important is looked at, and so forth. If, after taking into account the ranking as the tenth most important there are still some changes that cannot be separated, the final sorting is done by alphabetical order. This approach is similar to the one used for ranking success of the countries in the Olympic Games, which served as the inspiration. This is repeated for all of the branches and, then, on the supply chain level. Outcome of this

aggregation and sorting is the list of changes that are sorted according to perceived importance on the branch and supply chain levels. Considering that each change has a starting state (that is perceived as needed to change), an action (proposition of a change), and a new, circular, state (that is aimed for), it allows for a fruitful discussion about the notion of circular economy in the stony materials supply chain, based on the argument that perceptions determine the reality. It also facilitates the same discussion on the branch level, as well as comparison of perceptions between branches.

Another important measure on the branch level is formulated – the difference of perceptions within a branch. It is calculated as the number of changes that were ranked by companies from one of the branches divided by the total number of rankings that those companies made. Considering that 4 companies per branch are interviewed, the total number of rankings per branch is 4x10=40. In case that all companies from one branch have the same perception, and rank exactly the same ten changes, the result is 10/40=0.25. On the other hand, if the perceptions are completely different and each of the actors rank different ten changes (40 in total), the result is 40/40=1. Therefore, measure of difference of perceptions in a branch is a number, ranging from 0.25 to 1, which represents the level of uniformity of perceptions in the branch. The lower this number, the lesser the difference in (or the more uniform are) perceptions within a branch. This measure, besides quantitatively representing the differences of perception within a branch, also allows for comparison between branches, which will provide a relative reference for conclusion about the magnitude of difference between branches. It is also of interest to calculate this measure of difference in perceptions on the level of the supply chain, as it will provide insights into the dispersion of perception on that level.

Summing it up, analysis of the rankings of the changes, explained above, yields a list of changes arranged according to their perceived importance. Furthermore, it also results in the measure of difference in perceptions on the branch and supply chain levels.

3.4.2.2 Perceptions of responsibility – the SNA approach

The other part of data gathering provides the perceptions of the companies on the responsible actor for each of the changes in form of the tables, as described in Chapter 3.4.1 (Data gathering – Interviews). Three different levels of analysis are relevant for this research – individual actor level, branch level and supply chain level. Following is the step by step process of data analysis of perceptions of responsibility.

1. Aggregation – individual actor level

The starting point is the table encompassing perceived responsibility for the changes, represented by ones and zeros. There are a limited number of actors that are perceived as responsible. Therefore, the first step is to sum up the assigned responsibilities per actor. In other words, the number of times one actor was stated as responsible. This translates to summing up all values in each of the columns of the table. In parallel the whole table is summed up as well, resulting in the total number of responsibilities assigned by that particular interviewee. Then, for each perceived actor, "percentage of responsibility" is calculated as the number of times that actor was assigned responsibility divided by the total number of assigned responsibilities and multiplied by a 100. For example, if actor X was perceived as responsible for 13 changes, and the total number of assigned responsibilities is 39, then the percentage of responsibility for actor X is $\frac{13}{39} * 100 = 33.33\%$. "Percentage of responsibility" of each actor is represented in a graph, with this percentage on the vertical axis and the responsible actors on the horizontal axis.

2. Aggregation – branch level

This part deals with aggregation of results on the level of a branch. A number of companies from each branch provided input in the data gathering stage, which are all processed according to the aggregation on an individual actor level. Considering that different interviewees perceived a different set of actors as

responsible, it is not possible to directly add up these results. Therefore, a new table is made which has perceived changes as rows and all of the actors perceived as responsible by the companies from that branch as columns. This table is populated by the summed up perceptions of the interviewees. For example, if interviewee A assigned responsibility for change 3 to actor X, and interviewee B has also perceived actor X as responsible for change 3, and all other interviewees have perceived some other actor as responsible for that change, then the value in corresponding cell in the table would be 1+1=2. After this, summation in line with the process in step 1 is conducted, resulting in the "percentage of responsibility" for each actor on the branch level. This enables comparison between branches, but also provides additional insight to the analysis of perceptions on the level of individual actor. Similarly to the individual actor level, a graph is made representing the "percentage of responsibility" on the branch level.

It is of interest to analyze differences in perceptions between interviewees. Therefore, a "difference in perceptions" parameter is formulated. It is determined for each pair of interviewees and, additionally, between each interviewee and the aggregated branch level "percentage of responsibility". It is calculated as a sum of absolute values of difference in "percentage of responsibility" between two interviewees (or one interviewee and the "percentage of responsibility" on the branch level) for each perceived responsible actor. For example, if interviewee A assigned 50% of responsibility to actor X, and interviewee B assigned 20% to the same actor, then the "difference in perceptions" between interviewees A and B for actor X is $|50 - 20| = |20 - 50| = 30\%$. The higher the score the bigger the difference in perception between two interviewees and consequently, the bigger the (potential) clash between them.

Following from Chapter 3.4.1 (Data gathering – interviews) is the need for normalization of results in order to allow for aggregation on a higher (supply chain) level, blank answers, or the differing number of interviewees per branch. The basis for this normalization is the assumption that the perception of each branch is equally relevant. This is in line with the notion of circular economy, which proclaims integration of the supply chain and, consequently, the responsibility of all actors from the supply chain. Therefore, the total responsibility for each change is set to 1, and then divided between the actors that were perceived as responsible for that change proportionately to their non-normalized scores. Considering that there would be four interviewees per branch, there would be between zero (if all of the interviewees disagree with the change) and four responsibilities assigned per change. In the case of zero responsibilities assigned, that change would not be normalized but left with the value zero. As for the one with the four assigned responsibilities, the following example clarifies the process of normalization. If, for change 3 there were four responsibilities assigned to actors X, Y, Z and W (scoring 1 each), the normalized score of each actor would be 0,25. In other words we divide the responsibility scores of each actor with the number of assigned responsibilities for that change. If actors X, Y, Z had, respectively, 2, 1, and 1, responsibility score, then the normalized scores would have been, respectively, 0.5, 0.25 and 0.25. If there were three responsibilities assigned to three actors (each scoring 1), then the normalized responsibility score for those actors would have been 0,33. And so forth.

Branches can, in themselves, be considered networks that encompass companies that are their members. Therefore, the SNA approach can be applied. The "percentage of responsibility" table on the branch level represents the affiliation matrix. One set of entities are perceived changes, and the other perceived responsible actors. The values in the matrix represent the level of responsibility of a particular actor for a particular change. The higher the value, the bigger the responsibility. This affiliation matrix is turned into a graph with the use of the "Pajek" software package. The graph consists of the responsible actors and changes, with the lines between them representing the relation of responsibility. Special feature of this graph is that both actors and changes are arranged in a unique way, based on the zero-energy principle which takes into account the level of responsibilities between these two sets of entities. Therefore, the higher the responsibility score of an actor for a change, the closer they are on the graph. In this way an effective

overview is given of each branch, from which it is possible to observe the importance of actors and/or changes and relation between them.

3. Aggregation – supply chain level

Following a similar procedure as for the aggregation on the branch level, the perceptions are aggregated on the supply chain level. The important difference is that the normalized scores are used. The result is "percentage of responsibility" on the level of the supply chain. Also in line with the analysis on the branch level, "difference in perceptions" are calculated, with the difference that instead of individual actors, now the branches are in the focus. Considering that there is no higher level of analysis, there is no need for normalization of results on the level of supply chain. Therefore, the maximum total score of responsibility per change is 4. It is smaller if one of the changes was not agreed upon by at least one of the branches.

Another parameter that provides insights into the differences of perceptions is the number of actors perceived as responsible for a particular change. Ideally, the whole supply chain would have the same perception of responsible actors. That is, each change would have only one actor that is perceived as responsible for it by all interviewees. Analysis of the number of responsible actors per change shows the difference of perceptions per change between the interviewees. This adds additional perspective because it provides insights per change, in contrast to the "percentage of responsibility" and "difference in perceptions" parameters that are focused on responsible actors.

Initially, the SNA is applied in line with the analysis on branch level, resulting in a zero energy graph. However, as postulated in Chapter 3.1.1 (Social Network Analysis), an important aspect of two-mode networks is their duality. Two additional perspectives can be taken when conducting analysis. One analyzing the relations between actors based on the same changes that they were perceived as responsible for, and the other analyzing relations between changes based on the same actors being responsible for them. Again, a zero-energy graph is chosen for representation. This will provide insights into the actors that have to collaborate more extensively, and changes that should be tackled together. Although the "Pajek" software package has the ability of capturing these additional perspectives, it is of importance to understand the underlying process. Following from Chapter 3.1.1 (Social Network Analysis), affiliation matrix is a non-square, non-symmetrical matrix with the dimensions MxN, defined as $A = a_{ij}$, where $i \in [1, M]$ and $j \in [1, N]$. In our case set M consists of perceived needed changes, and set N of perceived responsible actors. Between these two sets relation of responsibility is observed, with a_{ij} representing the level of responsibility of actor j for the change i. In order to capture the additional perspectives, there is a need for transformation of the affiliation matrix. Namely, a two-mode MxN affiliation matrix needs to be transformed into two one-mode matrices, X^M and X^N, with dimensions MxM and NxN. This is achieved with the following operations (Wasserman & Faust, 1994):

$X^M = A^T * A$, whose entries record the level of responsibilities each pair of actors share.

$X^N = A * A^T$, that records the amount of responsible actors that each pair of changes has in common.

4. Perceived needed changes – differences in perceptions on responsibility of the actors

Each of the branches has its own perception of responsible actors. These perceptions, when aggregated, represent the perception of the supply chain. All of these perceptions are different and this part aims at providing further insights into the level of these differences by sorting changes for each important actor based on the perceived responsibility of that actor, for the perceptions of all of the branches and the supply chain. Importance of actors is determined based on the "percentage of responsibility", with the actors that were recognized as part of the supply chain included in any case. For example, if actor X is assigned different responsibilities by interviewees, and therefore, he is perceived responsible for different changes by different

branches. Sorting the changes per responsibility of each actor for each of the branches provides an overview of the difference in perception of the branches and the supply chain.

3.5 Validation of results

In order to ensure that the results are measuring the intended aspects, validation procedure is formulated. Branch organizations provided input for the first part of research. This input was then processed according to part one of the research methodology, and used as input for the part two, which yielded the final results that are to be validated. Furthermore, branch organizations represent interests of all of their member companies. Considering that part two of research methodology is focused on those companies, branch organizations can relate to these results and provide underlying reasons for the choices that were made. Moreover, branch organizations are knowledgeable about the notion of circular economy and current developments in the supply chain. Therefore, it is decided that the results are validated by the branch organizations.

Validation is organized in the form of a workshop, with representatives of all of the branch organizations present. During the workshop, the results are presented and the branch organizations representatives are asked to reflect on them. Namely, whether they recognize those results and what is the reasoning behind the answer that is provided. First, the results of each of the branches are shown, with the focus on feedback from representative from that branch, but with allowing the other representatives to contribute to the feedback if they wish to. After all of the branches are covered, results on the level of the supply chains are presented and the feedback from all representatives is gathered. Aside from validating results, this approach also provides some insight into the possible interpretation of results and the underlying reasons behind them.

With this step the research methodology is complete. Graphical summary of it can be observed in Figure 4. In the next chapter, results coming from application of this methodology to the stony materials supply chain are postulated.

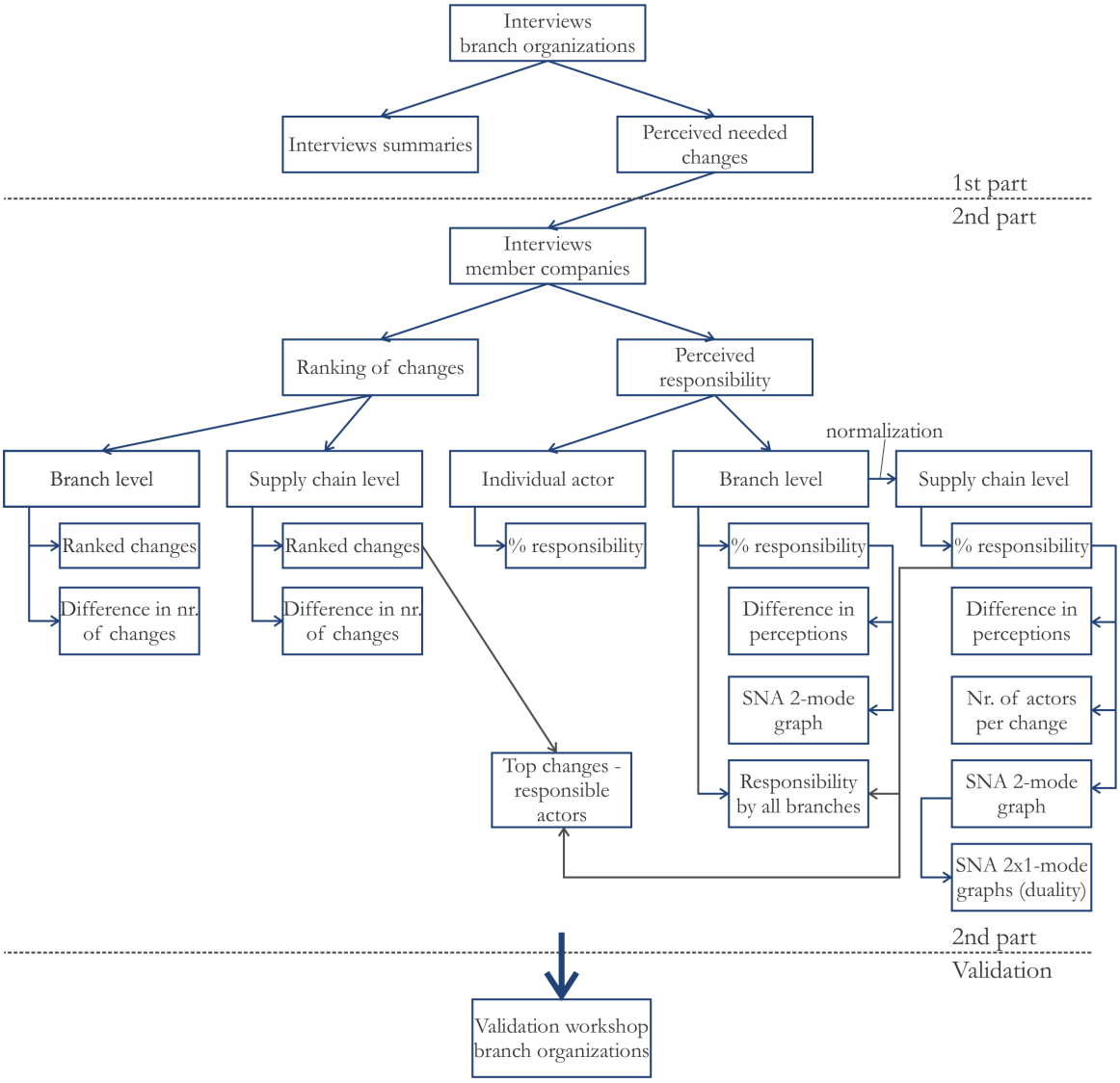


Figure 4: Research methodology

4 Inertia in the stony materials supply chain – underlying reasons

This chapter represents the results that are stemming from application of research methodology, formulated in previous chapter, to the stony materials supply chain and their implications for the inertia in the stony materials supply chain. First, results from part one of research are postulated, encompassing summaries of the interviews with the branch representatives and changes that were perceived as needed in order to achieve circularity. Second, the results of part two of research, focusing on perceptions of the actors in the supply chain, are postulated. Third, main observations from the validation workshop are postulated. Fourth, a summary of the main observations from the first three parts is formulated. In the end, interpretation of these observations in regard to inertia in the stony materials supply chain is conducted in the form of a discussion. This chapter provides an answer for the third research sub-question, which is formulated as: *"What are the underlying reasons for inertia in relation to the change towards circularity in the stony materials supply chain?"*.

4.1 Part 1 – perceived needed changes

In line with Chapter 3.3 (Part 1 – perceived needed changes), interviews were conducted with the representatives of demolition companies (DC), recycling companies (RC), primary aggregates producers (PAP) and concrete producers (CP) branches. Formulated methodology prescribes branch organizations as best fitting representatives for these interviews. However, in this case, there was one exception. Namely, the RC branch organization already provided input in the exploratory phase of this thesis. Therefore, it was decided not to use their input at this point. A recycling company, selected by the branch organization based on the formulated criteria, took its place.

4.1.1 Interviews summaries

This part postulates the summaries of the interviews conducted with the branch representatives. Full transcripts of these interviews can be found in Appendix B of this thesis. The summaries of the interviews with branch representatives are laid down in the following order: DC, RC, PAP, CP.

4.1.1.1 Demolition companies (DC)

VERAS is the national branch organization of demolition companies and asbestos removal companies. It represents around 100 demolition companies and 30 suppliers (law firms, education institutions and equipment producers). The interviewee (in further text DC) has the role of association manager, with the main duty being that of representing interests of its members. DC acknowledged the circular economy as one of the main things on the agenda of the association. To support this he stated that a policy was set up a few years back, with one of the goals being stimulating role of demolition companies within the circular economy.

4.1.1.1.1 Perspective on the notion of circular economy within the stony materials supply chain

DC pointed to exhaustion of primary resources as the underlying reason for becoming circular. He also stated that he thinks that achieving 100% circularity is not possible, but that everyone needs to do their best.

DC stated that the circularity is achieved when there is the ability to produce the material that is recyclable every time when it is at the end of its life. He added that the stony materials should be kept in the chain after demolition.

4.1.1.1.2 Perceived needed circularity-boosting changes and challenges on the level of the stony materials supply chain

When speaking about keeping the stony materials in the supply chain, DC said that this should be done by making them profitable. This implies that reinserting the stony materials in the supply chain is not profitable at the moment. This further connects with the need for a new way for appraising value, which will take into account all of the benefits of the circular approach.

According to DC, another important aspect of enabling circularity of stony materials is taking care of their quality, which is ensured with the separation at the source. Continuing, he adds that both separation at the source, as well as the minimum amount of demolished materials that has to be recycled should be prescribed within the procurement procedure with their customers. Customers are building owners, municipalities, etc.

Another change stated by DC is the need for change of behavior throughout the supply chain. Especially, the customers. New role of the demolition companies in circular economy as materials providers needs to be appreciated. Considering the current "as soon as possible, as cheaply as possible" approach to demolition, it is clear that this needs to change if the highest value is to be extracted from the demolished materials. More time is needed in order to have a careful demolition process. More space is needed in order to enable separation of materials at the source. More money is needed for treatment of materials that are more difficult to separate. From the technical viewpoint, demolition companies can treat and separate any material. Therefore, the triangle of more space, more time and more money needs to be provided to demolition companies in order for a high value demolition, reuse and recycling to take place. Also, DC sees the benefits in introducing new legislation that would encompass these perceived changes.

DC said that the pre-demolition audit must become an integral part of the demolition process. This encompasses making a materials passport of the building prior to its demolition. In this way the demolition process can be chosen and organized in a way that yields the most value out of the demolished materials.

Also, DC recognized transport of the stony materials as an important factor when making decision on the best treatment process and reuse. He provided an example of some contractors having demolition contracts with companies that are 50 - 80 kilometers away, while there were companies that were in immediate surroundings.

4.1.1.1.3 Perceived needed circularity-boosting changes and challenges on the level of the demolition companies' branch

DC identifies for self-promotion of the demolition companies, with the focus on their new position within the notion of circular economy in which they do not only demolish, but also offer new materials to the market.

4.1.1.2 Recycling companies (RC)

As reasoned earlier, based on recommendations from the recycling companies' branch organization (BRBS), a recycling company was selected as the representative of the recycling companies branch. It is a waste logistics and processing company that also supplies the secondary building materials. It mostly processes two types of waste, mixed demolition waste that is sorted in different types, and rubble (or debris waste) that is crushed, screened and washed with the goal of reuse in the production of new concrete. It processes 600000 tons of stony materials every year, of which some 150000 go back to the concrete industry.

The interviewee has the position of general manager (in the following text referred to as RC), with the responsibility for the functioning of the company, as well as for the investments and innovation within the company.

4.1.1.2.1 Perspective on the notion of circular economy within the stony materials supply chain

RC sees the notion of circular economy as something that has to be implemented for two reasons. First, he states that there is no choice because the reserves of primary materials are ending. He also adds that if we want to ensure equal quality of life and opportunities for future generations, realizing circular economy is mandatory. Second, he identifies new business opportunities that are to be realized within this new approach as the opportunity that is not to be missed and that it will drive the implementation of circular economy forward. Following from this are his expectations that the business models based on "product out of waste" approach will blossom in the coming years.

4.1.1.2.2 Perceived needed circularity-boosting changes and challenges on the level of the stony materials supply chain

First of all, RC acknowledged that the circular economy as a term is not yet fully defined and that it is open to interpretation, which further complicate the realization of the notion of circular economy. This implies that there is a need for a precise definition of the circular economy that is accepted, understood and used by all of the actors in the supply chain.

Then RC identified, as a first step, the need for raising awareness about the added value of the reuse of stony materials throughout the supply chain.

As a second step, he stated that the process needs to be fully transparent. It is clear from the transcript that by this he meant information and knowledge collection and sharing. RC gave an example of the Schiphol airport, which will have over 2000 (re)construction projects in 2018 with large amounts of stony materials as waste. The people from the Schiphol airport approached them in order to see what can be done with the excessive amount of waste that will be produced. RC's point was that it is important that the people from the Schiphol airport are informed about all of the possibilities for the waste treatment or reuse on a product level, because only then can they make the right decision. In order to know in which way this waste can be best reused/recycled free information flow is needed on all levels.

Next, RC pinpointed the importance of adequate pricing, especially for the demolition companies. He states that the demolition companies usually work for a small amount of money, which rids them of incentive to perform a quality separation of materials within their process. This then resonates through the supply chain, with a significant rise in the effort for achieving the needed quality of the waste materials, and therefore, also of the costs.

RC said that if the circular economy approach is going to work only when the whole supply chain is integrated around it. He added that there are difficulties with this integration occurring. The main problem is the thinking in the ways of the old (linear) economy. In addition, everybody has their own interests which are different and not oriented towards the notion of circular economy. From here it is concluded that there is a need for a new way of appraising the value which will include the benefits of becoming circular, and therefore, steer the interests towards the implementation of circular economy. In other words, the actors within the supply chain need to see and align their interest in adopting a circular approach. RC also stated that he finds the voluntary working groups that they were a part of highly inefficient because of the above stated reasons. As an example he gave the Concrete Agreement. There here been talks now for over three years between the actors and nothing has yet been accomplished. RC added that it would be ideal if the government would play a part in realizing the notions of circular economy by putting them in the law. He

also said that the investors also need to realize the potential of adopting circular approach. That is, of being able to reuse the building components on a product level.

4.1.1.2.3 Perceived needed circularity-boosting changes and challenges on the level of the recycling companies' branch

RC stated that he believes that the recycling companies as we know them today will not exist in about 30 – 40 years. As the circular approach advances, more and more materials will be reused on the product level, rather than being recycled. Therefore, there would be almost no need for recycling companies. Because of that he stated that the recycling companies need to somehow shift their business models. In his opinion, recycling companies will switch to a role of producers of end products, instead of current waste processing. He predicted that this will occur in parallel with the integration of the concrete and recycling companies. The result would be a small number of large companies that will offer everything under one roof and that will cover almost the whole market. Until this time comes, recycling companies need to introduce new technologies that will perfect the recycling process, and to actively seek to collaborate with the whole supply chain. Or, as RC put it, recycling companies have to, on one hand, innovate and, on the other, to participate in the whole value chain.

4.1.1.3 Primary aggregates producers (PAP)

Cascade is the branch association of the primary aggregates producers. It represents 14 companies, which cover 85 – 90 % of sand and gravel production market in the Netherlands.

The interviewee has the role of association director (in the following text referred to as PAP). Her role within the Cascade is association director, with the main duty being that of representing interests of its members. PAP stated that the circular economy is important for them as it affects their both day to day and future business.

Considering that the extraction of raw materials is to be minimized in the circular economy approach, it follows that anything other than stopping the extraction within the primary aggregates industry is unacceptable. However, if the situation in the Netherlands is fully appreciated, it may turn out that this is not the best option. This is based on the following reasoning of PAP. Specific situation within the Netherlands makes the primary aggregate industry different from the rest of the European countries. The Netherlands is basically a large river delta. Primary aggregates are located in and around the rivers, making them abundantly available. Furthermore, water safety is an important issue in the Netherlands. In order to secure it for the future, there is a national "Room for the rivers" plan. This plan proposes widening of the river basins throughout the country. This lead to extraction of primary aggregates at the locations where the needed widening is planned. These widenings would take place anyhow, but without the extraction of aggregates, there would be a problem of where to place the excavated land. Moreover, as the final stage of the extraction process the companies create natural and recreational areas in place of what mostly was heavily fertilized agricultural land. In addition, these projects are not financed by the taxpayers' money, but by the industry itself. Therefore, if a wider picture is considered, the production of primary aggregates might prove to be beneficial, even in the circular approach.

4.1.1.3.1 Perspective on the notion of circular economy within the stony materials supply chain

PAP states that the circular economy is a good new approach, but that the wider picture of sustainability needs to be taken into account when implementing it. However, are these really different? As already discussed, the notion of circular economy encompasses the negative externalities. Here, again, the vagueness of terms sustainability and circular economy is recognized as the problem that needs to be addressed.

4.1.1.3.2 Perceived needed circularity-boosting changes and challenges on the level of the stony materials supply chain

Stemming from the previous statement, and according to PAP, there is no unified understanding on the meaning of the circular economy approach in the stony materials supply chain. Therefore, there needs to be a precise definition of the circular economy, which is accepted and used in the whole supply chain.

PAP also states that a big problem is current disproportion between the theory, perceptions and reality regarding the circular economy. There is a lot of political pressure coming from the plans on both the European and national level, which supports the circular economy. These have adverse effect on the government officials who, without any real knowledge, blindly follow the perceived circular path. But as already stated, the definition of circular economy is not yet formulated. Therefore, their perceived notion of circular economy is usually based only on what is written in the plans or reports and their own, very limited, insights. This perception encapsulates building only from the reused or recycled materials at any cost, and completely excluding the primary aggregates. PAP stated that companies from her branch have already started to have difficulties because of this. However, the reality is different. In the best case, only 20 % of the current use of primary aggregates could be replaced with the secondary ones. This means that at least 80 % have to come from the primary aggregates producers.

Furthermore, PAP stated that the longevity of concrete structures implies that the structures that we are aiming at circulating today were built some 50 years ago. These structures were not designed with circularity in mind and it is very hard to reuse the materials from them. When these buildings are demolished we are left with the stony materials rubble, which contains concrete, masonry, etc. If we want to be able to put 20 % of secondary aggregates in the new concrete, we need to take the concrete out of this rubble. This is difficult and costly, because the buildings were not designed to facilitate it. In this way we get the appropriate secondary aggregates for reuse in the concrete industry, but the quality of the rubble is lowered, and it cannot be further used as the foundation material. This have further implications. The masonry materials cannot currently be reused in any way other than as a part of the stony materials demolition rubble in the road foundations. Therefore, if the concrete is taken out of the rubble, there is a problem of what to do with the masonry materials. Furthermore, there is also the question of what will then be used as the foundation materials for roads, housing developments, etc. PAP states that in her opinion there would not be a significant drop in demand for these foundations, contrary to what some of the reports say. Rubble is a good choice for this use because of its physical characteristics. Namely, the angular shape of the stony materials within it provide good stability for the foundation, which translates in to the possibility of using less cement and asphalt for the roads. Therefore, we have this paradoxical situation, where in achieving the maximum perceived circularity, we are creating new, potentially worse, problems. It is the opinion of the PAP that this is not a good approach.

PAP points out that longevity of structures also implies that this gap between supply of the secondary aggregates and demand for aggregates in the building industry will not close any time soon. First, the fact that we are building much more today than we used to build 50 years ago makes it clear that there is no way of building new structures completely out of recycled materials. Furthermore, the fact that nothing but the first life cycle was taken into account when designing buildings 50 years ago limits our ability to separate and treat those materials today. This reasoning shows that there would be demand for primary aggregates for a significant amount of time. Therefore, the current forcing of using the recycled aggregates at any cost is not sustainable in the long run.

PAP also singles out the current tendency to use more "dirty" aggregates and materials for production of new concrete as not beneficial for achieving circularity. These dirty materials consists of various health damaging, toxic, or materials that make further recycling impossible. The main point is that this approach appears as circular, but in the long term, because of impossibility of reuse or recycling in the next life cycle,

it is not. She gave an example of the use of the ashes from the incinerators in the Netherlands for production of new concrete, stating that these materials are harmful and disable recycling of the concrete that contains them for the next life cycle. PAP added that it is only worse if we know that the Netherlands is importing waste from other European countries in order to keep the incinerators running. Therefore, the concrete in the Netherlands contains incinerated waste from all across the Europe.

Another important point that PAP made is related to the government's support to the perception of having to reuse materials at any cost. In Netherlands there is a law called MIA/VAMIL that says that anyone that uses more than 30% of recycled aggregates gets a tax benefit. In theory, this law should boost circularity, but in reality, it resulted in excessive import of recycled aggregates from abroad. Nobody accounts for the transport that is needed for importing these aggregates, and which makes the whole thing absurd because of its use of energy and harmful emissions.

PAP stated that recycling is the last option. The current way of building should be stopped and shifted to the one that ensures reuse on a product level, and eliminates the need for recycling completely.

PAP stressed that in order to build in a circular way today, a choice of materials that would be used needs to be made based on the time when these materials are available; whether they are primary or secondary; location of the materials (and needed transport); quality; ability to be reinserted into the supply chain at the end of life cycle; and also taking into account other building projects in the vicinity. With taking all of this into account we can determine the optimum mix of primary and secondary aggregates. Another important point is to change the current practice of ordering the concrete one day before it is needed in order to allow more time for the analysis of the options. In other words, it is needed to plan ahead.

In order to enable the choice from the previous paragraph to be made, PAP says that a large database containing all the materials and products that are available in the urban mine is needed. This implies that the digital technologies can facilitate the notions of circular economy. It also hints at free sharing of the information within the supply chain and trust between the actors. PAP also states that the whole supply chain has to work together, if it is to achieve circularity. She also notes that that is currently not the case.

PAP singled out the law-prescribed use of the LCA (Life Cycle Assessment) as having the positive effect. However, she noted that it is far from perfect and that a new way of assessing value needs to be formulated, or the existing one changed. There are some developments in perfecting the existing LCA. For example, a new Module that is to be added to the LCA. The Module D, which aims at introducing the value of the materials for the following life cycles to the LCA. Another example is the development of material passports within the project called Madastar. There are also developments on the EU level with the formulation of a tool similar to the Dutch LCA. It is called PEF (Product Environmental Footprint]. Currently, the Netherlands is the only country in the European Union that uses the LCA.

PAP also stated that they are participating in the development of the Concrete Agreement. She also said that they are not content with how the process is organized, but she thinks that it will help a bit with the circularity.

4.1.1.3.3 Perceived needed circularity-boosting changes and challenges on the level of the primary aggregates producers' branch

PAP stated that considering that because the members of the association are raw material producers, and that they already contribute to the water safety and creation of nature and recreational areas, there is not much more they could do to boost circularity.

4.1.1.4 Concrete producers (CP)

BFBN (in the meantime became BetonHuis) is the branch organization of the concrete producers. It encompasses around 90 precast concrete producers, between 20 and 25 ready-mix concrete producers and

3 cement producers. Its members employ more than 6500 workers and have a combined turnover of around 1 billion euros.

The interviewee (in the following text referred to as CP) has the role of an advisor dealing with durability, sustainability and health, environment and safety within the concrete producers' branch. He confirmed that the circular economy is part of his responsibilities and stated that it is currently one of the hot topics in the branch.

4.1.1.4.1 Perspective on the notion of circular economy within the stony materials supply chain

CP stated that sticking with the linear economic model is not an option anymore, and that becoming circular is the way to go. He also noted that there have been developments within the branch regarding the circular economy for some 10 years now, with the ideas of flexible and industrial construction at the center. In his view, circular economy is achieved when we are able to reuse all of the materials that are coming to their end of life. Also, figuring out the way to achieve that is a priority, with the waste treatment hierarchy (ladder of Lansink) providing a good guideline. CP pointed out that from the viewpoint of circular economy and sustainability the best option is not to build any new objects. However, he admitted that in reality this is not possible.

An interesting observation was that the circular economy should not become an ideology, but that a wider picture of sustainability needs to be taken into account. In other words, circulating the products and materials at any cost can prove to be a bad option. An example of this, according to CP, is that when some end-of-life materials are becoming available at one location and there are no new developments in the vicinity, the transport costs, both monetary and environmental, that are incurred with moving those materials to a place where they can be reused make it an unviable option from the viewpoint of circular economy. This points to the fact that both terms, sustainability and circular economy, are not precisely defined. Many different interpretations are possible, which leads to confusion and contradictions as the one above.

4.1.1.4.2 Perceived needed circularity-boosting changes and challenges on the level of the stony materials supply chain

Ambiguity of the term "circular economy" implies the possibility of different interpretations of its meaning. This, in turn, hinders any meaningful discussion on the subject. If we take a look at the definitions of the circular economy that are given in Appendix A (Circular economy) of this thesis, the above given example does not hold. These definitions encompass "keeping materials at their highest value at any time" and "real costs that incorporate negative externalities". If this view was applied, it is clear that the transport and its costs, from the example above, would have been taken into account and the materials would not have been transported at all. This problem is further reinforced with the statement of CP that the supply chain is already circular, hinting at the current down-cycling into the road base materials. This contradicts the notion of circular economy discussed in this thesis, where the down-cycling is not recognized as an appropriate way of dealing with waste. CP also recognized this ambiguity with the statement that it depends on the definition used. Therefore, there is a need for formulating a definition of circular economy in the stony materials supply chain that is accepted and used by all of the actors within the supply chain.

CP also identified transport of end of life materials throughout the process of reusing them as an important factor when dealing with circularity. Simply put, the real costs of transport will determine a particular distance, which will mark the threshold for transport feasibility. This naturally points to the concept of geographical distribution. Geographical distribution comprises of defining geographical areas in which materials could be reused or recycled. In this way it is ensured that the transport costs, both internal and external, are not too high and that those do not make the whole process of reuse/recycling obsolete.

Another important challenge that came up during the interview is the longevity of concrete products. It has multiple implications for implementation of circular economy approach. CP stated that because of long life-cycle (30-50 years) of concrete products, we have to plan and design with future in mind. That is, to think of how are the materials that are used today going to be reused at the end of their life-cycle. He added that this is by no means easy, but that it has to be done because doing nothing is not an option. An example that was given was that of the mayor house in Woerden. The mayor house was supposed to be moved to an old office building. However, the interior structure of the office building was not up to the task. It was decided that the skeleton (load bearing construction) of the old office building should be used as the basis for the new mayor building. The point here is that if it is possible to reuse parts of the structure that were not designed for that, imagine what could be done if the whole product was designed for reuse. CP specifically singled out the need to design for reassembly at the end of life cycle. This approach also encompasses the standardization of concrete products and modular constructions.

CP acknowledged that building regulations or needs of people might change in such a long time, implying that the planned reuse of the product will become impossible. However, he points out that we have many levels of reuse, from the product level to material level, and that we have to explore each of those. He signifies the waste treatment hierarchy (ladder of Lansink) as the enabling tool in this process. He also mentions that we do not have answers to many questions, but that we need to keep thinking. Also, he acknowledges that new ways of dealing with challenges of becoming circular will come up, as long as we are dedicated to it. From here, it is hinted that further research is needed across the supply chain in order to identify and enable all possible reuses of concrete products and materials.

Another aspect that has to change, according to CP, is the current practice of focusing solely on costs when making decisions in the supply chain. This makes the notion of circular economy unattractive. A new way of appraising value needs to be devised in order to support circular business decisions. One that encompasses both benefits of the circular approach and disadvantages of the current linear economic model. He proposes the life-cycle assessment as the tool that is adequate for this purpose. He also hinted that there are some developments that aim to accommodate the reuse of materials within it. He also points out that the ISO 14000 standard dealing with the environmental life cycle assessment already allows for this. However, these parts of the standard are not used in the Dutch NEN-ISO version of the standard. In support to this CP also recognized the need for formulation of the value indicator.

CP states that there must be a way of making informed decisions on the best way of dealing with the end of life cycle materials that will take into account all of the relevant aspects. It could be that reuse at the material level is better, even though reuse at the product level is also possible. This certainly connects to the already discussed transport aspect. As well as with the need for further research and integration of the actors in the supply chain. Therefore, a tool for assessing the most beneficial treatment of the end of life-cycle products and materials has to be developed. In line with this, CP said that recycling the materials from the supply chain to the road base material could also be beneficial. In that case, we can look at the road bases as the material banks. This is because the quality of materials used in this way is kept at the same level, which enables these materials to be inserted back into new concrete products at the end of life-cycle.

Designing and planning for the future, as well as the needed further research imply the need for integration of the actors in the supply chain. This is backed by the CP's statement that everyone from the supply chain has to be involved, ready for cooperation and with alike circularity awareness level. He also recognized the Concrete Agreement as beneficial for this cause. In connection to this, he also added that the awareness about the notion of circular economy needs to rise within the supply chain.

4.1.1.4.3 Perceived needed circularity-boosting changes and challenges on the level of the concrete producers' branch

Wide variety of concrete products implies that there are different quality requirements for the materials used for their production. As CP states, almost everything is made out of concrete, from pavement systems, sewerage pipes, structural elements, walls, roofs, tiles to kitchen working surfaces. These different quality requirements can limit the amount of recycled materials that can be used for their production. For example, for sewer systems it is of utmost importance that they are watertight. Stony materials often have some small percentage of residue plastics, timber or masonry, which can allow for forming of porous sections in concrete pipes. Therefore, using stony materials in this case is not desirable. Another example are concrete kitchen surfaces that are smooth and polished, which is impossible to achieve if the stony materials are used as aggregate. In addition to this, he said that the concrete products could be contaminated during their life cycles on such a level that they cannot be reused even in the road base construction. Example of this are concrete pavements, which can get full of oil. CP said that, on the other hand, some other products allow for high percentage of stony materials. However, he stated that for this reason some of the goals defined in the Concrete Agreement are unattainable. Namely, the one stating that all end-of-life concrete is to be reinserted into the concrete chain as well as the one stating that the minimum content of recycled concrete aggregates in new concrete should be 5%.

4.1.2 Perceived needed changes

Interviews were conducted with a goal to capture the perception on the changes that are needed for transitioning to circular economy in the stony materials supply chain. These changes contain in themselves information about the current state within the supply chain, an action and the perceived circular state that is to be achieved. In this way, a complete picture regarding the notion of circular economy is formulated for the stony materials supply chain. In total, forty changes were identified. These changes are postulated in Table 1. From left to right, the table consists of a short description of a change, which of the interviewees perceived it as needed and a more elaborate description of the change and reasoning behind it.

Changes perceived as needed for achieving circularity in the stony materials supply chain		Stony materials supply chain				Detailed description of changes
		CP	DC	RC	PAP	
1	Developing new ways of appraising value that will support circular business decisions	x	x	x	x	The actors within the supply chain fail to identify the added value of the circular approach. Therefore, they have no incentive to make circular decision. The goal of this change is to provide a way of identifying the value of adopting the notions of circular economy.
2	Defining the notion of circular economy in the stony materials supply chain	x		x	x	It is clear from the interviews that the actors within the supply chain have different views on the notion of circular economy. In order to enable the implementation of the circular approach, these views have to be aligned. That is, a single definition of the circular economy within the stony materials supply chain has to be agreed on in the whole supply chain.
3	Accounting for real costs of transport	x	x		x	Most of the interviewees recognized transport as part of the reuse/recycle process that is often overlooked although it can lead to significant external costs that make the whole process pointless. This was supported by a few examples. Therefore, real transport costs need to be taken into account.

4	Integrating the supply chain	x		x	x	The actors perceive the current level of collaboration within the supply chain as not sufficient for implementation of the circular approach. Therefore, further integration is needed.
5	Raising awareness about the potential of the notion of circular economy within the supply chain	x		x		Currently, not all actors within the supply chain are aware of the potential benefits of the circular approach. This needs to change, if the notions of circular economy are to be implemented.
6	Conducting research across the supply chain with the goal of identifying and enabling all possible reuses of concrete products and materials	x				It is perceived that current reusing and recycling options are not enough and that there are many more possibilities if the research is conducted on the level of supply chain.
7	Introducing the concept of geographical distribution of the market areas in which a company can operate.	x				Geographical distribution implies creating dedicated areas in which one company operates. In this way negative externalities of the transport are kept under control, which is the reason why this changed was perceived.
8	Standardizing concrete products	x				Concrete is the most used construction material. It is everywhere around us. Naturally, there is a great variety of concrete products. In order to boost recycling and reusing of concrete products, there needs to be standardization of concrete products.
9	Using the waste treatment hierarchy (ladder of Lansink) when making decision about the stony materials waste	x				Although postulated in the law as a guideline, the waste treatment hierarchy is not used. It is perceived that by using the waste treatment hierarchy (ladder of Lansink) the circularity of the supply chain would be boosted.
10	Incorporating value of reuse/recycling in the Life Cycle Assessment	x				LCA is a tool which has to be used for almost all new construction developments. However, there is no way of appraising value of reuse or recycling within it. Therefore, incorporating a way to do that into the LCA would be beneficial for the circularity of the supply chain.
11	Developing new value indicators	x				Currently there are no indicators in use that take into account circularity aspects of products in the supply chain. These are needed in order to enable making of circular decisions.
12	Developing a tool for assessing the most beneficial treatment of end-of-life products and materials	x				Taking all of the options into account when deciding about the treatment of the end-of-life materials is hard and time consuming. Particularly because there needs to be a free flowing information and knowledge sharing across the supply chain, which is currently not the case. Therefore, developing a tool that will help with this decision will greatly enhance circularity.
13	Appreciating road foundations as material banks	x				Current trend of down-cycling the most of stony materials into the road base material is recognized as a bad practice in the circular approach. However, implementation of the notions of circular economy is a process that takes time. Therefore, in the current situation, road foundations should be viewed as material banks, in absence of a better option. Materials that are put in road bases remain clean during their life cycle and can be recycled at the end of their life.

14	Acknowledging the differences in quality requirements between different concrete products and their impact on the amount of recycled materials that can be used for the production of those products	x				Current developments towards circular economy encompass introducing a fixed percentage of end-of-life concrete that has to be reused when producing new concrete. However, it is not always possible to meet this condition. First, specific concrete products have specific quality requirements which may limit or completely exclude the possibility of this reuse. Furthermore, it is possible that the end-of-life concrete is contaminated to the point where it is not reusable any more. On the other hand, there are concrete products for which it is possible to use higher percentages of end-of-life concrete. Therefore, it is important to acknowledge this potential limitation.
15	Planning and designing with future in mind	x				Longevity of structures implies that actions taken today will dictate the circularity of the construction sector in 50 or more years. Therefore, it is important to take this into account when planning and designing new constructions today.
16	Designing for reassembly	x				In theory of circular economy reuse at the product level is more valuable than reuse at the material level. Therefore, it is important to design for reassembly in order to enable this higher value to be captured.
17	Designing modular constructions	x				It is hard to predict the needs of people and society in 50 years time. Therefore, it is important to design modular constructions that will allow for easy change of the intended function of the construction.
18	Keeping quality of the stony materials at the high level by separation at the source		x			With separation at source, the demolition process would have higher quality stony materials as output, which supports the notions of circular economy. Therefore this part of the process should become standard part of demolition companies' job.
19	Prescribing separation at the source and the minimum amount of demolished materials that have to be recycled in the procurement procedure		x			In order to ensure separation at the source and recycling of end-of-life materials and therefore support the circularity of the supply chain, these should become part of the standard demolition procurement procedure.
20	Enabling high value demolishing, reuse and recycling by providing more time, more space and more money for the demolition companies		x			Demolition is perceived as something "unimportant and boring" that needs to be done, and it is usually thought of only when there are already plans for a new structure that will replace the one that needs to be demolished. At that point, there is usually a large incentive for the party that wants the structure demolished, for it to be done as soon as possible and at the lowest possible cost. This limits the demolition companies in retrieving as much value as possible from the end-of-life materials. In turn, this hinders the other actors in the stony materials supply chain and implementation of the circular approach within it. Therefore, the importance of the demolition job must be acknowledged and enough space, time and money secured for the demolition process in order for high value demolition to take place.

21	Incorporating Pre-Demolition Audit in demolition process		x			Current practice of demolition focuses on the as fast and as cheap as possible removal of the unwanted structure, without taking into account the material content of the structure. This results in use of demolition processes that lower the value of the demolished waste materials. Pre-Demolition Audit encompasses creation of the inventory of materials used in the structure that is to be demolished prior to the demolition. With this knowledge the demolition process can be planned in such a way that yields the most value out of the end-of-life materials. Therefore, introduction of the Pre-Demolition Audit in the demolition process would boost the notions of the circular economy.
22	Raising the awareness of the supply chain about the new role of demolition companies as materials providers		x			Implementation of circular approach has disruptive effect on the supply chain, with changing roles for all of the actors. In that sense, the demolition companies will become raw materials providers. The sooner the whole supply chain becomes aware of this, the sooner the notions of circular economy may be implemented.
23	Introducing new technologies that will make the recycling process better			x		The better the recycling technologies, there are more and better options for reuse of stony materials.
24	Making the process fully transparent - in terms of information and knowledge gathering and sharing across the supply chain			x		In order for the best choice of the treatment of end-of-life materials to take place, the decision makers need to be fully aware about all options for treatment, reuse and recycling of those materials. Therefore, free information and knowledge flow across the supply chain is mandatory.
25	Incorporating adequate pricing for demolition companies		x	x		Current pricing for demolition companies does not provide incentive for them to opt for a high value demolition process.
26	Putting the notions of circular economy in the law			x		Voluntary agreements between parties are perceived as ineffective. An example of the Concrete Agreement is given, within which nothing was accomplished although there were talks between parties for 3 years. Therefore, government action, in terms of prescribing in law what needs to be done for circularity to be achieved, is needed.
27	Creating new business models that will allow for transitioning to circular economy			x		Circular economy will disrupt current roles and business models for the actors in the stony materials supply chain. Therefore, it would be beneficial to formulate new business models that will correspond to this new situation. In this way, actors will have a clearer picture of what the future holds, and could adjust accordingly.
28	Aligning the theory, perceptions and reality regarding the possibilities in realizing the notion of circular economy				x	Theory identifies how would a fully circular supply chain function. However, implementation of a circular approach is a lengthy process. Real picture encompasses knowledge of the current state of circularity, but also awareness about what is possible at which point in time. Perception of actors and parties in the supply chain vary and this causes friction between the actors, effectively hindering the whole process of implementation and incentivizing actors to behave in a strategic way. Therefore, it is of importannce to align theory, reality and perceptions about the notions of circular economy and its implementation.

29	Ensuring that everybody in the supply chain is knowledgeable about the circular economy and the real situation regarding its possibilities in the stony materials supply chain				x	Everybody involved in the stony materials supply chain should have enough knowledge and understanding of the notions of circular economy and specificities of the supply chain. Only in this way can there be a constructive progress towards circularity.
30	Relieving political pressure on government officials				x	Currently, some government officials, under pressure from the hype around the notion of circular economy, are insisting on 100% circularity, although it is not possible to achieve that at this moment. This is having adverse effect on the actors in the supply chain in terms that they are expected to deliver something that they are not, yet, able to, or their current business models are under pressure. This is not beneficial for the circularity of the supply chain and, therefore, should change. An example was given of the problems of one of the actors in getting a permit from government with the reason being insistence on the impossible 100% circularity.
31	Taking into account the gap between the supply of secondary aggregates and demand for aggregates in the building industry. And, therefore, the need for primary aggregates in the years to come				x	This is part of the reality vs. theory problem. Some actors are insisting on 100% circularity, although it is not possible at the moment, nor in the foreseeable future. A simple fact behind this is that structures that are nearing their end of life have been built 50 years ago. This longevity of structures has multiple implications. First of all, 50 years ago, considerably less structures were built than are being built today. This implies that even if we were able to reuse all of the end-of-life materials, that would simply not be enough to meet the quantities that are needed today. It is estimated that today, in the best case scenario, some 20 % of the aggregates in concrete could come from secondary materials. Second, all of the structures built in the past were not designed with reuse or recycling in mind, making the processes of demolition and recycling relatively inefficient in terms of the amount and quality of the retrieved materials. Third, as there are more and more structures needed and as it would always be structures built 50 years ago that are reused or recycled, this gap in quantities between secondary materials available and primary materials needed will remain to exist. And with that, also, the need for primary materials. Taking this into account in the process of implementation of the circular approach is of importance.
32	Not reusing and recycling at any cost				x	Insisting on circularity at any cost may prove to be disadvantageous in the end. An example was given of importing large quantities of recycled materials, which incurred significant real costs because of the transport involved.

33	Addressing and analyzing the implications of the notion of circular economy for the quality of the stony materials' rubble and its usability. Namely, if the concrete materials are taken out of the stony materials' rubble, the quality of the remaining rubble is significantly lowered				x	Currently, the biggest chunk of the stony materials waste is being processed as rubble. Rubble consists of various mixed, stony, materials like masonry, gypsum, concrete, ceramics, etc. that are crushed to aggregate sizes. It is of superb quality for use in road foundations, mostly because of the sharp edges and high friction between particles. When rubble is used as the base material for roads, there is need for less asphalt and less cement when constructing a road. If we want to reuse end-of-life concrete in the production of new concrete, than concrete needs to be taken out of this rubble. The process of getting it out is time consuming and costly. Furthermore, when the concrete, as the strongest material in the rubble, is taken out the quality of rubble drops beyond the point of where it can be used for road foundations. This would have been okay if reuse for all other constituents of the rubble is possible. However, masonry cannot currently be reused in any other way than as part of the rubble. Therefore, these implications should also be further analyzed and taken into account if there is to be successful implementation of the circular approach in the supply chain.
34	Stopping the use of "dirty" aggregates in production of new concrete because it hinders its reuse in the next life cycles				x	There is a trend of using materials that represent waste in other industries for production of concrete. These materials consist of various health damaging, toxic or materials that disable reuse in the next life cycle. Therefore, this practice, although maybe appealing as circular in the short term, hinders the notions of circular economy in the long term and as such should be stopped. An example was given of use of the ashes from the incinerators in the Netherlands from production of new concrete. It is only worse when one realizes that the Netherlands is importing waste from other countries in order to incinerate it.
35	Changing the laws that are stimulating import of recycled aggregates [MIA/VAMIL]				x	MIA/VAMIL law states that anyone that uses more than 30 % of recycled aggregates gets a tax benefit. This law should in theory boost circularity, but in reality it lead to excessive import of recycled aggregates. This import implies transport which makes the whole point of using recycled aggregates obsolete because of massive negative externalities.
36	Making the decision about the optimum mix of aggregates (primary and secondary) based on the time these materials are available, whether they are primary or secondary, location of materials and needed transport, quality, ability to be reinserted in the supply chain at the end of life cycle, taking into account other projects in the vicinity				x	There are not enough secondary aggregates to completely replace primary aggregates. This implies use of mixed aggregates. However, the most beneficial mixture is to be determined on the case basis, taking into account the parameters postulated in the corresponding perceived change.

37	Planning ahead - allow enough time for taking all of the options into account when ordering concrete				x	Current practices encompass ordering of concrete needed for the construction process in almost a " I need it today" fashion. This disables the process of analyzing all of the options available and deciding on the most beneficial one. Therefore, it should change.
38	Creating a database that contains all materials and products that are available in the urban mine				x	In order to boost reuse and recycling there has to be a register of the available products for reuse and materials for recycling in the urban environment. In that way, it would be possible to plan and design with circularity in mind.
39	Using material passports (e.g. Madastar)				x	Currently, there are is no tracking of the materials that are used in the construction industry. Knowing how much of which materials are where could boost circularity in numerous ways. Demolition companies would know upfront what are they dealing with and could plan for the highest value extraction out of the end of life materials. Also, by knowing exactly what is in each structure it is also known which end-of-life materials will be available and where. In other words, new developments could be planned and designed with those end-of-life materials in mind. Furthermore, potential buyers would know exactly which materials were used. Moreover, materials can be tracked throughout multiple life cycles, which can provide valuable information. Therefore, use of material passports would greatly support the implementation of circular economy.
40	Adopting the way of building that ensures reuse on a product level and eliminates the need for recycling completely				x	In order for the notions of circular economy to be implemented completely, a new way of building needs to be introduced which supports it. According to the circular approach this encompasses creating structures that are reusable on a product level. The sooner this new approach to building is incorporated the sooner the circular economy will be possible within the stony materials supply chain. Considering the longevity of structures, this switch should be made as soon as possible.

Table 1: perceived needed changes

4.1.2.1 Observations and discussion

As can be observed in all of the interviews, the interviewees are enthusiastic about the notion of circular economy. In addition, they all stated that they are dealing with it regularly and that it is part of current focus of their branches. Furthermore, circularity is perceived as the inevitable future development and as the way to go by all of the branches' representatives. This confirms the observations from the introductory part, namely, that there is a great hype and urgency surrounding the circularity at this moment.

Another interesting notion stemming from the interviews is the negative reflection of three (out of four) interviewees on the Concrete Agreement. It is even more interesting because there was not a question that addressed the Concrete agreement directly, meaning that these interviewees needed to bring it up themselves. There are three main reasons for this negative perception. First, the fact that the Concrete Agreement is in development for three years now, but there is still no progress. Second, the opinion that the goals stated in the Concrete Agreement are unattainable. And third, the process of its development is perceived as strategic and unfair to some of the actors. This supports the statement from the introductory chapter, stating that the development and signing of the Concrete agreement is obviously flawed. Connecting to the previous observation, that there is great hype and urgency, it validates the statement that there is inertia in the stony materials supply chain with regard to the change towards circularity.

Taking a look at the perceived needed changes (Table 1), it can be seen that only five (out of forty) changes were perceived as needed by more than one interviewee. Those changes are at the top of the table. Furthermore, one of those five changes, perceived by three (out of four) interviewees, actually states the need for formulation of the notion of circular economy that is accepted by the whole supply chain. From here it is clear that the perceptions of the actors in the supply chain are differing significantly.

The interviews were designed to capture the perception of needed changes on both the branch and the supply chain levels. Completing this successfully, it can be seen that most of the perceived changes were attributed to the supply chain level. In other words, the responsibility for making the change happen is not assigned to a particular actor, but rather to the supply chain as a whole. Precisely, only three (out of forty) changes were perceived as needed on the level of one of the branches. This points to the transfer of responsibility from the individual actor level to that of the supply chain and to the difference in perception of responsibility. This implies that, indeed, diffusion of responsibility phenomenon has taken roots in the stony materials supply chain.

Another observation coming from the interviews is that each interviewee had a personalized interpretation of circular economy. This is observable from their circular storylines, which were framed in a way that best suited their interests, hinting at the strategic behavior. Looking at the possible reasons for this, the first thing is obviously the ambiguity of the notion of circular economy that allows for different interpretations. Another one is the disruptive effect of a change towards circularity, which implies complete change in the current business practices within the stony materials supply chain. New business models need to be formulated and incorporated, followed by reshuffling of market roles of the actors in the supply chain. Considering that the most of the companies today are successfully operating in the current linear setup, making a change implies a risk of losing their market "comfort zone". Furthermore, following from the ambiguity of the notion of circular economy, the actors are uncertain as to what exactly is to be achieved. Combining the high risks and uncertainties stemming from the circular approach provides some insights into the reasons for observed strategic behavior.

Summing it up, key observations from this part are:

- Forty changes that were perceived as needed (Table 1), which serve as the starting point for the second part of research and provide insights about the perceptions of the stony materials supply chain on the notion of circular economy.
- Interviewees acknowledge the hype surrounding the notion of circular economy and urgency for making a change towards it.
- 3 (out of 4) interviewees reflected in a negative manner to the Concrete Agreement. This supports the observation that there are obstacles that are hindering its ratification and application, and in turn, the existence of inertia in the stony materials supply chain.
- Only 5 (out of 40) perceived needed changes is seen as needed for making a change towards circularity by more than one actor. This supports the assumption of differences in perceptions between the actors in the stony materials supply chain.
- Only 3 (out of 40) changes were attributed to the level of individual actors. That is, the most of the changes were attributed to the level of supply chain, implying existence of diffusion of responsibility phenomenon in the stony materials supply chain.
- Each interviewee had a personalized circular storyline, in line with their strategic interests. This is because of the ambiguity of the notion of circular economy, in combination with uncertainties and high risks that stem from the disruptive nature of implied change.

4.2 Part 2 – perceptions on responsibilities and importance of changes

In this chapter perceptions of responsible actors on the levels of individual actors, branches and supply chain, stemming from the second part of research, are postulated, analyzed and discussed. Furthermore, conclusions are drawn about the implications of these results for the stony materials supply chain and a brief reflection on the interview process is provided. These conclusions represent the answer to the third research sub-question, which was formulated as: *""What are the underlying reasons for inertia in relation to the change towards circularity in the stony materials supply chain?"*. First, perceptions on responsibility are analyzed. Then, perceptions on the priority of needed changes are postulated.

First part of research resulted in the forty changes that are perceived by the actors from the stony materials supply chain as need for achieving circularity. These changes served as input for the second part of research and enabled formulation of data-gathering table and cards, as described in Chapter 3 (Research methodology). Cards, used in the interview process, can be found in Appendix C of this thesis, while the data gathering tables can be observed in Appendix D.

As postulated in Chapter 3 (Research methodology), the four branch organizations were asked to provide lists of companies that are, in their view, advanced and innovative in terms of circularity, with a goal of interviewing four companies per branch. However, the primary aggregates producers' branch organization was able to name only two companies that fulfill these criteria. This was seen as the possible risk in the research design phase because the number of member companies is considerably smaller (10 times) than in the other branch organizations. Furthermore, considering their perception that they are already doing everything that they can to boost circularity, as postulated in Chapter 4.1.1 (Interviews summaries), it is not expected that they are advanced in terms of circularity or dealing with it regularly. The normalization procedure, postulated in Chapter 3 (Research methodology), allows for difference in number of interviewees, and enables further aggregation of results and analysis.

This part is structured as follows. First, the results of perceptions of responsibilities are postulated. This is followed by the perceptions of changes for which the important actors are responsible. In the end, perceptions on priority of changes are presented.

4.2.1 Perceptions on responsibilities

Data gathered from the interviews directly represents the perceptions of individual actors. Perceptions on that level on their own are not relevant for this research as it aims at analyzing the bigger picture. However, they represent a starting point for formulation of that bigger picture and, therefore, they are represented in Appendix D of this thesis. Following from deliberation above, this chapter is structured as follows. First, perceptions of responsibility are formulated and analyzed on the level of the branches. Then, the perceptions of the supply chain as a whole are put under the spotlight.

4.2.1.1 Branch level

In this part, perceptions on the level of branches are looked into. The order in which the branches are addressed is as follows: Demolition companies (DC), Recycling companies (RC), Primary aggregates producers (PAP) and Concrete producers (CP). In the end, a summary of all the main observations on the branch level is postulated.

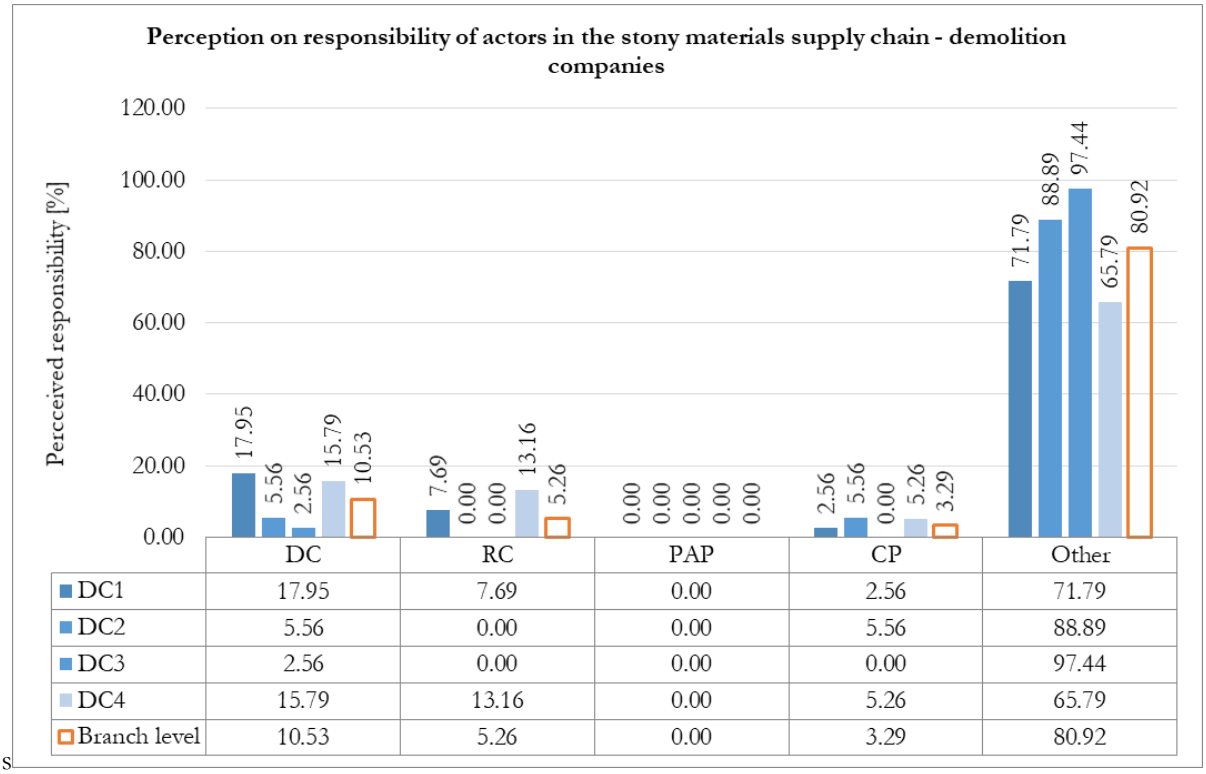
4.2.1.1.1 Demolition companies (DC)

Here, the perceptions of demolition companies' branch are postulated, analyzed and the main observations are pinpointed. In line with Chapter 3 (Research methodology), first, percentages of responsibilities

assigned by the companies from this branch, as well as the aggregated score on the level of the branch are postulated. Second, the analysis of differences in perceptions in-between the interviewees, as well as between the interviewees and branch as a whole, are looked into. Third, the SNA is conducted and the resulting graph is presented.

4.2.1.1.1.1 Percentages of responsibilities

In this part percentages of responsibilities, calculated according to Chapter 3 (Research methodology), are presented in form of graphs. First graph focuses on the percentages of responsibilities assigned to the actors that were recognized as part of the stony materials supply chain. Namely, DC, RC, PAP and CP. Other actors that were recognized as responsible are represented in the "Other" column. This can be observed in Figure 5. Percentage of responsibility is represented on the vertical axis, while the horizontal one encompass actors that were perceived as responsible. For each of the responsible actors there are five columns. First four (blue) columns represent the perceptions of the interviewed companies from the demolition companies' branch, while the last one represents the perception of the branch as a whole. This is also clear from the adjoining table, which provides a clearer overview of who was perceived responsible by whom. DC1, DC2, DC3, DC4 are abbreviations used for the four demolition companies that provided input for this part of research. In order to enable traceability of the research, tables encompassing perceptions aggregated on the demolition companies' branch level, before and after the normalization can be found in Appendix E of this thesis.



	DC	RC	PAP	CP	Other
DC1	17.95	7.69	0.00	2.56	71.79
DC2	5.56	0.00	0.00	5.56	88.89
DC3	2.56	0.00	0.00	0.00	97.44
DC4	15.79	13.16	0.00	5.26	65.79
Branch level	10.53	5.26	0.00	3.29	80.92

Figure 5: Perception on responsibility of the actors in the stony materials supply chain – demolition companies

Analysis of Figure 5 yields three main observations, which are as follows:

- The most of responsibility is assigned to the actors outside the stony materials supply chain. Precisely, 80.92%.
- Branch of primary aggregates producers is assigned zero responsibility.
- Considering only the actors from the stony materials supply chain, demolition companies perceived themselves as being the most responsible ones with 10.53% assigned responsibility.

The second graph, which can be observed in Figure 6 expands the first one by showing all of the actors that were perceived as responsible by the demolition companies' branch. Main observations from it are:

- The supply chain (SC) is perceived as the most responsible actor, with 32.89% of assigned responsibility.
- Government (Gov) is perceived as the second most responsible, with 25.66% of assigned responsibility
- Branch of demolition companies (DC) have the third highest responsibility score, and also represents the only actor besides Gov and SC that scores higher than 10%.

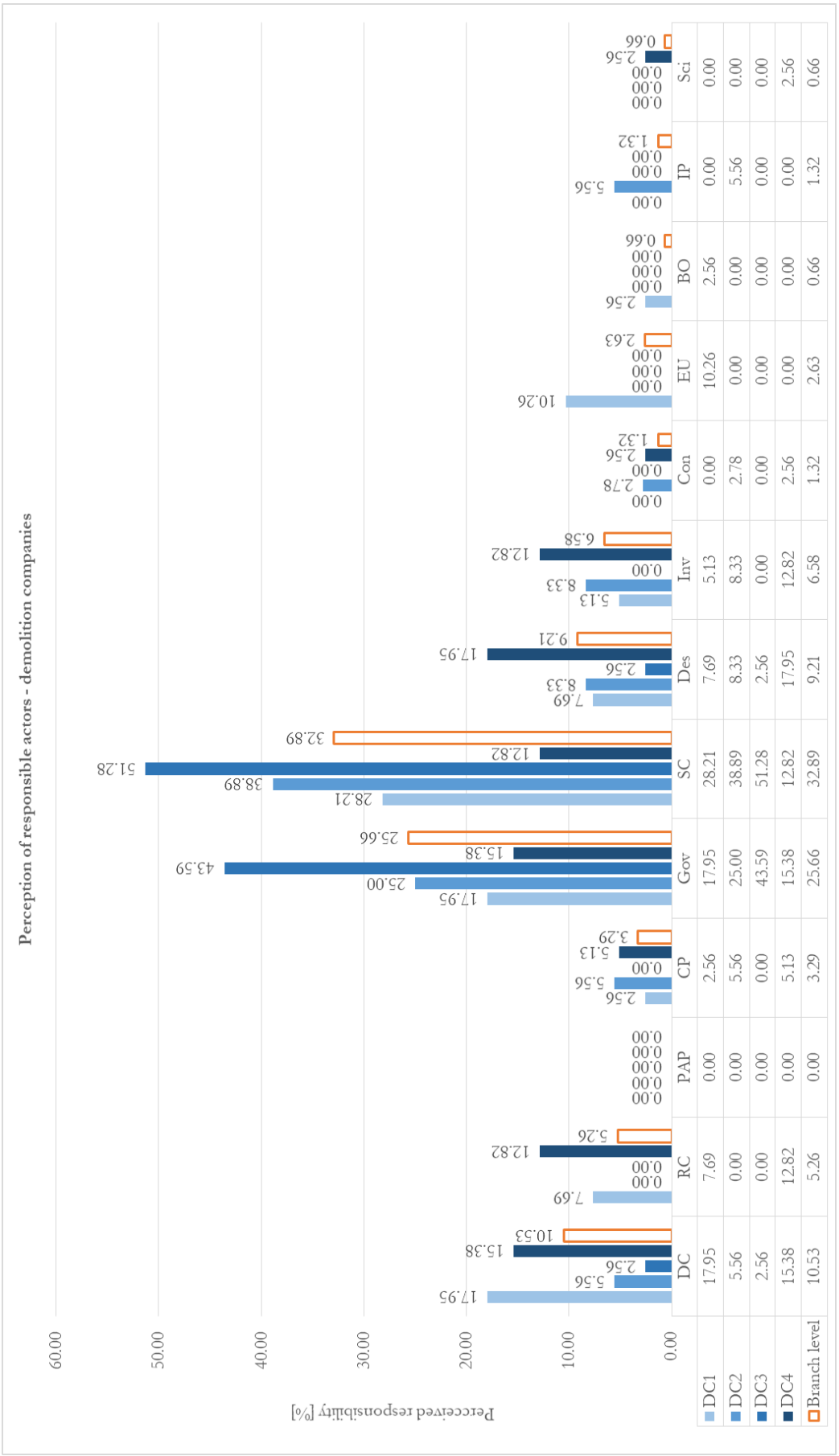
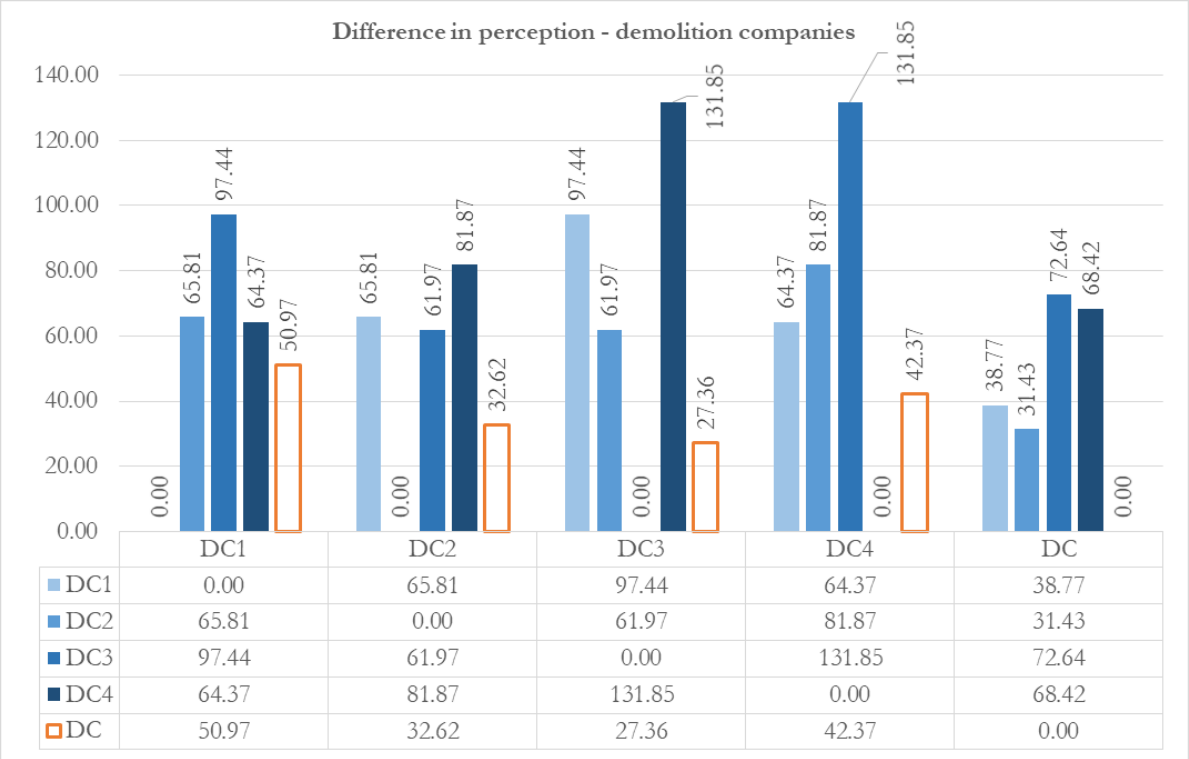


Figure 6: Perception of responsible actors – demolition companies

4.2.1.1.1.2 Differences in perceptions

Differences in perceptions, as formulated in Chapter 3 (Research methodology), are calculated for the DC branch and graphically represented in Figure 7. Vertical axis represents the difference in perceptions in percentages, while the horizontal axis details between which actors the differences are measured. Columns represent the differences in perceptions between the stated actor and the others. Perhaps the most interesting is the comparison of perceptions of individual companies with the perceptions on the branch level, which are represented in the columns for the actor DC.



	DC1	DC2	DC3	DC4	DC
DC1	0.00	65.81	97.44	64.37	38.77
DC2	65.81	0.00	61.97	81.87	31.43
DC3	97.44	61.97	0.00	131.85	72.64
DC4	64.37	81.87	131.85	0.00	68.42
DC	50.97	32.62	27.36	42.37	0.00

Figure 7: Differences in perceptions – demolition companies

4.2.1.1.1.3 SNA

As postulated in Chapter 3 (Research methodology), the SNA approach is applied to the level of the branches, resulting in an SNA graph that can be observed in Figure 8. Blue nodes represent the 40 changes that were perceived as needed in the first part of research. Perceived responsible actors are represented with gray nodes. The lines connecting responsible actors to changes represent the perceived relation of responsibility. The closer the nodes, connected with a line, are, the higher the level of responsibility between them. Furthermore, the thicker the line is, the higher the level responsibility it presents. In addition, grayscale color palette is also used to represent the level of responsibility, with the higher responsibility represented with the black end of spectrum. Orange circles represent identified islands, as defined in Chapter 3.1.1 (Social Network Analysis). Islands, in the sense of this research, represent areas of accumulation of responsibility and they are in line with the percentages of responsibilities graph. Red circles pinpoint other important observations.

The key observations stemming from Figure 8 are:

- Branch of primary aggregates producers is assigned zero responsibility.
- Perceived needed change number 7 was not recognized by any of the interviewees.
- The largest island of responsibility around the supply chain

- Island of responsibility around government
- Island of responsibility around branch of demolition companies
- Island of responsibility around designers.

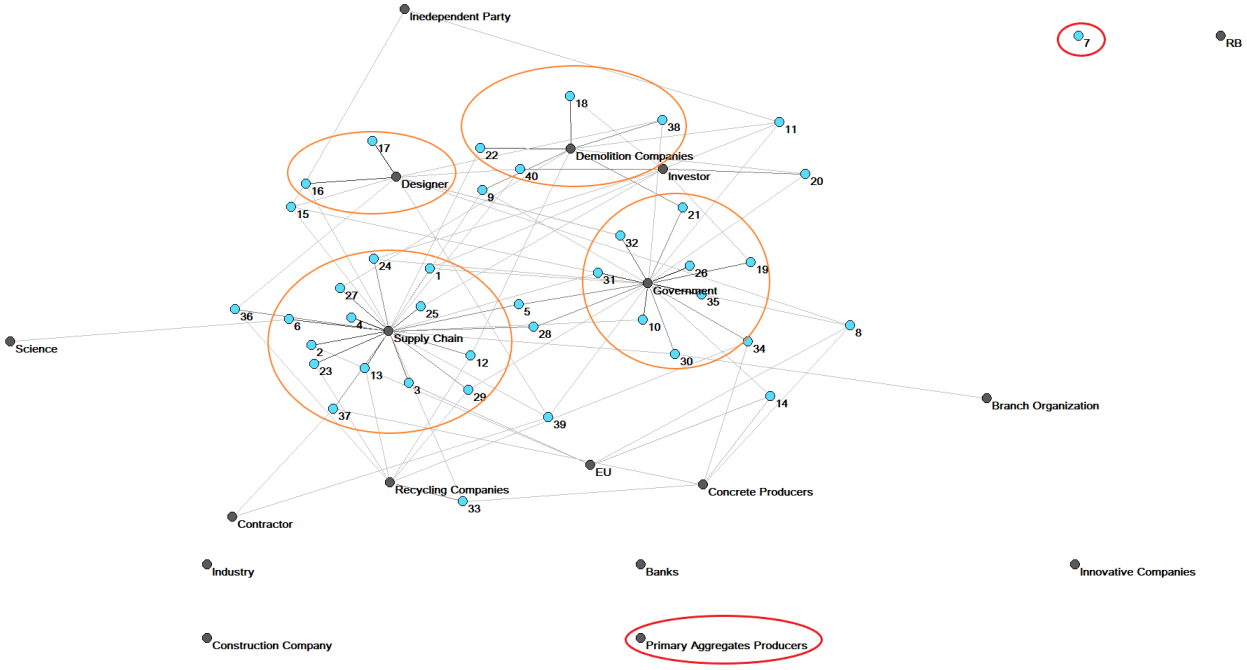


Figure 8: SNA – demolition companies

4.2.1.1.2 Recycling companies (RC)

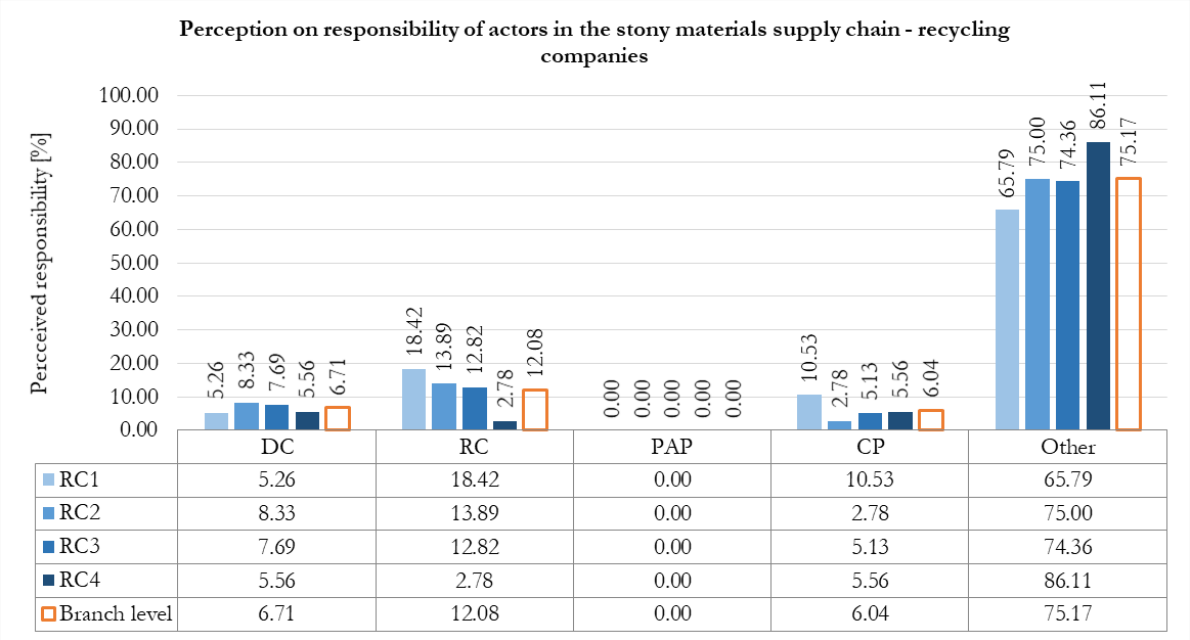
This part addresses perceptions of recycling companies' branch. In line with the previous part, first, percentages of responsibilities are postulated. This is followed by the differences in perceptions and, in the end, the results of the SNA.

4.2.1.1.2.1 Percentages of responsibilities

Figure 9 represents the perception of the recycling companies' branch on the responsibility of actors within the stony materials supply chain.

Three main observations are made in Figure 9, which are as follows:

- The largest chunk of responsibility (75,17%) is assigned to the actors outside the stony materials supply chain.
- Looking only at the actors from the stony materials supply chain, the branch of recycling companies perceive themselves as the most responsible with 12,08% of assigned responsibilities.
- Branch of primary aggregates producers is assigned zero responsibility.



	DC	RC	PAP	CP	Other
RC1	5.26	18.42	0.00	10.53	65.79
RC2	8.33	13.89	0.00	2.78	75.00
RC3	7.69	12.82	0.00	5.13	74.36
RC4	5.56	2.78	0.00	5.56	86.11
Branch level	6.71	12.08	0.00	6.04	75.17

Figure 9: Perception on responsibility of actors in the stony materials supply chain – recycling companies

Figure 10 represents assignment of responsibility to all of perceived responsible actors. Three key observations are made:

- First, government is by far seen as the most responsible actor (40.27%),
- The branch of recycling companies is the second most responsible actor second 12.08% of assigned responsibility.
- Except government and branch of recycling companies, none of the other actors score higher than 10%.

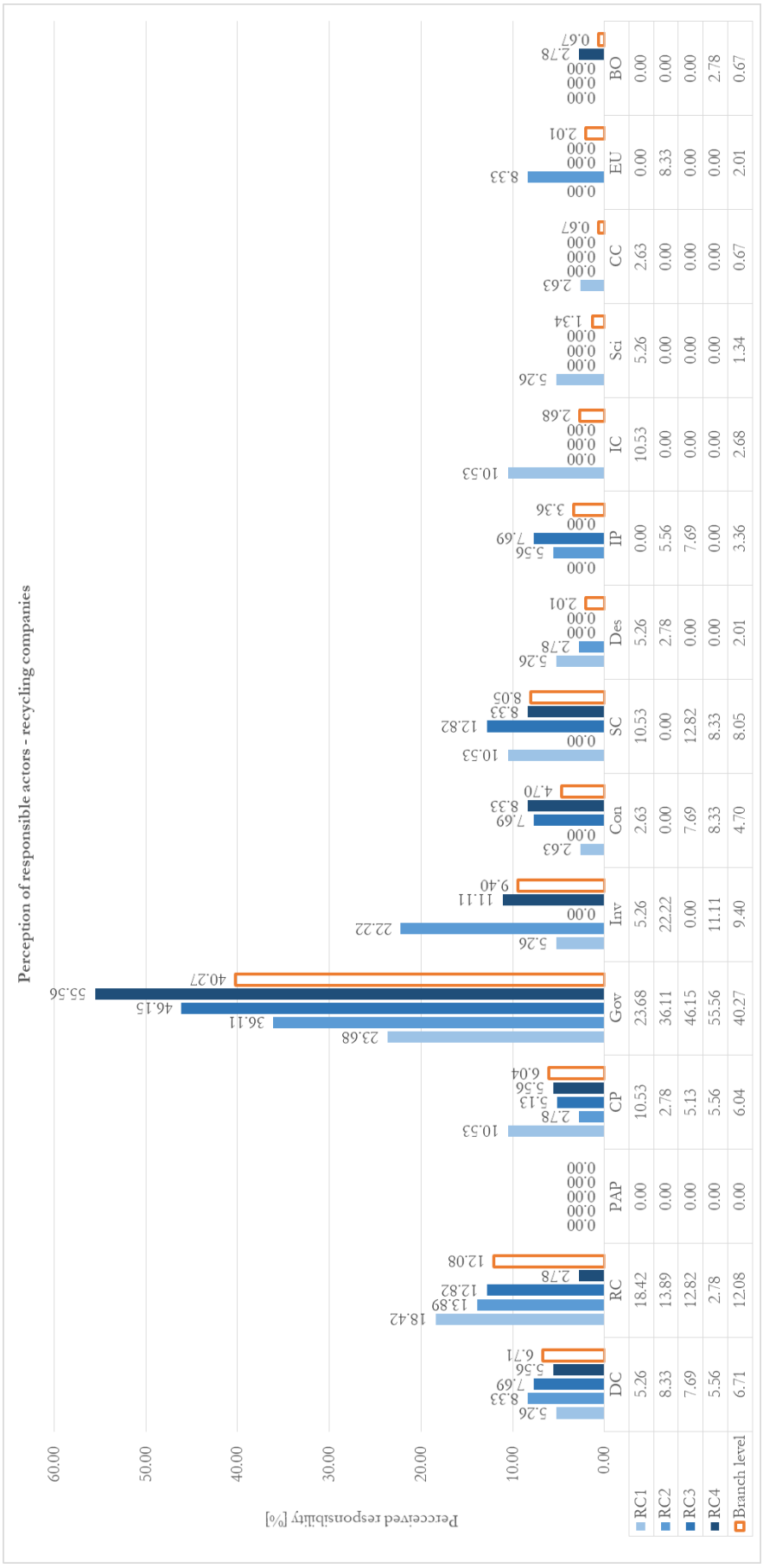
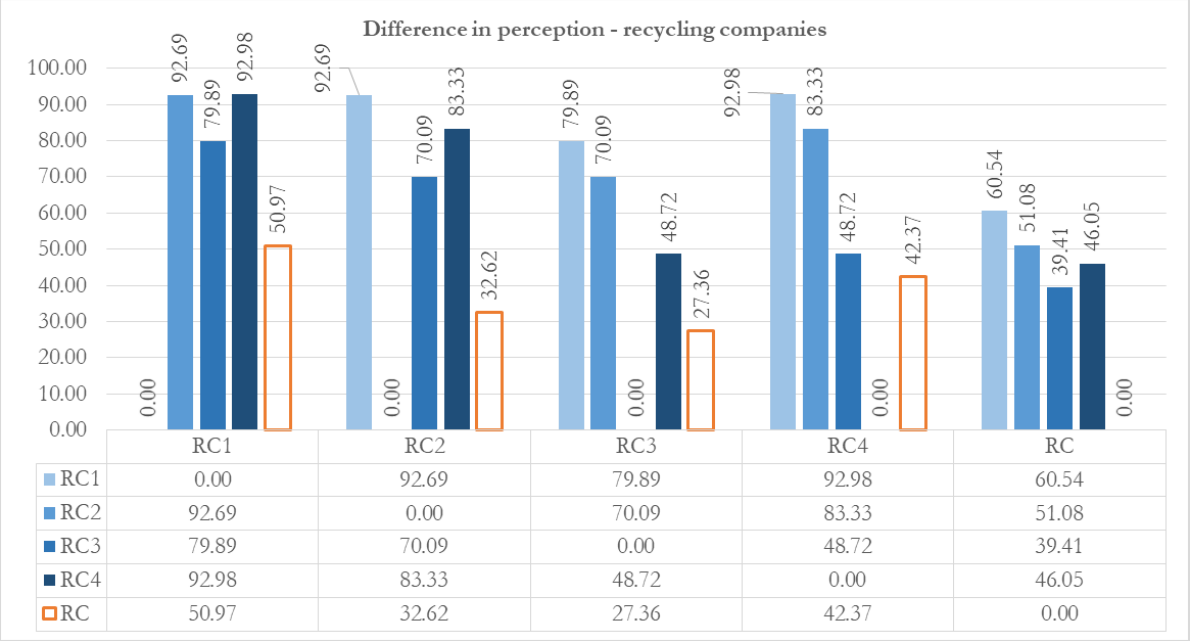


Figure 10: Perception of responsible actors - recycling companies

4.2.1.1.2.2 Differences in perceptions

Differences in perceptions in-between the interviewees, as well as between interviewees and the branch as a whole are postulated in Figure 11.



	RC1	RC2	RC3	RC4	RC
RC1	0.00	92.69	79.89	92.98	60.54
RC2	92.69	0.00	70.09	83.33	51.08
RC3	79.89	70.09	0.00	48.72	39.41
RC4	92.98	83.33	48.72	0.00	46.05
RC	50.97	32.62	27.36	42.37	0.00

Figure 11: Difference in perceptions – recycling companies

4.2.1.1.2.3 SNA

Figure 12 represents the output of the SNA applied to the branch of recycling companies. The main observations are:

- Primary aggregates producers' branch is unconnected to any changes, which is in line with the 0% responsibility assigned to it.
- The only responsibility island is the one surrounding government, and it is a rather large one.

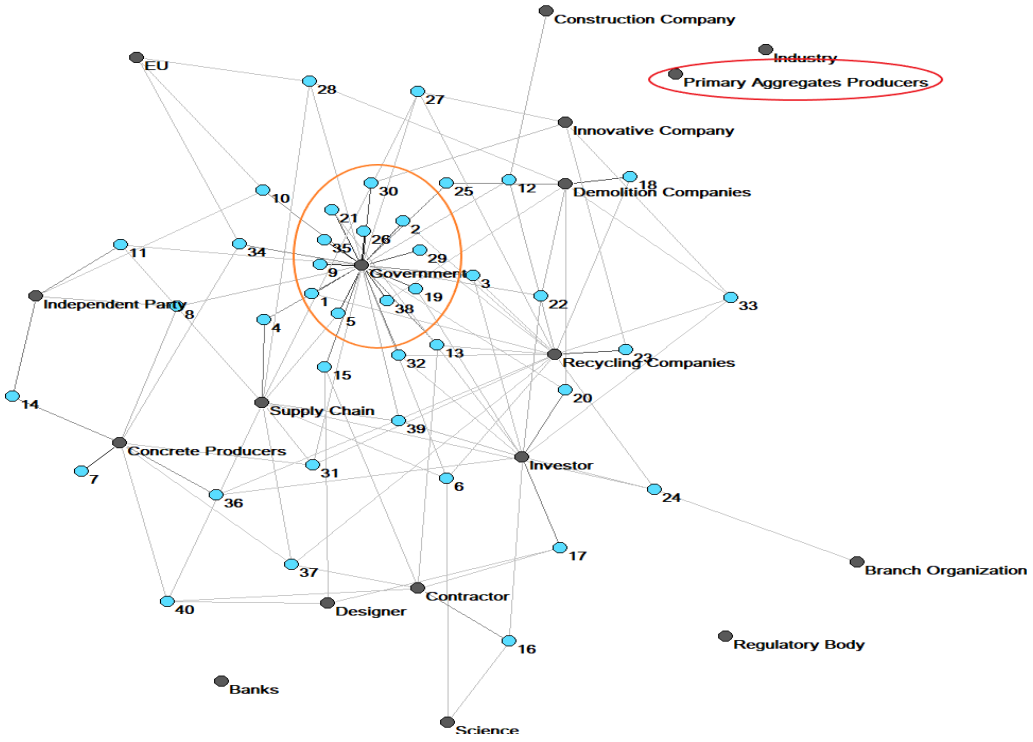


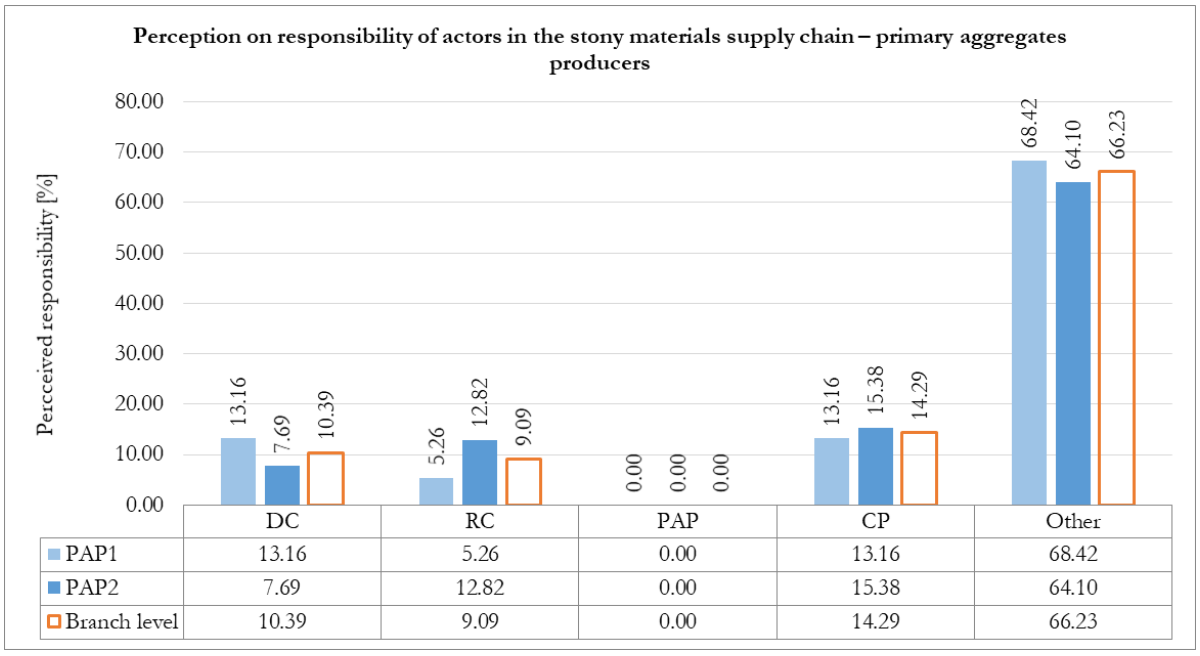
Figure 12: SNA – recycling companies

4.2.1.1.3 Primary aggregates producers (PAP)

Similarly to previous parts, first, the percentages of responsibilities are postulated. However, for the PAP branch it is not of interest to analyze differences in perception considering that only two representatives were interviewed. Therefore, second, results of the SNA are presented.

4.2.1.1.3.1 Percentages of responsibility

In Figure 13, perceived responsibility of the actors within the stony materials supply chain is presented, while Figure 14 expands by postulating assigned responsibilities for each of the responsible actors.



	DC	RC	PAP	CP	Other
PAP1	13.16	5.26	0.00	13.16	68.42
PAP2	7.69	12.82	0.00	15.38	64.10
Branch level	10.39	9.09	0.00	14.29	66.23

Figure 13: Perception on responsibility of actors in the stony materials supply chain – primary aggregates producers

Considering Figure 13, the main observations are:

- Most of responsibility is assigned to the actors outside the stony materials supply chain. Precisely, this amounts to 66.23%.
- Branch of primary aggregates producers assigned 0% to themselves
- Concrete producers' branch is perceived as the most responsible actor (14.29%) from the stony materials supply chain.

Key observations from Figure 14 are:

- Government is assigned the most responsibility (27.27%).
- Coming second is the supply chain with 16.88% of assigned responsibility.
- Third place is reserved for concrete producers' branch with 14.29%.
- The only other actor that scores higher than 10% of assigned responsibility is branch of demolition companies with 10.39%.

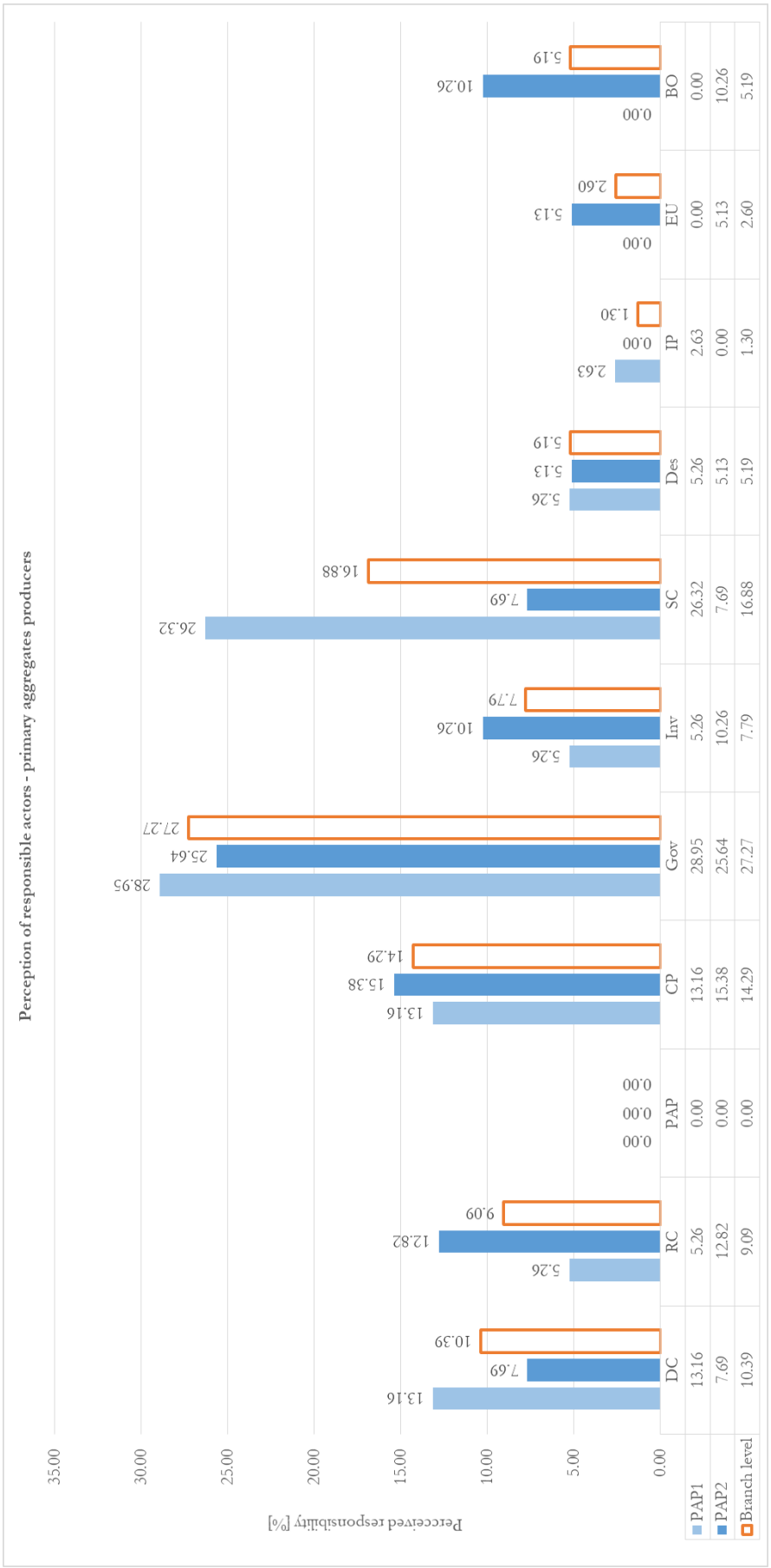


Figure 14: Perception of responsible actors – primary aggregates producers

4.2.1.1.3.2 SNA

Figure 15 postulates the results of the SNA for the primary aggregates producers' branch. Main observations are:

- Primary aggregates producers' branch is unconnected to any changes, which is in line with the 0% responsibility assigned to it.
- Change number 7 is not assigned a responsible actor, meaning that the PAP branch disagrees with that change.
- The largest responsibility island surrounds government.
- Responsibility island around branch of concrete producers
- Responsibility island encircling demolition companies' branch.

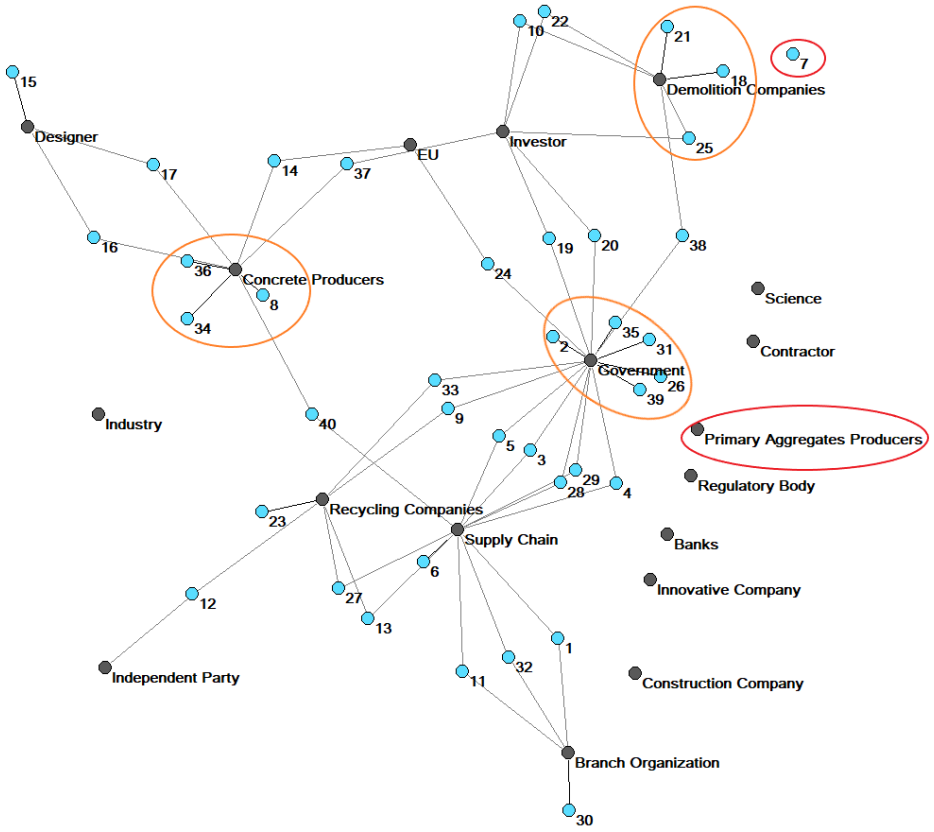


Figure 15: SNA - primary aggregates producers

4.2.1.1.4 Concrete producers (CP)

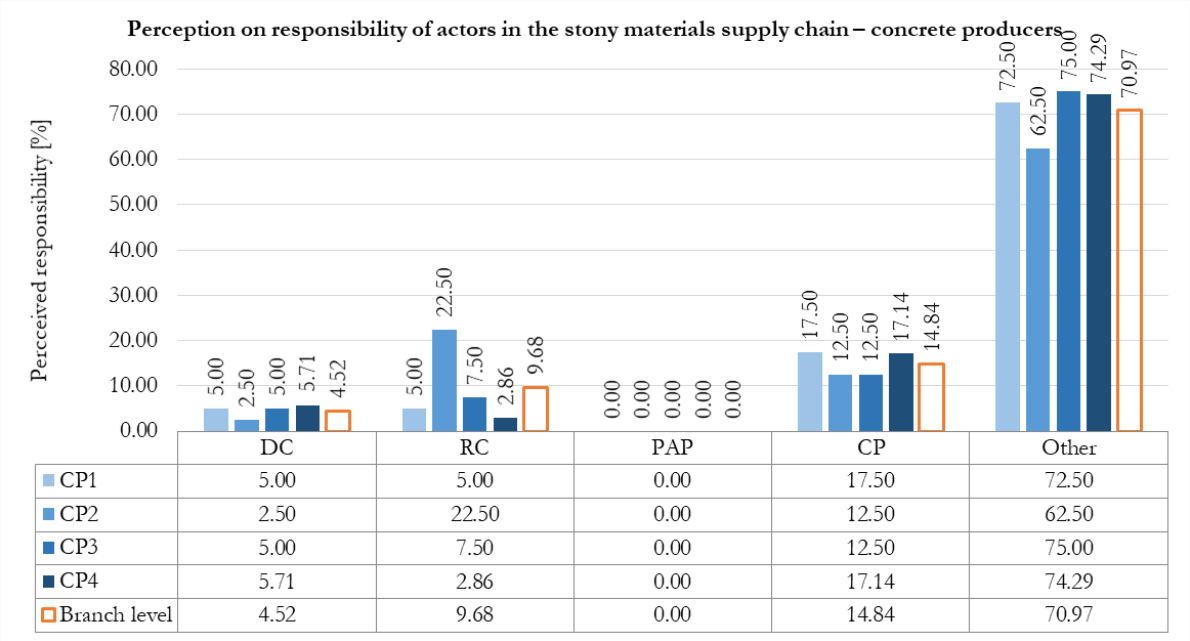
This part postulates the perceptions of the concrete producers' branch on responsible actors and underlines the main observations. First, the percentages of perceptions are formulated, which is followed by the analysis of differences in perceptions. In the end, the results of SNA are presented.

4.2.1.1.4.1 Percentages of responsibility

In Figure 16 perceptions of the branch of concrete producers on responsibility of the actors from the stony materials supply chain is postulated. Key observations are:

- The highest amount of responsibility is assigned to the actors outside the supply chain (70.97%).
- Branch of primary aggregates producers is assigned zero responsibility.

- The branch of concrete producers perceive itself as the most responsible (14.84%) when only the actors in the stony materials supply chain are concerned.



	DC	RC	PAP	CP	Other
CP1	5.00	5.00	0.00	17.50	72.50
CP2	2.50	22.50	0.00	12.50	62.50
CP3	5.00	7.50	0.00	12.50	75.00
CP4	5.71	2.86	0.00	17.14	74.29
Branch level	4.52	9.68	0.00	14.84	70.97

Figure 16: Perception on responsibility of actors in the stony materials supply chain – concrete producers

Figure 17 depicts the perception on responsible actors of the concrete producers' branch. Key observations are as follows:

- The most responsibility is assigned to government. This amounts to 32.9%.
- In the second place, with 17.42%, are investors.
- The third place is occupied by concrete producers' branch itself, with 14.84%.

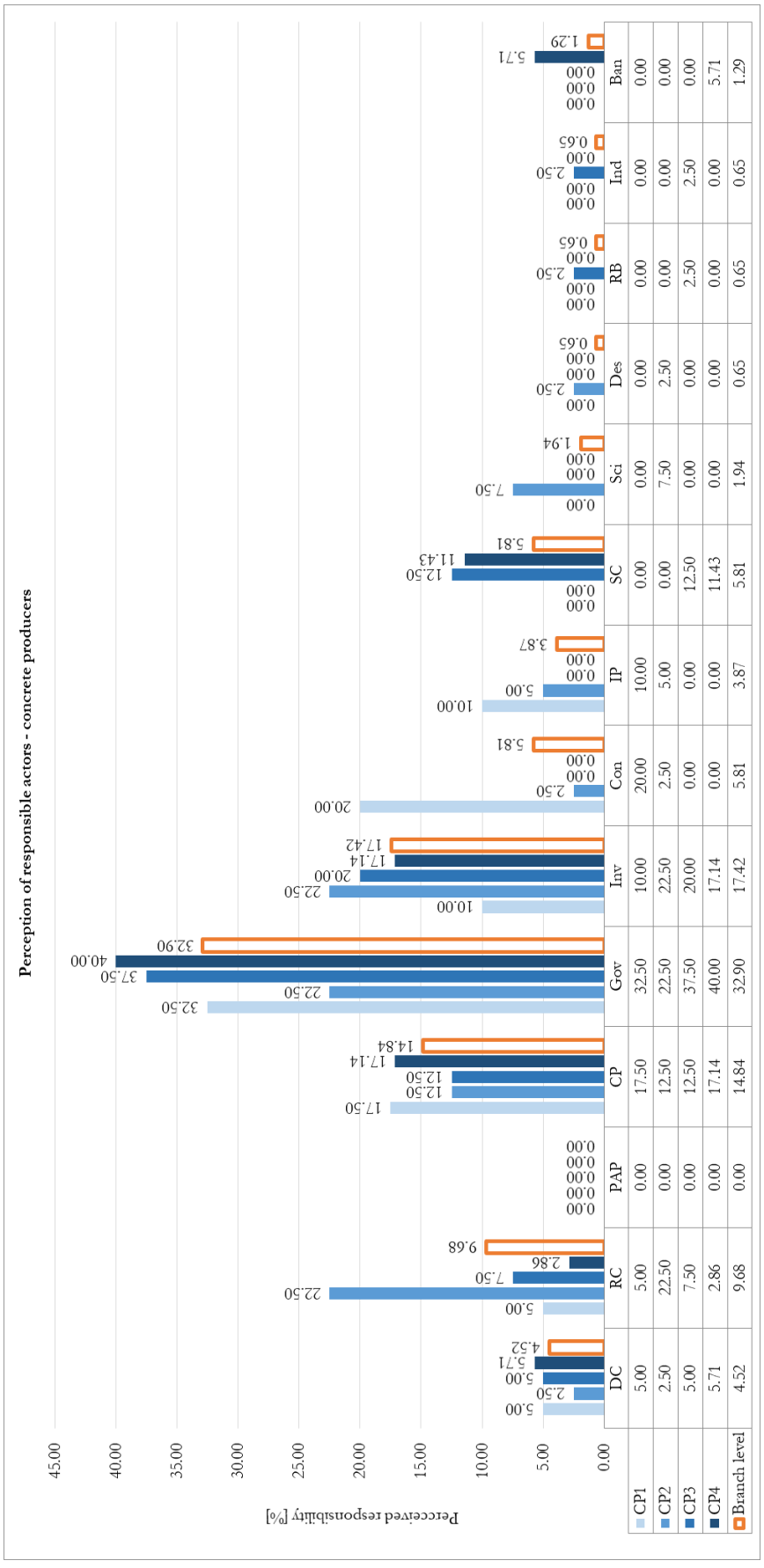
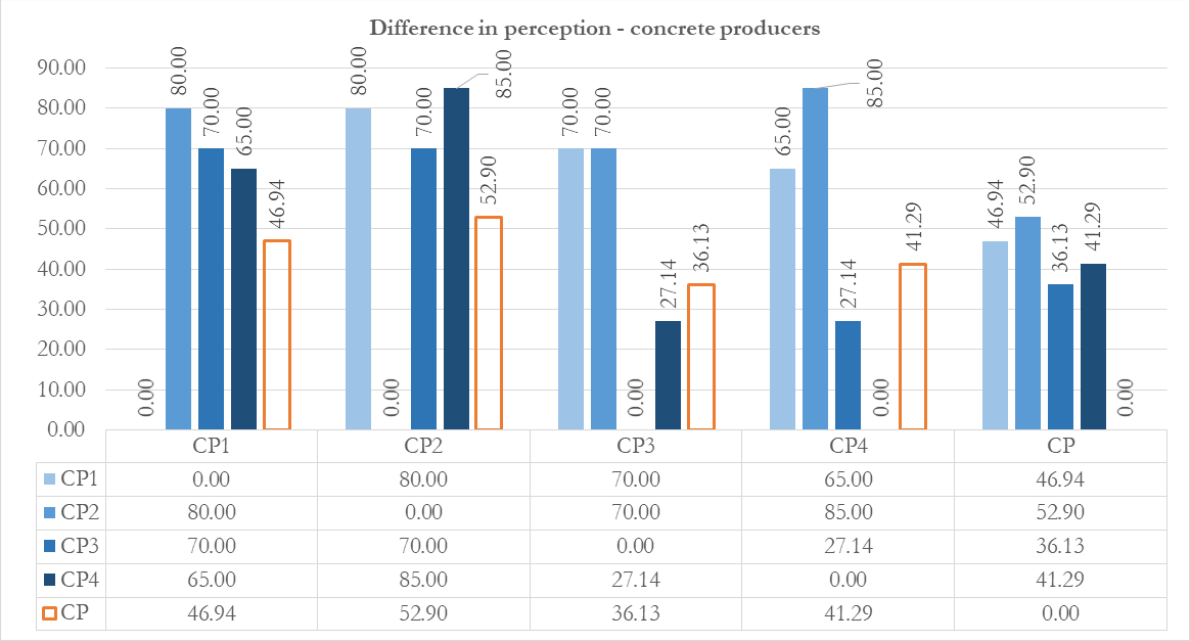


Figure 17: Perception of responsible actors – concrete producers

4.2.1.1.4.2 Differences in perceptions

Figure 18 depicts differences in perceptions between the interviewees from the concrete producers' branch as well as between the perceptions of the interviewees and the perception of the branch as a whole.



	CP1	CP2	CP3	CP4	CP
CP1	0.00	80.00	70.00	65.00	46.94
CP2	80.00	0.00	70.00	85.00	52.90
CP3	70.00	70.00	0.00	27.14	36.13
CP4	65.00	85.00	27.14	0.00	41.29
CP	46.94	52.90	36.13	41.29	0.00

Figure 18: Differences in perceptions - concrete producers

4.2.1.1.4.3 SNA

Figure 19 graphically represents results of the SNA of perceptions of the concrete producers' branch. Key observations are:

- Branch of primary aggregates producers is assigned zero responsibility.
- The largest responsibility island surrounds government.
- Responsibility island around concrete producers' branch.
- Responsibility island with investors at the center.

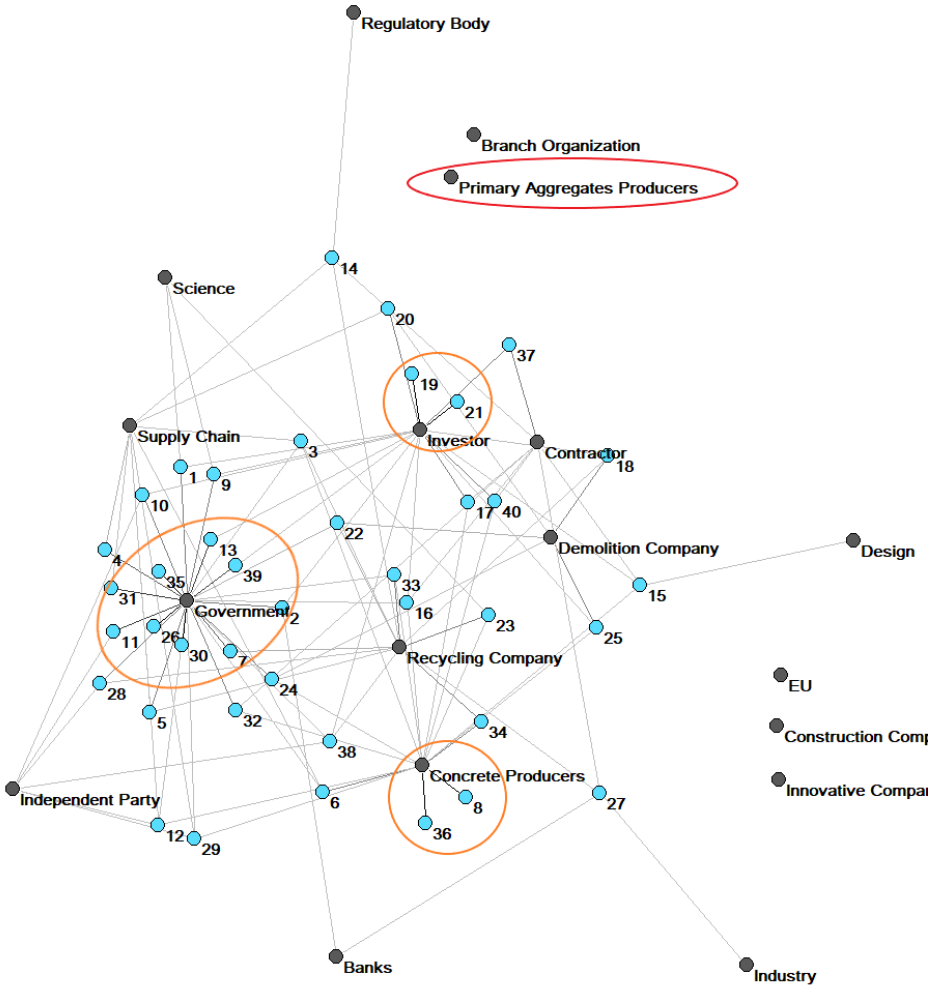


Figure 19: SNA – concrete producers

4.2.1.2 Supply chain level

In this part, perceptions on the level of stony materials supply chain are analyzed, in line with Chapter 3 (Research methodology). First, percentages of responsibilities are postulated. Second, differences of perceptions are laid down. This is followed by analysis of the number of actors that are perceived as responsible for each change. In the end, the SNA is applied and results are presented.

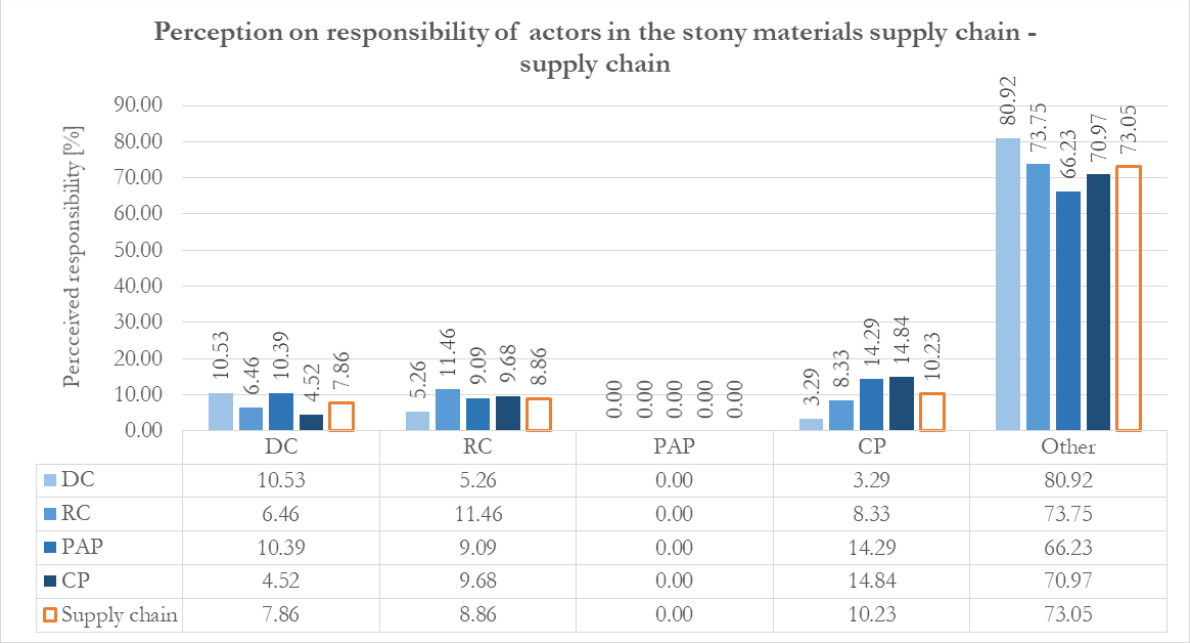
4.2.1.2.1 Percentages of responsibilities

Percentages of responsibilities are calculated as described in Chapter 3 (Research methodology), with the meaning of the output graphs explained in the previous chapter. First, perceptions of the supply chain on the responsibility of the actors within the stony materials supply chain are postulated. Second, the perceptions on all responsible actors are laid down. Perceptions on responsibility, aggregated on the level of the stony materials supply chain can be found in Appendix F of this thesis.

Figure 20 represent perception of the supply chain on responsibility of actors in the stony materials supply chain. The difference here, compared to the analysis on the branch level is that now, instead of perceptions of companies from one branch, perceptions of branches are represented. Therefore, the first four columns represent the perceptions of different branches, and the fifth column represents the perception of the supply chain as a whole.

Key observations from Figure 20 are:

- 73.05% of responsibilities are assigned to the actors outside the stony materials supply chain.
- The rest is more or less equally distributed between DC, RC and CP branch, with CP leading with 10.23%.
- Branch of primary aggregates producers is assigned zero responsibility.



	DC	RC	PAP	CP	Other
DC	10.53	5.26	0.00	3.29	80.92
RC	6.46	11.46	0.00	8.33	73.75
PAP	10.39	9.09	0.00	14.29	66.23
CP	4.52	9.68	0.00	14.84	70.97
Supply chain	7.86	8.86	0.00	10.23	73.05

Figure 20: Perception on responsibility of actors in the stony materials supply chain - supply chain

Figure 21 shows perceptions of the supply chain on the responsible actors. Key observations are:

- Government has, by far, the biggest responsibility assigned to it (31.54%).
- The supply chain comes second, with 15.56% of assigned responsibility.
- Third place is reserved for branch of concrete producers (10,23%), making it the highest scoring actor from the stony materials supply chain.
- Investors are the only other actor that scored above 10% of assigned responsibility.
- Branch organizations are assigned 1.9% of responsibility on the level of the supply chain. Zooming in it is observed that only the branch of primary aggregates producers assigned more than 1% to them (6.41%).

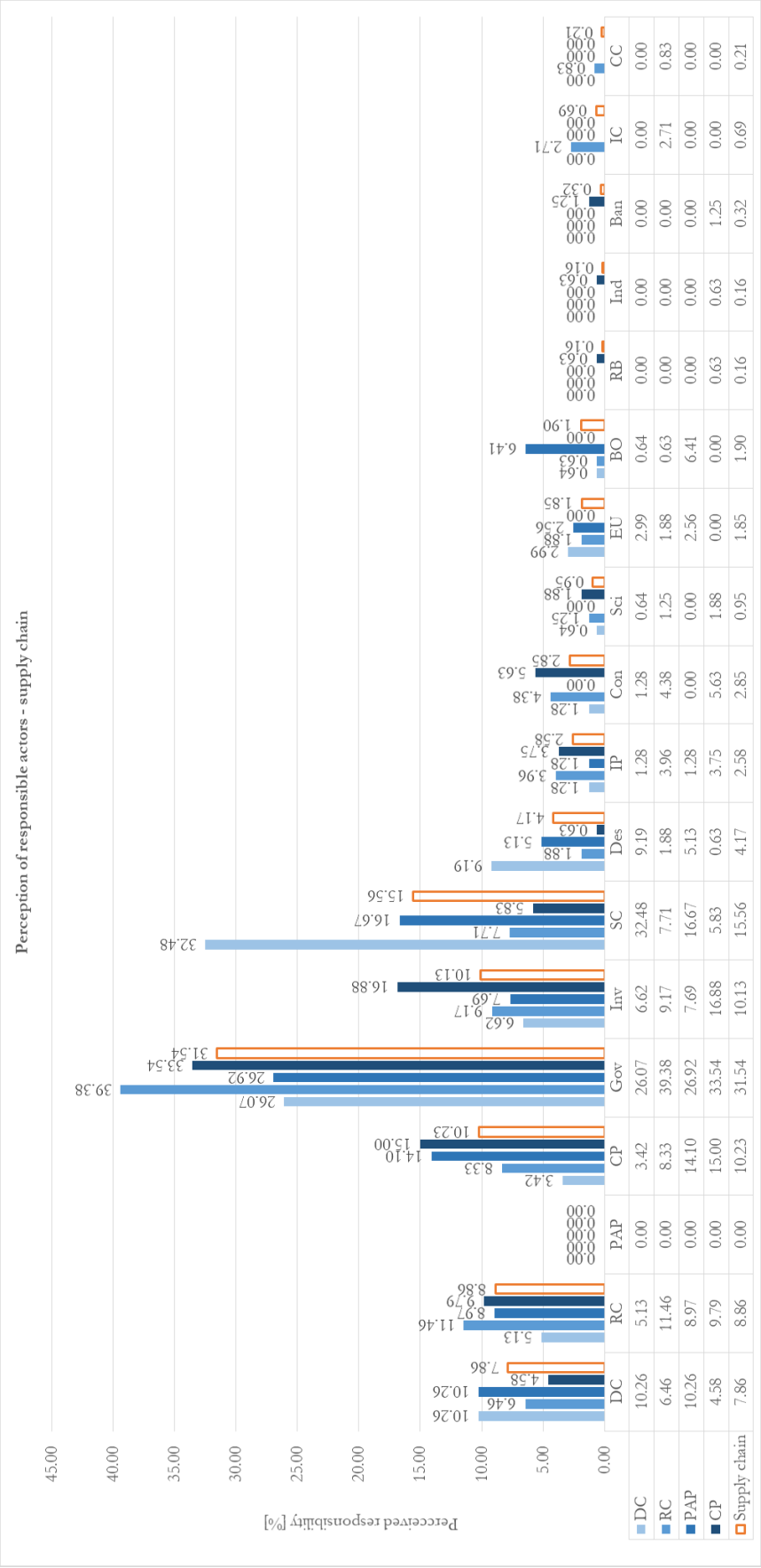
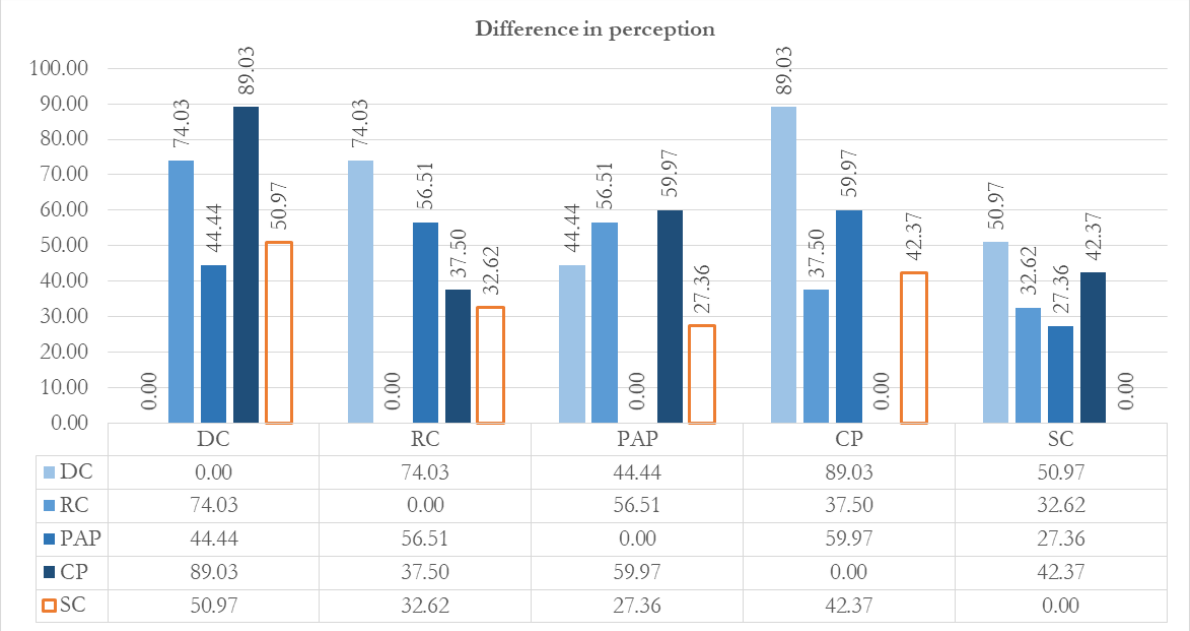


Figure 21: Perception of responsible actors - supply chain

4.2.1.2.2 Differences of perceptions

Here, differences in perceptions in-between the branches from the stony materials supply chain, as well as between the branches and the supply chain as a whole are presented. These are graphically represented in Figure 22.



	DC	RC	PAP	CP	SC
DC	0.00	74.03	44.44	89.03	50.97
RC	74.03	0.00	56.51	37.50	32.62
PAP	44.44	56.51	0.00	59.97	27.36
CP	89.03	37.50	59.97	0.00	42.37
SC	50.97	32.62	27.36	42.37	0.00

Figure 22: Differences in perceptions – supply chain

It is of interest to analyze the difference of perceptions of the branches and the supply chain, which are depicted with the four columns above the actor supply chain (SC) in Figure 22. Main observations are:

- The highest difference of 50.97% is attributed to the branch of demolition companies.
- The concrete producers' branch is following, with 42.37%.
- Third place is reserved for branch of recycling companies with 32.62%,
- The actor with the least difference is primary aggregates producers' branch, that scored 27.36%.

4.2.1.2.3 Number of actors perceived as responsible per change

Figure 23 represents the number of different actors that are perceived as responsible for each of the changes. Vertical axis represent the count of different responsible actors per change, while the horizontal axis pairs that to the forty changes that were perceived as needed. Main observations are:

- Only 2 (out of 40), or 5% of, changes that were assigned one responsible actor. If a change, on the supply chain level has only one actor assigned as responsible, then all of the interviewees stated the same actor as responsible, implying that there is no difference in perceptions when it comes to that change. In this case, changes number 26 and 35 have only one actor (government) assigned as responsible.
- 8 (out of 40), or 20%, of changes have 3 or less actors assigned as responsible.
- 27 (/40), or 67.5%, of changes have 5 or more actors perceived as responsible for them.

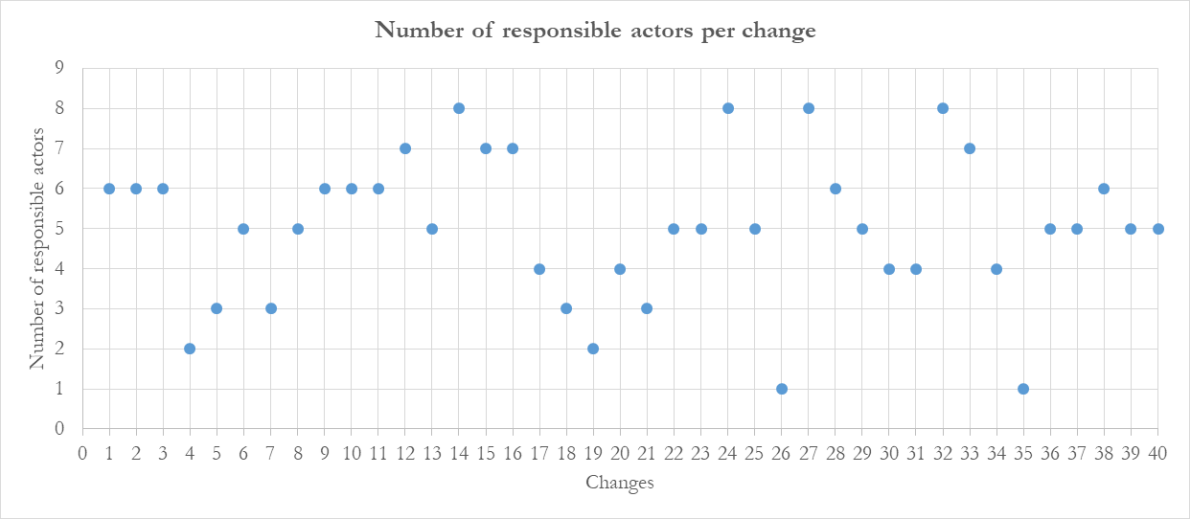


Figure 23: Number of actors perceived as responsible per change

4.2.1.2.4 SNA

In this part, results of the SNA on the level of supply chain are postulated. Three different perspectives are taken in this analysis. The first, represented in Figure 24, is in line with the SNA conducted on branch level, analyzing both sets of entities (responsible actors and changes) and the relation of responsibility between them. The other two, however, focus on one set of entities and the relations between them as a consequence of joint responsibility or having the same responsible actors. Figure 25 depicts the relations between the changes based on having the same responsible actors. In other words, the more responsible actors one change shares with the other one, the stronger the relation. Figure 26 represents relations between the actors based on their joint responsibility for changes. Figure 27 zooms in on the middle part of Figure 26 in order to provide a clearer overview of relations between actors.

From Figure 24, following are the main observations:

- Primary aggregates producers' branch is not assigned any responsibility.
- The largest and central responsibility island surrounds government.
- Responsibility island around branch of concrete producers.
- Responsibility island with branch of demolition companies at its center.
- Responsibility island around recycling companies' branch.
- Responsibility island encompassing designers.

Based on Figure 25, there is one key observation:

- Three groups of changes are identified based on the relations between them. The outer one, comprising of the changes that are outside of the larger ellipse. The middle one, consisting of changes inside the larger ellipse, but excluding the changes in the smaller ellipse. And the central one, with only the changes in the smaller ellipse as a part of it.

Figures 26 and 27 represent the relations between actors and, in line with Figure 25, there are two main finding stemming from them:

- Three groups of actors are identified based on their connectedness and centrality.
- The government, investor and supply chain actors play a central role in making a change towards circularity.

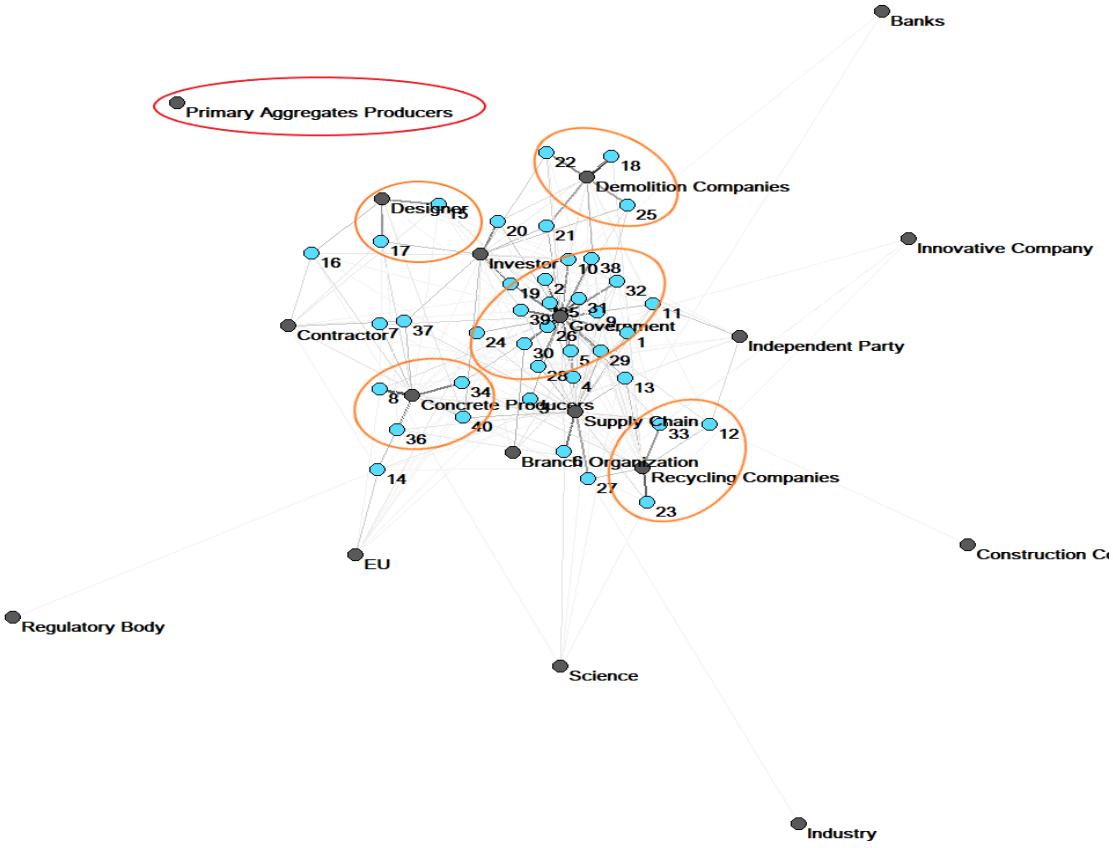


Figure 24: SNA, 2-mode - supply chain

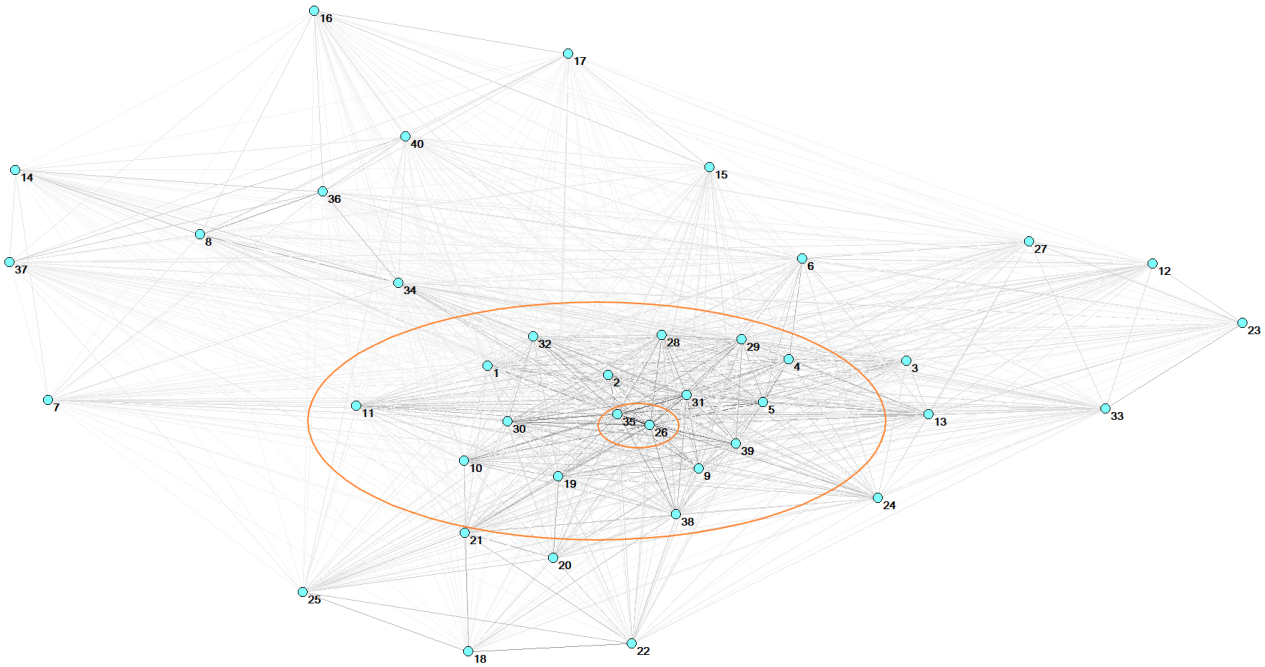


Figure 25: SNA, 1-mode, changes - supply chain

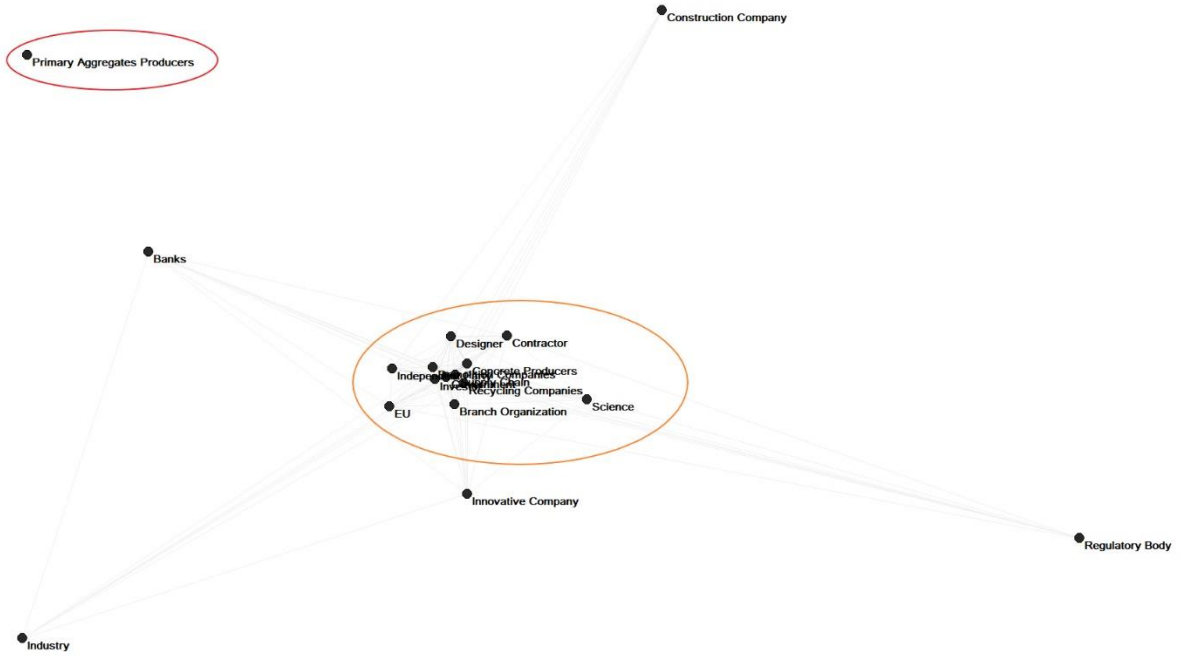


Figure 26: SNA, 1-mode, responsible actors – supply chain

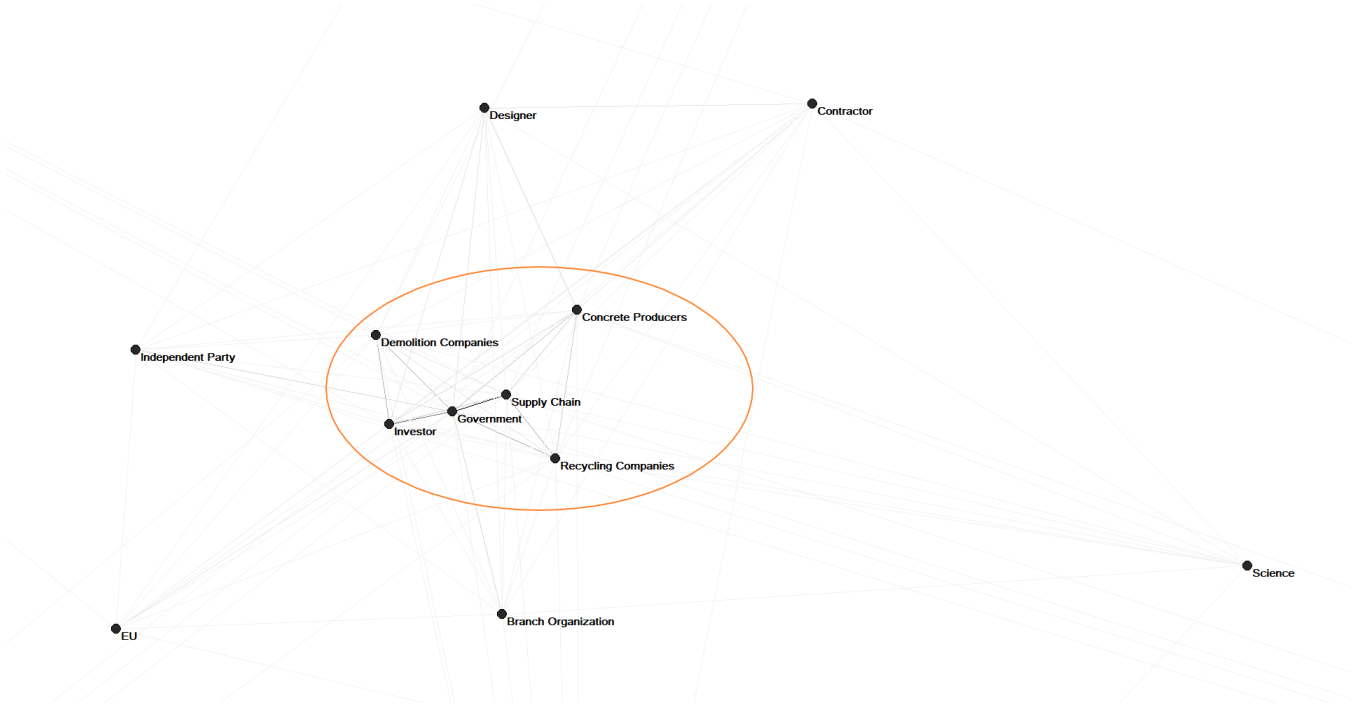


Figure 27: SNA, 1-mode, responsible actors, detail zoomed-in - supply chain

4.2.2 Perceptions on responsibility of important actors

Each actor has assigned responsibility for different changes to different actors. Therefore, in this part for each actor (DC, RC, PAP, and CP) perception on assignment of responsibility to important actors is postulated in the form of five changes for which those actors were assigned the most responsibility.

Following from Chapter 3 (Research methodology), first, important actors have to be identified. It is decided that important actors are, aside from the four branches, those with the high assigned responsibility. Therefore, from Figure 21, it follows that important actors are DC branch, RC branch, PAP branch, CP

branch and government, supply chain, investor and designer. However, considering that the PAP branch was assigned 0% responsibility, it will be excluded. These are represented in Tables 2 to 6.

- General observation is made that the perceptions vary considerably in-between branches and between branches and the supply chain, with different actors being perceived as responsible for different changes.

Percpetion of responsibility - demolition companies																		
Demolition companies			Recycling companies			Concrete producers			Government			Supply chain			Investor			Designer		
Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility
18	Separation at the source	3.00	33	Quality of rubble without concrete	2.00	8	Standardization of products	1.00	26	Law on circular economy	4.00	4	Integration of the supply chain	4.00	20	More time, space and money	2.00	17	Modular constructions	4.00
22	New role of demolition companies	3.00	12	Tool for best treatment	1.00	14	Different quality requirements	1.00	35	No laws stimulating import of secondary	4.00	2	Formulating circular economy	3.00	40	Build for product level reuse	2.00	16	Design for reassembly	3.00
9	Ladder of Lansink	2.00	13	Roads as material banks	1.00	33	Quality of rubble without concrete	1.00	10	Reuse/recycling in the LCA	3.00	6	Conducting research across the supply chain	3.00	1	New ways of appraising value	1.00	8	Standardization of products	1.00
21	Pre Demolition audit	2.00	23	New recycling technologies	1.00	34	No to "dirty" aggregates	1.00	31	Gap between secondary and needed materials	3.00	13	Roads as material banks	3.00	11	New value indicators	1.00	15	Plan and design for future	1.00
38	Urban mine database	2.00	29	Knowledge about circular economy	1.00	37	Allowing enough time for best choice	1.00	5	Raising awareness	2.00	23	New recycling technologies	3.00	18	Separation at the source	1.00	32	Not reusing and recycling at any cost	1.00

Table 2: demolition companies – perception of responsibility, assigned changes

Percpetion of responsibility - recycling companies																		
Demolition companies			Recycling companies			Concrete producers			Government			Supply chain			Investor			Designer		
Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility
18	Separation at the source	3.00	23	New recycling technologies	3.00	36	Optimum aggregate mix - taking everything into account	2.00	9	Ladder of Lansink	4.00	4	Integration of the supply chain	2.00	17	Modular constructions	2.00	15	Plan and design for future	1.00
25	Adequate pricing for demolition companies	2.00	1	New ways of appraising value	1.00	7	Geographical distribution	1.00	26	Law on circular economy	4.00	5	Raising awareness	1.00	20	More time, space and money	2.00	17	Modular constructions	1.00
20	More time, space and money	1.00	2	Formulating circular economy	1.00	8	Standardization of products	1.00	1	New ways of appraising value	3.00	6	Conducting research across the supply chain	1.00	3	Real costs of transport	1.00	40	Build for product level reuse	1.00
22	New role of demolition companies	1.00	3	Real costs of transport	1.00	14	Different quality requirements	1.00	2	Formulating circular economy	3.00	11	New value indicators	1.00	16	Design for reassembly	1.00	1	New ways of appraising value	0.00
28	Aligning theory, perceptions and reality	1.00	6	Conducting research across the supply chain	1.00	31	Gap between secondary and needed materials	1.00	5	Raising awareness	3.00	24	Fully transparent process	1.00	19	Separation at the source and minimum amount of recycling in procurement procedure	1.00	2	Formulating circular economy	0.00

Table 3: recycling companies – perception of responsibility, assigned changes

Percpetion of responsibility - primary aggregates producers																				
Demolition companies			Recycling companies			Concrete producers			Government			Supply chain			Investor			Designer		
Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility
18	Separation at the source	2.00	23	New recycling technologies	2.00	8	Standardization of products	2.00	2	Formulating circular economy	2.00	6	Conducting research across the supply chain	2.00	10	Reuse/recycling in the LCA	1.00	15	Plan and design for future	2.00
21	Pre Demolition audit	2.00	9	Ladder of Lansink	1.00	34	No to "dirty" aggregates	2.00	26	Law on circular economy	2.00	1	New ways of appraising value	1.00	19	Separation at the source and minimum amount of recycling in procurement procedure	1.00	16	Design for reassembly	1.00
10	Reuse/recycling in the LCA	1.00	12	Tool for best treatment	1.00	36	Optimum aggregate mix - taking everything into account	2.00	31	Gap between secondary and needed materials	2.00	3	Real costs of transport	1.00	20	More time, space and money	1.00	17	Modular constructions	1.00
22	New role of demolition companies	1.00	13	Roads as material banks	1.00	14	Different quality requirements	1.00	35	No laws stimulating import of secondary	2.00	4	Integration of the supply chain	1.00	22	New role of demolition companies	1.00	1	New ways of appraising value	0.00
25	Adequate pricing for demolition companies	1.00	27	Circular business models	1.00	16	Design for reassembly	1.00	39	Material passports	2.00	5	Raising awareness	1.00	25	Adequate pricing for demolition companies	1.00	2	Formulating circular economy	0.00

Table 4: primary aggregates producers – perception of responsibility, assigned changes

Percpetion of responsibility - concrete producers																				
Demolition companies			Recycling companies			Concrete producers			Government			Supply chain			Investor			Designer		
Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility
18	Separation at the source	2.00	23	New recycling technologies	2.00	8	Standardization of products	4.00	26	Law on circular economy	4.00	3	Real costs of transport	1.00	19	Separation at the source and minimum amount of recycling in procurement	4.00	15	Plan and design for future	1.00
25	Adequate pricing for demolition companies	2.00	33	Quality of rubble without concrete	2.00	36	Optimum aggregate mix - taking everything	3.00	35	No laws stimulating import of secondary	4.00	4	Integration of the supply chain	1.00	21	Pre Demolition audit	4.00	1	New ways of appraising value	0.00
20	More time, space and money	1.00	34	No to "dirty" aggregates	2.00	6	Conducting research across	2.00	11	New value indicators	3.00	5	Raising awareness	1.00	17	Modular constructions	2.00	2	Formulating circular economy	0.00
22	New role of demolition	1.00	3	Real costs of transport	1.00	34	No to "dirty" aggregates	2.00	13	Roads as material banks	3.00	6	Conducting research across	1.00	20	More time, space and money	2.00	3	Real costs of transport	0.00
24	Fully transparent process	1.00	5	Raising awareness	1.00	3	Real costs of transport	1.00	30	Relieving political pressure	3.00	12	Tool for best treatment	1.00	37	Allowing enough time for best	2.00	4	Integration of the supply chain	0.00

Table 5: concrete producers - perception of responsibility, assigned change

Percpetion of responsibility - supply chain																				
Demolition companies			Recycling companies			Concrete producers			Government			Supply chain			Investor			Designer		
Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility	Nr	Change	Responsibility
18	Separation at the source	3.00	23	New recycling technologies	2.50	8	Standardization of products	2.58	26	Law on circular economy	4.00	4	Integration of the supply chain	2.33	19	Separation at the source and minimum amount of recycling in procurement procedure	2.08	15	Plan and design for future	1.75
22	New role of demolition companies	1.92	33	Quality of rubble without concrete	1.75	36	Optimum aggregate mix - taking everything into account	2.50	35	No laws stimulating import of secondary	4.00	6	Conducting research across the supply chain	2.25	20	More time, space and money	2.00	17	Modular constructions	1.75
21	Pre Demolition audit	1.50	12	Tool for best treatment	1.08	34	No to "dirty" aggregates	2.00	31	Gap between secondary and needed materials	2.75	5	Raising awareness	1.50	21	Pre Demolition audit	1.25	16	Design for reassembly	1.25
25	Adequate pricing for demolition companies	1.50	13	Roads as material banks	1.00	14	Different quality requirements	1.33	39	Material passports	2.33	27	Circular business models	1.50	17	Modular constructions	1.00	40	Build for product level reuse	0.50
38	Urban mine database	1.25	27	Circular business models	1.00	7	Geographical distribution	1.00	2	Formulating circular economy	2.25	3	Real costs of transport	1.42	25	Adequate pricing for demolition companies	1.00	32	Not reusing and recycling at any cost	0.33

Table 6: supply chain - perception of responsibility, assigned changes

Furthermore, considering that government is assigned by far the most responsibility, as can be observed in Figure 21, it is of interest to analyze the changes for which it was perceived as the most responsible on the level of supply chain. Therefore, Table 7 represents the 10 changes for which government is perceived as the most responsible actor. From left to right, first, there is a rank of the perceived change based on responsibility for it that is assigned to government. Second, a short formulation of perceived change is postulated and, third, a number of the perceived change, according to Table 1, is laid down.

Government					
Rank	Change	Nr	Rank	Change	Nr
1	Law on circular economy	26	**6**	Raising awareness	5
2	No laws stimulating import of secondary	35	**7**	Ladder of Lansink	9
3	Gap between secondary and needed materials	31	**8**	Relieving political pressure	30
4	Material passports	39	**9**	Separation at the source and minimum amount of recycling in procurement procedure	19
5	Formulating circular economy	2	**10**	Reuse/recycling in the LCA	10

Table 7: ten changes for which government was assigned the most responsibility, ranked

4.2.3 Perceptions on importance of changes

In this part perceived importance of the changes on the levels of branch organizations and supply chain are postulated. First, for each branch and the supply chain ten changes that are perceived as most important are presented, while the rankings of all of the forty changes for each of the actors can be found in Appendix G of this thesis. Second, measure of difference of perceptions, as formulated in Chapter 3 (Research methodology), is postulated for all of the branches. In the end, the assignment of responsibility for the changes that were ranked within top ten on the supply chain level is postulated in the form of a table stating the percentages of responsibility assigned to each of the actors per change. Furthermore, complementing this, the ten most important changes are marked on the supply chain level SNA graph, which visually positions these changes.

From Table 8, representing perceived importance of changes, two key observations are:

- Perceived priority of changes varies greatly in-between branches and between branches and the supply chain.
- In total, the actors perceived 29 unique changes as part of the ten most important.

Final rank	SC		DC		RC		PAP		CP	
	Nr.	Change	Nr.	Change	Nr.	Change	Nr.	Change	Nr.	Change
1	23	New recycling technologies	26	Law on circular economy	23	New recycling technologies	34	No to "dirty" aggregates	15	Plan and design for future
2	26	Law on circular economy	35	No laws stimulating import of secondary	9	Ladder of Lansink	2	Formulating circular economy	22	New role of demolition companies
3	15	Plan and design for future	39	Material passports	10	Reuse/recycling in the LCA	28	Aligning theory, perceptions and reality	6	Conducting research across the supply chain
4	34	No to "dirty" aggregates	23	New recycling technologies	27	Circular business models	31	Gap between secondary and needed materials	32	Not reusing and recycling at any cost
5	17	Modular constructions	5	Raising awareness	26	Law on circular economy	15	Plan and design for future	16	Design for reassembly
6	39	Material passports	34	No to "dirty" aggregates	24	Fully transparent process	36	Allowing enough time for best choice	17	Modular constructions
7	27	Circular business models	22	New role of demolition companies	21	Pre Demolition audit	29	Knowledge about circular economy	10	Reuse/recycling in the LCA
8	9	Ladder of Lansink	38	Urban mine database	12	Tool for best treatment	30	Relieving political pressure	11	New value indicators
9	10	Reuse/recycling in the LCA	21	Pre Demolition audit	17	Modular constructions	8	Standardization of products	27	Circular business models
10	22	New role of demolition companies	9	Ladder of Lansink	34	No to "dirty" aggregates	32	Not reusing and recycling at any cost	36	Optimum aggregate mix - taking everything into account

Table 8: perceptions of importance of changes

Table 9 represents the measure of difference in perceptions on importance of changes for each of the branches in the stony materials supply chain. Key observations are:

- All branches scored relatively high.
- Branch of primary aggregates producers scored the highest, 0.95.
- Concrete producers' branch is second with 0.66.
- Branch of demolition companies came third, scoring 0.60
- The least differences are observed in recycling companies' branch that scored 0.55.

DC	RC	PAP	CP
0.60	0.55	0.95	0.66

Table 9: measure of difference of perceptions on the branch levels

Table 10 represents the percentages of responsibility of actors for each of the ten changes that are in top ten of changes based on importance. Making comparison with the percentages in Figure 21, depicting perception of responsibility of the actors on the level of supply chain for all forty changes, it is observed that:

- Government is even more dominant because of the percentages of responsibility assigned to other actors is lower. For example, the second most responsible actor, supply chain, moved from 15.56% to 9.17% of assigned responsibility when only the ten most important changes are taken into account.

Final rank	Supply chain level		Responsible actors																
	Nr.	Change	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	Sci	EU	BO	RB	Ind	Ban	IC	CC
1	23	New recycling technologies	0.00	62.50	0.00	6.25	0.00	0.00	18.75	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	6.25	0.00
2	26	Law on circular economy	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	15	Plan and design for future	0.00	0.00	0.00	6.25	18.75	6.25	6.25	43.75	6.25	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	34	No to "dirty" aggregates	0.00	18.75	0.00	50.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00
5	17	Modular constructions	0.00	0.00	0.00	18.75	0.00	25.00	0.00	43.75	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	39	Material passports	0.00	0.00	0.00	0.00	58.33	14.58	14.58	6.25	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	27	Circular business models	6.25	25.00	0.00	0.00	6.25	0.00	37.50	0.00	0.00	6.25	0.00	0.00	0.00	0.00	6.25	6.25	6.25	0.00
8	9	Ladder of Lansink	12.50	12.50	0.00	0.00	56.25	6.25	6.25	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	10	Reuse/recycling in the LCA	12.50	0.00	0.00	0.00	43.75	18.75	6.25	0.00	12.50	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00
10	22	New role of demolition companies	47.92	8.33	0.00	0.00	16.67	20.83	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		%	7.92	12.71	0.00	8.13	32.50	9.17	9.58	9.38	1.88	3.75	1.25	1.25	0.00	0.00	0.63	0.63	1.25	0.00

Table 10: ten most important changes – assignment of responsibility

Figure 28 represents the SNA graph on the level of supply chain (Figure 24), with the ten most important changes marked with red circles. Key observations are:

- Government is obviously dominant with four of the changes in its vicinity.
- Designer is surprisingly also an influential actor considering that both changes 15 and 17 are in the top ten.

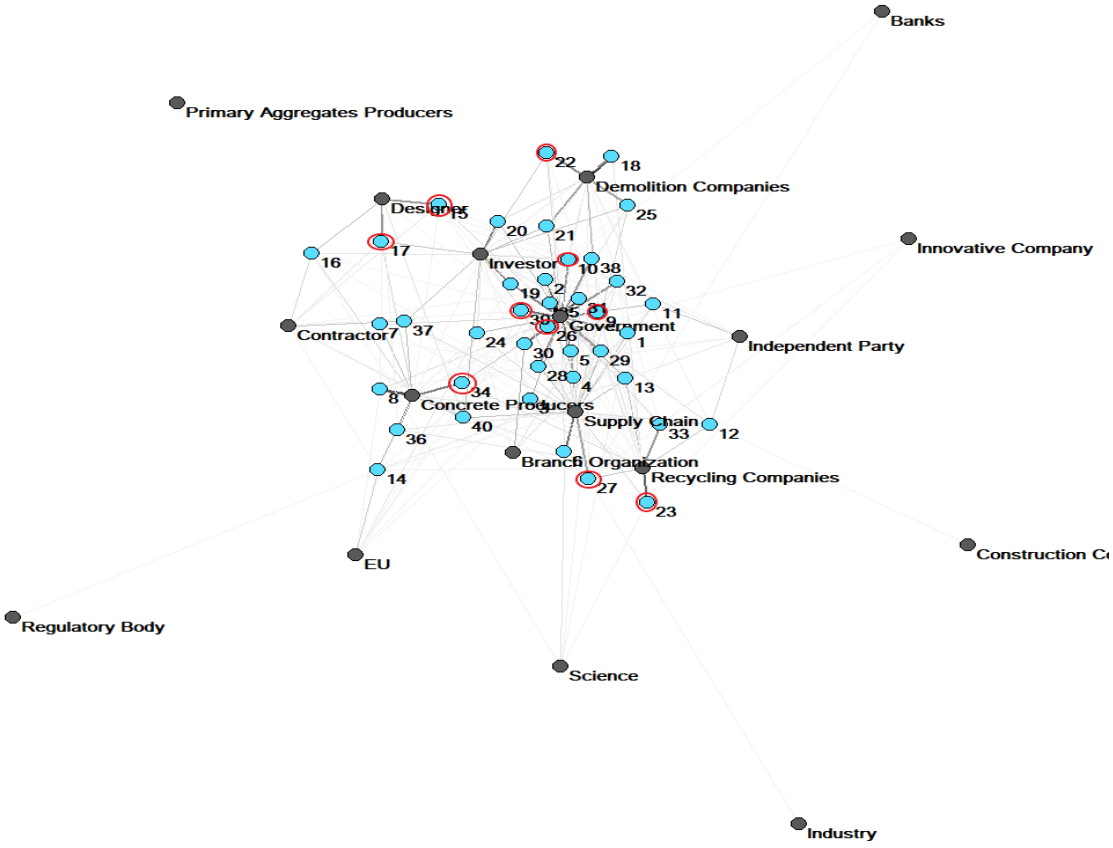


Figure 28: SNA graph, supply chain level with the ten most important changes singled out

4.3 Validation workshop

Validation workshop was conducted in line with its formulation in Chapter 3 (Research methodology). On a general level, it is noted that the participants reacted positively to the research as a whole, noting that this approach was not taken before. Now, the focus is turned towards the results and reflection of the branch organizations on them. This part is structured in line with the structure of the workshop itself. Therefore, first, the reflections on the results on branch levels are postulated, which is followed with the reflection on results on the level of supply chain.

4.3.1 Demolition companies

The representative of DC branch generally recognized all of the results, with the most relevant feedback following. First, when showed the percentages of responsibility graph (Figure 6), he stated that he recognizes the results and that he would maybe expect even more responsibility attributed to government and investors. When confronted with differences in perceptions graph (Figure 7), he stated that these high differences are present because of two reasons. First, some companies from his branch, aside from doing demolition, they also have other lines of work like recycling, or similar. Therefore, they have different business models and different interests. Second, he stated the there are around a hundred members within his branch, and that during the discussion about circular economy in branch meetings these differences were present. When shown the SNA graph (Figure 8), he stated that he recognizes the identified islands. However, he would expect a more central position of the investors because they are paying and have interest of letting DC to do their job. Representative of the RC branch organization backed this. RC further pointed that assigning that much responsibility to the supply chain is a bit vague, to which DC responded that it is

hard to explain, but that it is expected to see that they think that everybody is responsible. PAP observed the low responsibility assigned to the branch organizations, to which everybody reacted in a disappointed manner.

Summing it up, the main observations are:

- Even more responsibility could have been assigned to government
- Different lines of work imply different business models and interests, and, therefore, the differences in perceptions between the companies from the branch of demolition companies.
- Representative of the recycling companies' branch noted that the branch of demolition companies assigned too much responsibility to supply chain.
- Small amount of responsibility assigned to branch organization.

4.3.2 Recycling companies

RC branch representative recognized all of the results. Here, the most interesting feedback is postulated. First, reflecting on Figure 10, RC stated that the high responsibility assigned to government is recognizable within his branch. This is because the branch has been trying to create a market in the stony materials sector for a long time, without success. Therefore, they are frustrated and now they look to government instead to the supply chain with the maxim "We have tried for so long and we do not know what to do anymore. Help us.". When confronted with the differences in perceptions (Figure 11), the RC recognized the results. As a reason for these high differences, he stated the fact that the companies do not communicate that often with each other and that different companies have different business focuses and that some of them have additional lines of work. The SNA graph (Figure 12) yielded recognition from RC. When asked about the difference between his and DC branch in perceptions of responsibility of the supply chain actor (DC – high, RC – low), RC stated that if you want a viable business case in recycling than you need some regulations. Therefore, the government. He explained that even today if the landfilling ban was removed there would not be this much recycling going on. PAP pointed that this is clear if situation in other countries that do not have such laws are observed.

Therefore, the main observations of this part are:

- High responsibility assigned to government because of the frustration of the branch for trying to make it work for a long time.
- High differences of perceptions between the companies is attributed to the different lines of work that the companies within the branch have and the fact that they do not communicate on a regular basis.
- If a sustainable business case in recycling is to be achieved, then new laws need to be introduced. Parallel is drawn with the introduction of the land filling ban, which enabled recycling practices in the Netherlands. This also supports the high responsibility assigned to government.

4.3.3 Primary aggregates producers

PAP representative generally recognized all of the result stemming from her branch. Commenting on Figure 14, she stated that they think that government has to make some rules in order to spur circularity. Furthermore, reflecting on the high responsibilities assigned to supply chain, she stated that some of the branch members also have recycling companies, and that they see all aggregates as good aggregates. Relating to CP branch, she stated that they think that CP branch is a bit afraid of buying secondary aggregates. When asked about the 0% percent of responsibility assigned to themselves, she stated that for her branch demolition and recycling are too far in order to consider themselves responsible. However, she also pointed

that they took part in the Concrete Agreement in order to make sure that the real situation in regard to circular economy is taken into account. This was followed by a discussion about what circularity actually is with RC pointing that it is broader than recycling and demolition, hinting at the product level reuse as the final goal.

Key observations stemming from this part are:

- Concrete producers' branch is a bit afraid of buying secondary materials.
- There is a need for government to introduce some rules in order to spur the change to circularity.

4.3.4 Concrete producers

CP branch representative acknowledged most of the results. He did not see the assigning most of responsibility to government (Figure 17) as recognizable within his branch. He stated that contractor and investor should score more, as they provide money for circular developments, for which there is no great demand at the moment. When reflecting on differences in perceptions (Figure 18) he stated that it was completely expected, because there were two interviewees from the ready mix concrete sector, and the other two from the prefabricated sector. When reflecting on responsibilities assigned to the CP branch by other actors, he stated that he did not expect such a high ranking of the "standardization of products" change. He added that it is important for them that the value of concrete waste materials is well appreciated.

Key observations from this part are:

- Expectation of more responsibility assigned to investor and contractor as they determine demand for circular products and, consequently, less responsibility assigned to government.
- Differences of perception of companies within the branch are present because of their different lines of work.
- Value of concrete waste materials has to be recognized in order to spur the change towards circularity.

4.3.5 Supply chain

All branch organizations recognized the results on the supply chain level. Some of the observations they made are postulated. RC noted that on the supply chain level 75% of responsibility was assigned to the actors outside the supply chain, leaving only 25% for the supply chain itself. There was also a discussion about what are the implications of this research to the Concrete Agreement. There was a general agreement that there is a contradiction in going for the agreement that is voluntary on one hand, and stating that the government is the most responsible actor for achieving circularity on the other.

Following from above, the main observations are:

- High level of responsibility is assigned to the actors that are outside the stony materials supply chain.
- With the introduction of voluntary agreements as an important policy instrument, the government obviously perceives the supply chains as responsible for making a change towards circularity. This is in contradiction with the perception of the stony materials supply chain, which assigned the most responsibility to government.

4.4 Summary of key observations

This part summarizes the main observations from the results postulated in this chapter with the goal of setting a basis for the discussion about the implications of the results for the stony materials supply chain in the next part. The summary is made in form of a table (Table 11). Each observation is numbered for easy referencing later on, and for each observation a reference is made to where it can be found (Figure/Table, Chapter).

Key observations - branch level				
Perceptions on responsibility		Reference	Observation nr.	Observations
4.2.1.1 Branch level	4.2.1.1.1 DC	4.2.1.1.1.1 Figure 5	1	80.92% to Other
			2	0% to PAP
			3	10.53% to DC (highest from SC)
		4.2.1.1.1.1 Figure 6	4	32.89% to SC
			5	25.66% to Gov
			6	10.53% to DC
		4.2.1.1.1.2 Figure 7	7	Considerable differences in between interviewees and between interviewees and branch level
		4.2.1.1.1.3 Figure 8	8	Change nr. 7 not recognized
			9	SC island
			10	Gov island
			11	DC island
			12	Des island
	4.2.1.1.2 RC	4.2.1.1.2.1 Figure 9	13	75.17% to Other
			14	0% to PAP
			15	12.08% to RC (highest from SC)
		4.2.1.1.2.1 Figure 10	16	40,27% to Gov
			17	12.08% to RC
			18	All others <10%
		4.2.1.1.2.2 Figure 11	19	Considerable differences in between interviewees and between interviewees and branch level
		4.2.1.1.2.3 Figure 12	20	Gov island
	4.2.1.1.3 PAP	4.2.1.1.3.1 Figure 13	21	66.23% to Other
			22	0% to PAP
			23	14.29% to CP (highest from SC)
		4.2.1.1.3.1 Figure 14	24	27.27% to Gov
			25	16.88% to SC
			26	14.29% to CP
			27	10.39% to DC
		4.2.1.1.3.2 Figure 15	28	Change nr. 7 not recognized
			29	Gov island
			30	CP island
			31	DC island
	4.2.1.1.4 CP	4.2.1.1.4.1 Figure 16	32	70.97% to Other
			33	0% to PAP
			34	14.84% to CP
		4.2.1.1.4.1 Figure 17	35	32.9% to Gov
			36	17.42% to Inv
			37	14.84% to CP
		4.2.1.1.4.2 Figure 18	38	Considerable differences in between interviewees and between interviewees and branch level
		4.2.1.1.4.3 Figure 19	39	Gov island
			40	Inv island
			41	CP island

Key observations			
Perceptions on responsibility	Reference	Observation nr.	Observations
4.2.1.2 Supply chain level	4.2.1.2.1 Figure 20	42	73.05% to Other
		43	10.23% to CP (highest from SC)
		44	0% to PAP
	4.2.1.2.1 Figure 21	45	31.54% to Gov
		46	15.56% to SC
		47	10.23% to CP
		48	10.13% to Inv
	4.2.1.2.2 Figure 22	49	Considerable differences in between branches and between branches and supply chain level
		50	50.97% DC vs. SC
		51	42.37% CP vs. SC
		52	32.62% RC vs. SC
		53	27.36% PAP vs. SC
	4.2.1.2.3 Figure 23	54	2(/40) changes with 1 responsible actor
		55	8(/40) changes with 3 or less responsible actors - 20%
		56	27(/40) changes with 5 or more responsible actors - 67.5%
	4.2.1.2.4 Figure 24	57	Gov island
		58	CP island
		59	DC island
		60	RC island
		61	Des island
	4.2.1.2.4 Figure 25	62	Three groups of changes identified based on their centrality. Key changes: 26 and 35.
	4.2.1.2.4 Figure 26	63	Three groups of actors identified based on their centrality.
	4.2.1.2.4 Figure 27	64	Key actors: Gov, Inv and SC
4.2.2 Perception on responsibility of the important actors	Table 2	65	From these Tables, differences in perceptions of responsibility is observed based on the different changes for which the (same) important actors are perceived as responsible by branches and supply chain
	Table 3		
	Table 4		
	Table 5		
	Table 6		
	Table 7	66	Top ten of changes for which the responsibility is assigned to government
4.2.3 Perceptions on importance of changes	Table 8	67	Differences in perceptions on importance of changes between branches and between branches and supply chain
		68	29 unique changes are perceived by actors as part of top ten most important ones.
	Table 9	69	Measure of difference - relatively high for all branches
		70	0.95 PAP
		71	0.66 CP
		72	0.60 DC
		73	0.55 RC
	Table 10	74	Government is even more dominant when only the top ten most important changes are taken into account
	Figure 28	75	Obvious centrality of government
		76	Designer is also an influential actor

Key observations			
Perceptions on responsibility	Reference	Observation nr.	Observations
4.3 Validation workshop	4.3.1 DC	77	Maybe even more responsibility to government
		78	Differences because of different lines of work that the companies do --> different business models --> different interests
		79	More responsibility for investor because they are paying and determining the scope of demolition
		80	RC observed that there is too much responsibility assigned to the SC by DC
		81	Very little responsibility for the BO
	4.3.2 RC	82	High responsibility of government is due to the frustration of the branch because they tried to make it work for a long time.
		83	High differences because of companies not communicating regularly and because of different lines of work they have
		84	If you want a sustainable business case in recycling then there have to be some laws to enable that (like today - the landfilling ban) --> government most responsible
	4.3.3 PAP	85	CP branch is a bit afraid of buying secondary aggregates
		86	Government is needed to put in some rules
	4.3.4 CP	87	Did not expect so much responsibility attributed to government, but rather to investor and contractor as they dictate the demand for circular products, which is currently on a low level
		88	Differences expected because of different lines of work of companies
		89	Importance of recognition of value of concrete waste
	4.3.5 SC	90	High level of responsibility assigned to the actors outside of the supply chain (75%)
		91	Concrete Agreement: contradiction - government transfers responsibility to the supply chain, but the supply chain sees government as responsible.

Table 11: summary of key observations

4.5 Discussion – underlying reasons for inertia in the stony materials supply chain

This part relates the main observations postulated in the previous part of this chapter to the inertia in the stony materials supply chain that was observed in Chapter 2 (Literature review) of this thesis. In the same chapter, it was pinpointed that ambiguity of the term "circular economy" allows for different interpretations and, consequently, argued that, together with the phenomenon of diffusion of responsibility, it might be the underlying reason for emergence of inertia. First, the assumption stating that there are differences of perceptions between the actors in the stony materials supply chain is supported with relevant observations postulated in Table 11. Second, observations are postulated that confirm the diffusion of responsibility assumption made in Chapter 1.1 (Problem statement). Third, discussion about the underlying reasons for differences in perceptions and diffusion of responsibility, and therefore for inertia as well, in the stony materials supply chain is laid down. In this way the third research sub-question, *"What are the underlying reasons for inertia in relation to the change towards circularity in the stony materials supply chain?"*, is answered.

4.5.1 Differences of perceptions

First, differences of perceptions on responsibility are pinpointed on the level of the branches. That is, in-between the companies from each of the branches, as well as between the companies and the branch as a whole. Observations 7, 19 and 38 show that these differences are, indeed there, and that they are significant. Therefore, there are differences in perceptions on the level of the branches.

Moving one level up, to the stony materials supply chain as a whole, first, observation 49 shows that these differences are also present in-between branches, as well as between branches and the supply chain. From the observations 50 – 54, it can be seen that differences in perceptions of responsibility between branches and supply chain are 27% for PAP branch, 32.5% for RC branch, 42.5% for CP branch and 51% for DC branch. It is also observable that these are even higher when comparing branches, which is expected considering that the supply chain level represents the aggregated scores from the branches. Second, observations 54 – 56 show that for 67.5% of the changes five or more actors were perceived as responsible. Furthermore, there were only two changes (5%) for which only one actor was assigned responsibility. When there is only one actor to whom the responsibility is assigned, it means that all of the actors have the same perception for that change. Third, observation 65 observes the differences in perceptions between branches based on the different changes for which the same actors are perceived as responsible by different branches. Fourth, observation 67 shows that there are differences in perceptions in-between branches and between branches and the supply chain on importance of changes. Fifth, observations 69 – 73 encapsulate a measure of difference for each of the branches, based on the perception on importance of changes. DC scored 0.6, RC 0.55, CP 0.66 and PAP 0.95. Value of this measure is in the range from 0.25 to 1, with 0.25 meaning that all of the companies from one branch perceived the same changes as important, and 1 that the perceptions on the ten most important changes is completely different between the companies from one branch. Based on that, the differences within each of the branches is observed to be high (observation 69). This is further supported with the fact that when comparing perceptions of branches and supply chain on the ten most important changes, twenty-nine different unique changes are observed (observation 68). Therefore, it is concluded that, also, in-between branches and between branches and supply chain there are significant differences in perceptions of responsibility.

From above, it is clear that there are significant differences in perceptions in-between the companies from the same branch, between companies and corresponding branch, in-between branches and between branches and the supply chain as a whole. Therefore, the assumption that differences of perceptions are present on every level of the stony materials supply chain is confirmed. This is pinpointed with the observation from part one of research, stating that considering that there are only five (out of forty) changes that were perceived as needed by more than one of the branches, making it clear that there are significant differences in perception. Furthermore, as this research dealt with "what" should be done, without touching upon "how", and that it encompassed a 4-actor material-flow based scope, it is expected that the differences are even larger than observed. All of the above is summarized in Figure 29, which relates to the observations in Table 11.

Observation nr.	Observations
7	Considerable differences in between interviewees and between interviewees and branch level - DC
19	Considerable differences in between interviewees and between interviewees and branch level - RC
38	Considerable differences in between interviewees and between interviewees and branch level - CP

Observation nr.	Observations
49	Considerable differences in between branches and between branches and supply chain level
50	50.97% DC vs. SC
51	42.37% CP vs. SC
52	32.62% RC vs. SC
53	27.36% PAP vs. SC
54	2(/40) changes with 1 responsible actor
55	8(/40) changes with 3 or less responsible actors - 20%
56	27(/40) changes with 5 or more responsible actors - 67.5%
65	From these Tables, differences in perceptions of responsibility is observed based on the different changes for which the (same) important actors are perceived as responsible by branches and supply chain
67	Differences in perceptions on importance of changes between branches and between branches and supply chain
68	29 unique changes are perceived by actors as part of top ten most important ones.
69	Measure of difference - relatively high for all branches
70	0.95 PAP
71	0.66 CP
72	0.60 DC
73	0.55 RC

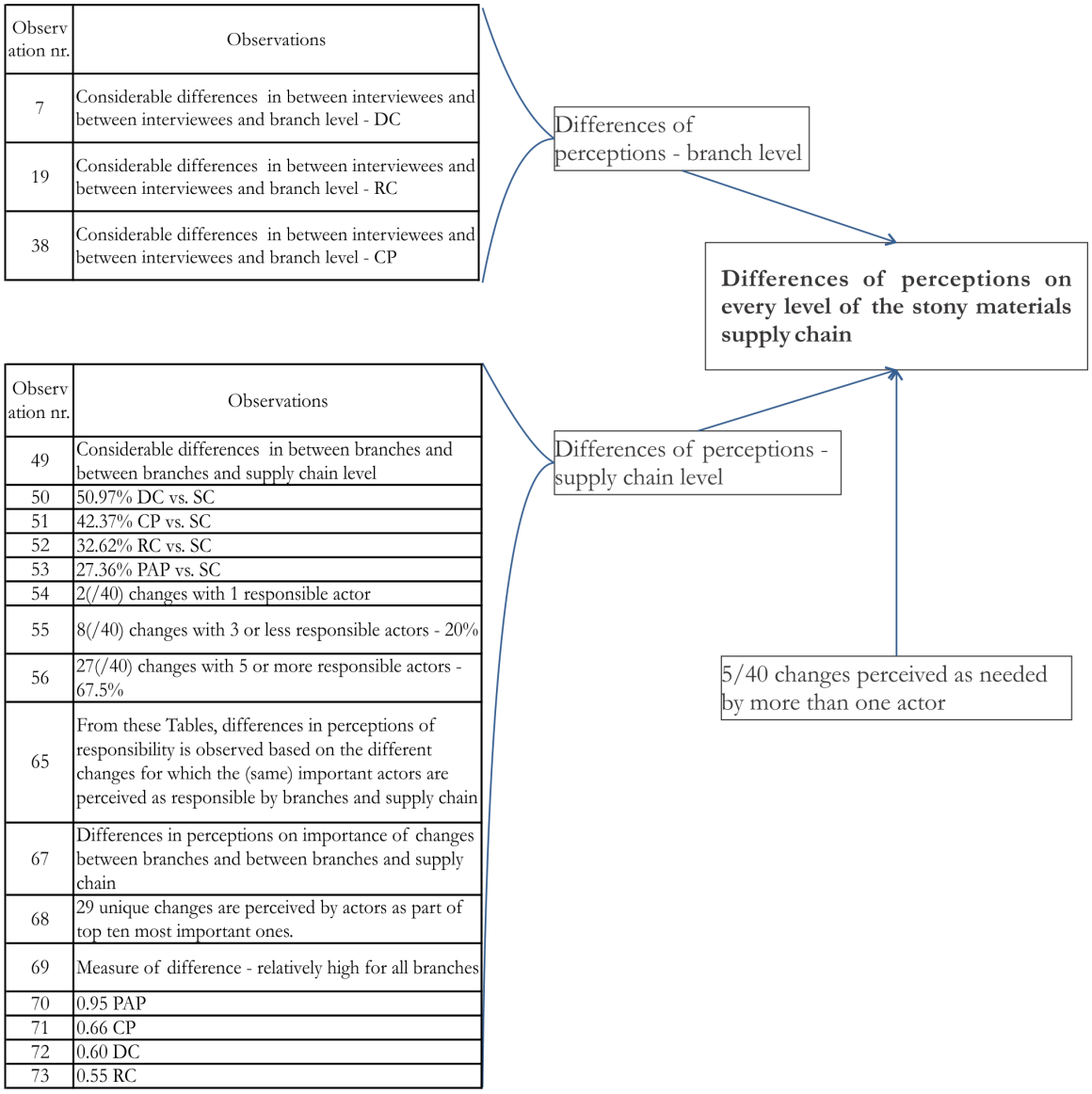


Figure 29: Differences of perceptions - reasoning

4.5.2 Diffusion of responsibility

Following from Chapter 2 (Literature review), it is argued the phenomenon of diffusion of responsibility is present in the stony materials supply chain. In order to confirm this assumption, first, the branch level observations are stated. This is followed by an analysis of the observations on the supply chain level.

Starting with the branch level, first, from observations 1, 13, 21 and 32 it can be seen that the largest part of responsibility is assigned to actors outside the supply chain. Namely, DC branch assigned 81% to other actors, RC 75%, PAP 66% and CP 71%. Second, observations 3, 15, 23 and 34 show that the most responsibility assigned to an actor within the supply chain ranges from 10.5% to 15% in the four branches. Third, observations 4, 5, 16, 24, 25, 35, 36 show that the actors perceived as the most responsible per branch are outside the supply chain. Precisely, DC branch perceived the supply chain as the most responsible actor with 33% of assigned responsibility. For RC branch that is government with 40%. PAP branch also sees government as the most responsible with 27%. CP branch shares that view with 33% of responsibility assigned to government. Combining this with the responsibilities assigned to the actors in the supply chain, it is observed that almost three times more responsibility is assigned to the actors outside the supply chain. Fourth, observations 9 – 12, 20, 29 – 31 and 39 – 41, representing the islands of responsibility

on the SNA graphs, clearly point to centrality of the actors outside the supply chain for changing towards a circularity in the stony materials supply chain. Fifth, all four branches assigned 0% responsibility to the PAP branch, including themselves (observations 2, 14, 22 and 33). Therefore, the responsibility for making a change towards circularity is diffused to outside of the supply chain on the level of branches.

Looking at the level of the supply chain, first, observation 42 states that 73.05% of responsibility is assigned to the actors outside the supply chain. This is supported by the recognition of all branch representatives in the validation workshop (observation 90). Second, CP branch is the actor within the supply chain with the most responsibility assigned (10%, observation 43), while government represent the actor with the most responsibility (31%, observation 45) outside the supply chain. Responsibility of the most responsible actor within the supply chain is three times lower than that of the actor outside the supply chain with the most responsibility. Third, supply chain is perceived as the second most responsible actor, with 15.56% of assigned responsibility (observation 46). Recognition of supply chain as responsible actor is a direct manifestation of diffusion of responsibility. 0% of responsibility is assigned to PAP branch (observation 44), completely excluding one (out of four) actors within the supply chain. Fourth, observations 57- 61 represent the islands of responsibility from the SNA graphs, which show the importance of actors outside the stony materials supply chain for the change towards circularity in the stony materials supply chain. Particularly, government plays a major role in this change. Fifth, observation 63 identifies three groups of actors based on the centrality in 1-mode SNA graph on the level of supply chain. In other words, based on the level of assigned responsibility, actors are divided into three groups. This clearly points to diffusion of responsibility. Therefore, the phenomenon of diffusion of responsibility is present at the level of the stony materials supply chain.

The reasons stated above confirm the assumption that the diffusion of responsibility phenomenon is present in the stony materials supply chain on all levels. This is further supported with the observation from part one of research, stating that responsibility for only three (out of forty) changes were assigned to companies from one of the branches, with the remaining thirty-seven assigned to the level of supply chain. All of the above is summarized in Figure 30, which relates to the observations in Table 11.

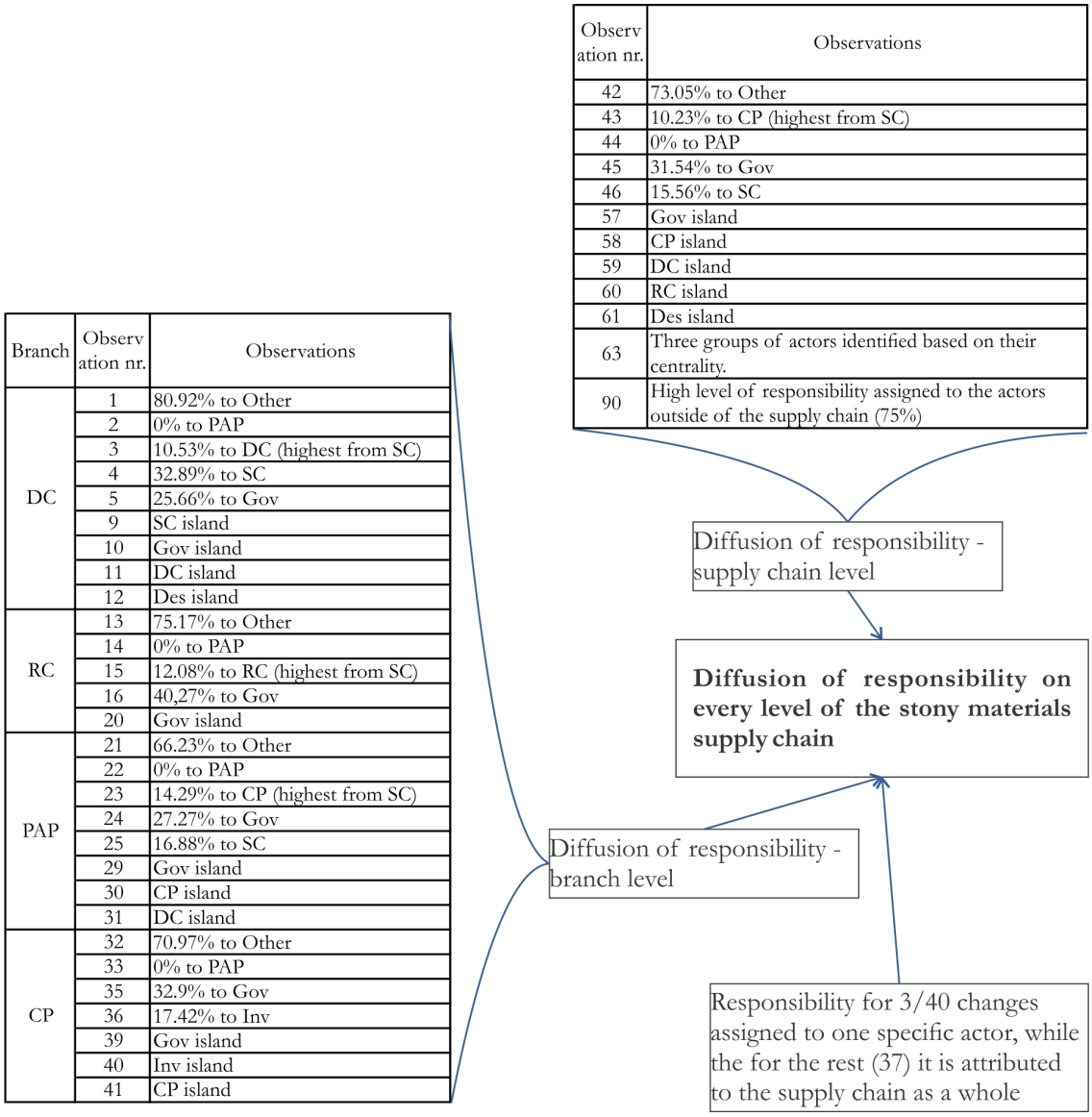


Figure 30: Diffusion of responsibility - reasoning

4.5.3 Discussion - underlying reasons

This parts looks into the reasons for the confirmed differences of perceptions and diffusion of responsibility, and therefore also for inertia, in the stony materials supply chain.

Starting with the differences in perceptions on the branch level, feedback from the validation workshop points to the fact that companies, even in the same branch, have different lines of work, which imply different business models and, therefore, different interests. Namely, DC, RC and CP branch representatives pointed to that as a reason for difference in perceptions of the companies within branches (observations 78, 83 and 88). As already stated, a change towards circularity promises significant benefits for companies that make it. Furthermore, there is a plan for the Netherlands to become circular in 2050. Therefore it is expected that becoming circular is one of the main interests of companies. However, as postulated, this is not the case. This contradiction leads to a conclusion that the companies do not see the benefit of becoming circular and, therefore, do not have vested interest in making a change towards it. This is supported with statement from the CP branch representative during the validation meeting that all they need for becoming circular is recognition of the value of stony materials waste (observation 89). This is further backed by the results of the first part of research, perceived needed changes and their perceived

ranking. Namely, change number 27 states the need for formulation of circular business models that will pinpoint the benefits that will stem from making a change towards circularity. Furthermore, this change is perceived as the seventh most important in the stony materials supply chain. Moreover, perceived change number 1 pinpoints the need for development of new ways of appraising value in order to support circular business decisions. In addition, change number 10 addresses the issue of inability of LCA to take into account the value of reuse or recycling. Also, change number 11 supports this with the propositions of creating new value indicators in order to support decisions leading to circularity. Therefore, one side of the problem is the lack of incentive for the companies within the stony materials supply chain to make a change towards circularity.

As already postulated in introductory part and as it is further elaborated in Appendix A of this thesis, each supply chain has its own specificities that influence the interpretation and application of the notion of circular economy. When it comes to the stony materials supply chain, the most important one is that of longevity of its products. Namely, products from the construction sector, buildings and structures, which at the end of their lives go into the stony materials CDW stream, have characteristically long life cycles. These span for fifty or more years and have serious implications for the companies in the sector. First, they imply high levels of uncertainties. Second, they hinder the function over ownership principle, as detailed in Appendix A of this thesis, because of those uncertainties. Furthermore, the companies today are developing strategic plans for up to ten years in advance, which makes taking into account what is to be done with the products at the end of life cycles impossible. Moreover, all of the companies present in the market today have successful business models, which are adapted for today's linear economic model. Introducing circularity would seriously destabilize this existing equilibrium, as it implies disruption on every level. Furthermore, the notion of circular economy is not strictly defined and multiple interpretations are possible. This adds to the uncertainty of the companies as it may prove that their vision of circularity is, in the end, not the "right" one. Therefore, the companies are discouraged to go out of their current market "comfort zones" and change towards circularity, especially if the risks and uncertainties, implied by the longevity of products, and ambiguity of the notion of circular economy are taken into account. This is further supported with the finding from part one of research, stating that actors have different circular stories, personalized to fit their strategic interests. The question is raised whether it is even possible to transition to circularity slowly, playing by the rules of linear economy? Or is an instant overhaul needed in the form of an immediate circular shock therapy?

RC branch representative, when reasoning about the differences of perceptions in the validation workshop, also stated that this is the case because the companies are not communicating regularly between themselves, and that there is no way for their interests to be aligned (observation 83). This can be explained with the fact that the branch organizations, as the only connector for all companies within a branch, were assigned only a tiny bit of responsibility for the changes leading to circularity. This is observable on the level of the branches and supply chain from the SNA graphs (Figure 8, Figure 12, Figure 15, Figure 19, Figure 24). Furthermore, this is also recognized during the validation workshop (observation 81). This gains even more significance if it is known that change number 4 (Integration of supply chains) is perceived as the thirtieth (out of forty) according to importance, and that responsibility for it was not assigned to the branch organizations. Connecting this to the theory of organizational structure, which is briefly touched upon in Chapter 2 (Literature review), the notion of circular economy implies development of a "network" structure within supply chains, which implies long-term cooperation between the parties based on mutual interests. One of the previous paragraphs concluded that there is lack of mutual interests of the actors in the stony materials supply chain for a change to circularity and, therefore, it is doubtful that this needed "network" structure will form. Therefore, integration of supply chains, one of the main aspects of the notion of circular economy, is seriously hindered because the branch organizations are not given enough credit and responsibility, and because the companies are unable to see the benefits of becoming circular.

Government was perceived as the most responsible actor for making a change towards circularity (observation 45). This is further supported with observation 73, which analyzed the top ten changes based on responsibility assigned to government, pinpointing the centrality of the government if the change towards circularity is to be made (observation 74). RC branch representative stated that the reason for this is frustration of the branches within the supply chain. Namely, the argument here is that the supply chain has been trying for a long time to incorporate business models that are in line with the notion of circular economy, but without success. Now, they are expecting help from the government, because obviously they are not able to do it (observation 82). This is supported by the DC branch representative that stated he would possibly expect that the DC branch would have attributed even more responsibility to the government (observation 77). In general, expecting the government to act in order to implement circularity is supported with the current market situation. Namely, as already mentioned, the Netherlands is one of the leading countries when it comes to recycling. However, the reason for this is the landfilling ban, which is in place since 1997 (Overheid.nl, 1997), that forbids landfilling of CDW stream, including the stony materials. The RC branch representative stated that if this ban was removed today, there would be much less recycling going on (observation 84). Therefore, the government artificially created the current recycling market in the Netherlands. From here stems the notion that if a sustainable business models are to be achieved in regard to circularity, government needs to impose new rules that will ensure incentive for companies to engage in circular practices. This is further supported with PAP branch representative's statement that the government needs to put in some rules in order to spur the change towards circularity (observation 86). Furthermore, perceived needed change number 26, ranked as the second most important, proposes that a law regulating the notion of circular economy should be introduced (Table 8). Therefore, the supply chain is expecting the government to intervene and create a sustainable circular business opportunities for them. However, one of the main principles of circular economy, according to Ellen MacArthur Foundation (2015b), is that of incorporating real costs into the prices and letting them guide the industry. This, besides incorporating of negative externalities, also entails removing any taxes, subsidies or laws imposed by governments that influence these prices.

Another important finding from the validation workshop is the statement of the DC branch representative that he expected more responsibility to be assigned to investor, considering that he is the one providing the money and determining the scope of demolition process (finding 79). In addition, the representative of CP branch noted that he expected more responsibility assigned to contractor and investor because they determine the scope of the new projects and provide money for them (finding 87). He also added that this is currently not the case. Looking at Figure 3, depicting the scope of the stony materials supply chain, it can be seen that DC and CP branches represent opposite ends of the supply chain. Both of their statements relate to the lack of incentives for circular practices, with DC relating to the investor that provides money for demolition and CP to investor that finance the new construction project and contractor that designs and deliver it. Therefore, it can be said that the supply chain, as scoped in this research, is constrained from both, end-of-life and start-of-life, sides in terms of incentive for applying the notion of circular economy.

As already postulated in Chapter 2.1 (the Concrete Agreement), Dutch government has in the last years adopted voluntary agreements as an important policy instrument. An example of that are the Green Deals, which promote voluntary agreements between companies, civil organizations and different instances of government under the private law, meaning that it is not a law put down by government, but a voluntary contract between parties, one of which is the government. The goal of Green Deals is to stimulate green growth, which encompasses the notion of circular economy. It is clear from here that the perception of the government is that responsibility for making a change towards circularity lies within supply chains. This is in contrast with the observations from this research, which show that the perception of the stony materials supply chain on responsibility for changing towards circularity is mostly assigned to the government (observation 45). Effectively, the government and the stony materials are indirectly pointing fingers at each other, while the inertia for the changing towards circularity remains. Representatives of all branches

recognized these contradictory perceptions of government and supply chain, and stated that that is the main cause for the failure of the Concrete Agreement (finding 91). However, taking everything else postulated in this chapter into account, it can hardly be concluded that exactly and only this is the reason for the setback of the Concrete Agreement. It is rather a combination of everything postulated above.

Summing it up, the companies within the stony materials supply chain do not see the benefits of becoming circular. They lack incentives from both sides of the supply chain in monetary terms, as well as from the government in terms of introducing new legislations, taxes and/or subsidies. This is confirmed with observation 63, SNA 1- mode graph, which identifies three key actors for making a change to circularity in the stony materials supply chain: government, investor and supply chain. Furthermore, longevity of products implies high uncertainties for the companies. These are only enhanced with the ambiguity and disruptive nature of the notion of circular economy, which threaten to shatter their "comfort zone" of the current market. Moreover, the lack of incentive manifests itself in lack of mutual interests of the companies from the supply chain, which, in turn, hinders the needed integration of supply chain. In addition, there is a clear clash between the government and the stony materials supply chain in terms of perception of responsibility for making a change to circularity. While the supply chain perceives the government as the most responsible one, the government assigns the responsibility to the supply chain. Combination of everything above is the underlying reason for manifestation of inertia within the stony materials supply chain and continuous setbacks of the Concrete Agreement.

4.5.4 Conclusions

In this part, the main conclusions from this chapter are postulated, followed by graphical representation of reasoning behind them that relates to the key observations from Table 11 and other parts of this thesis.

Differences in perceptions and diffusion of responsibility are present in the stony materials supply chain and represent the main reasons behind the observed inertia. Underlying reasons for this are:

- Lack of incentives for companies in the stony materials supply chain to make a change towards circularity (Figure 31).

Observation nr.	Observations
78	Differences because of different lines of work that the companies do --> different business models --> different interests
79	More responsibility for investor because they are paying and determining the scope of demolition
83	High differences because of companies not communicating regularly and because of different lines of work they have
87	Did not expect so much responsibility attributed to government, but rather to investor and contractor as they dictate the demand for circular products, which is currently on a low level
88	Differences expected because of different lines of work of companies
89	Importance of recognition of value of concrete waste

Change nr.	Changes
1	New ways of appraising value
10	Reuse/recycling in the LCA
11	New value indicators
27	Circular business models

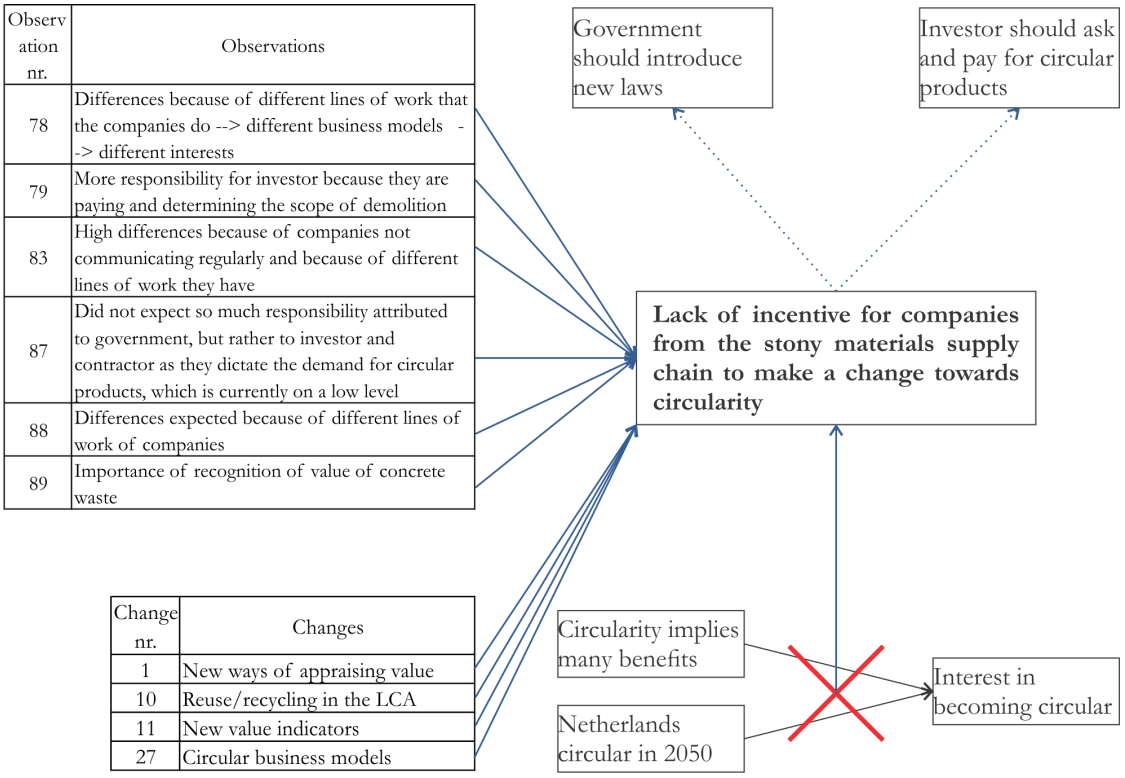


Figure 31: Lack of incentive - reasoning

- High uncertainties and risks in relation to making a change towards circularity for companies in the stony materials supply chain (Figure 32).

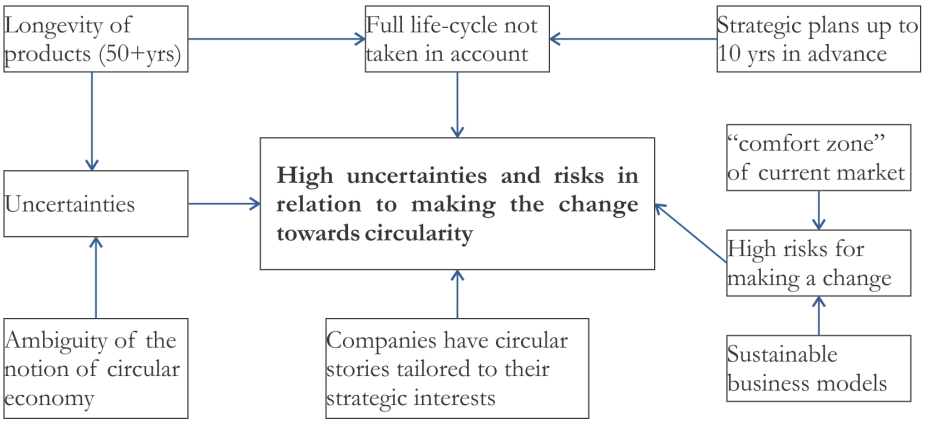


Figure 32: High uncertainties and risks - reasoning

- Lack of mutual interests for making a change towards circularity between actors in the stony materials supply chain (Figure 33).

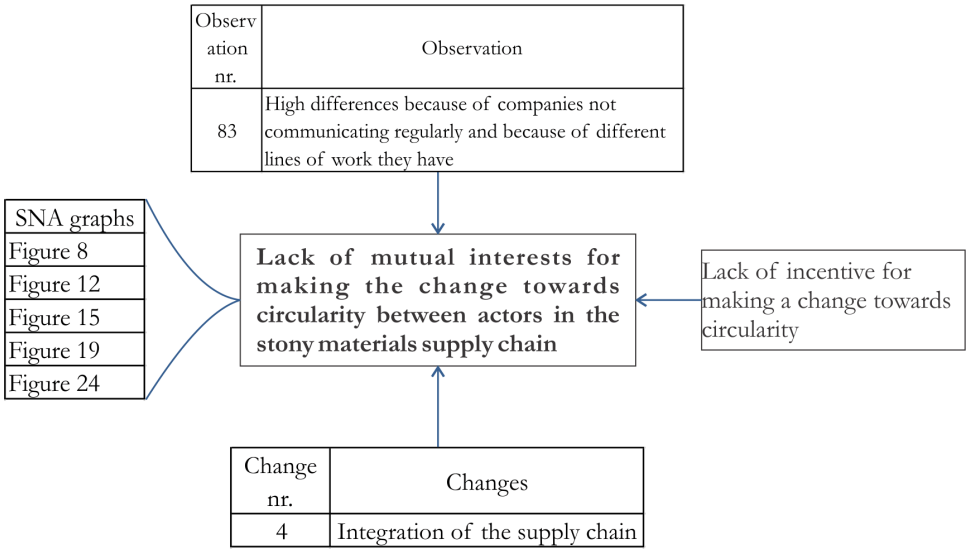


Figure 33: Lack of mutual interests - reasoning

- Clashes of perceptions on all levels in the stony materials supply chain, and especially between the supply chain and the government (Figure 34).

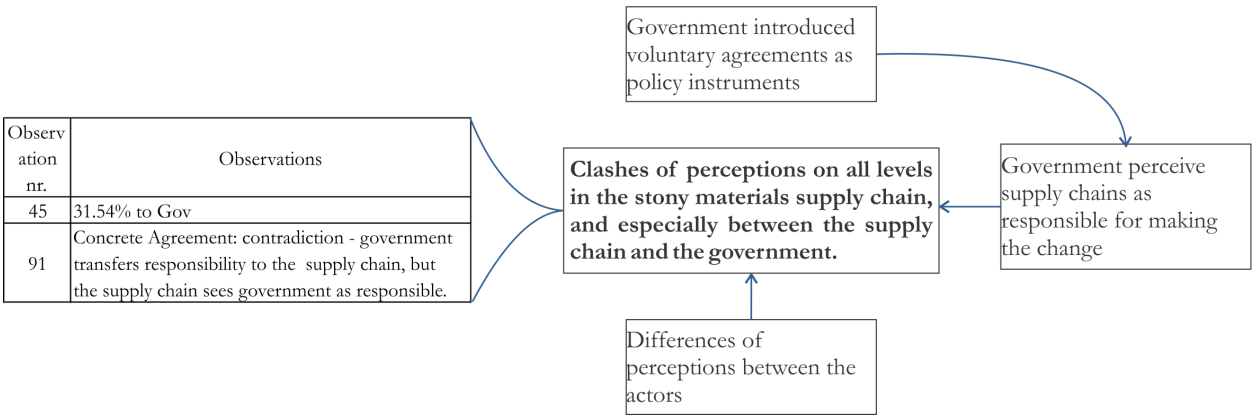


Figure 34: Clashes of perceptions on every level - reasoning

5 Discussion

In this part, the implications of the observations on the stony materials supply chain level for supply chains in general are discussed. Furthermore, the relevance of this research is pinpointed in the context of existing literature. In this way it provides an answer to the fourth research sub-question, which was formulated as: *"How do the underlying reasons for inertia in the stony materials supply chain translate to other supply chains?"*.

In Chapter 4 (Inertia in the stony materials supply chain – underlying reasons), the differences in perceptions of the actors and the existence of diffusion of responsibility phenomenon in the stony materials supply chain were confirmed and discussed as the underlying reasons for manifestation of inertia in regard to making a change towards circularity. As already discussed, each supply chain has its own specificities, which influence interpretation and implementation of the notion of circular economy to it. Therefore, generalization of results is dependent on the specificities of the stony materials supply chain, but also on specificities of other supply chains to which it should apply. Specificities of other supply chain need to be studied on a case-to-case basis, and their implications for the observations of this research interpreted. However, by scanning on-line databases containing examples of circular practices (Circle Economy, 2018; Ellen MacArthur Foundation, 2018; SITRA, 2018), it is observed that these are mostly one-off developments, indicating the existence of inertia in other supply chains as well. Therefore, although unique specificities of other supply chains may further contribute to inertia, it is argued that the conclusions from previous chapter are applicable.

In the case of the stony materials supply chain in the Netherlands, there are a few that impact the change towards circularity. First, the longevity of products of the stony materials supply chain was recognized as relevant for the change towards circularity. As deliberated in Chapter 4, longevity of products results in additional uncertainties and risks for companies in the supply chain, discouraging them from making that change. However, these represent just a small part of uncertainties that the change to circularity implies by itself. Namely, implementation of circular practices entails disruption on every level of current linear practices and therefore, brings many uncertainties for the companies. Therefore, the longevity of products does not influence the observations from the previous chapter to the extent of them being inapplicable on the general, supply chain, level. In other words, removing the uncertainties implied by longevity of products would not influence the key findings or conclusions of this research.

Second, another specificity that left its mark in the previous chapter is that of regulations imposed by the government in the Netherlands that influenced the markets relevant for the stony materials supply chain. Namely, the landfilling ban, which resulted in the Netherlands becoming the leader in the amount of recycled materials. As stated in Chapter 4, this regulation had positive effects on the circularity of the stony materials supply chain. Therefore, if it was not in place the situation would have been worse, and with it the inherent problems of difference in perceptions and diffusion of responsibility as well. Therefore, it is concluded that the existence (or not) of the landfilling ban does not influence the observations from Chapter 4.

Third, another specificity of the supply chains in the Netherlands is the introduction of the voluntary agreements as an important policy instrument by Dutch government. Considering that the concrete case used in this research was the voluntary Concrete Agreement, it is expected that it is a precondition for applicability of the findings to the general level. However, knowing that it is not yet ratified, with multiple setbacks behind it, and that one of the findings uncovered a clash on a higher level, between the supply chain and the government, it is concluded that existence (or not) of voluntary agreements does not influence the observations from the previous chapter.

Therefore, it is concluded that specificities of the stony materials supply chain do not influence the generalization of the findings and conclusions from the previous chapter. Considering that the above stated

specificities are present in every supply chain that is part of the construction sector in the Netherlands, it is of interest to note that the findings of this research are directly applicable to all of those supply chains.

As already mentioned in Chapter 1.1 (Problem statement), Papachristos (2014) acknowledged the existence of inertia in supply chains in relation to their transitioning to the closed-loop supply chains. He argued that the main cause of inertia is the competition between the manufacturers of original products and recyclers/refurbishers that are offering their products on the same market. However, according to the notion of circular economy, the ownership of the materials/products remains with the same actor when applicable. In other words, closing of the loop is also achieved at the company level, which implies that the manufacturer of original product and the recycler are the same actor. Furthermore, Papachristos (2014) used a system dynamics modelling approach based on product flow on the level of a generalized supply chain for assessment, neglecting the importance of social aspects of changing towards circularity and innate specificities of individual supply chains. Therefore, although recognizing the inertia of supply chains for making the change towards circularity, he addressed it in a way that is not in line with the main notions of circular economy. Furthermore, as Banerjee (2012), observed, and as it was pinpointed by examples in Chapter 1.1 (Problem statement), there is a great disproportion between the introduced policies and general talk about the notion of circular economy, and the actions that actually aim at achieving it. This points to the inertia when it comes to translating the policies into actions. Moreover, there is a general lack of literature and research related to the notion of circular economy that is recognized in relevant scientific literature (Elia et al., 2017; Ellen MacArthur Foundation & Granta Design, 2015; Geng et al., 2013; Ghisellini et al., 2016; Mendoza et al., 2017; Tisserant et al., 2017), as postulated in Chapter 1.1 (Problem statement). Therefore, this research, contributes to solving the scientifically recognized problem, which is observed in real-life as well, and at the same time expands the currently scarce literature on the notion of circular economy. It accomplishes that by analyzing the observed inertia in supply chains in line with the notion of circular economy, with perceptions of the actors from supply chains and the SNA approach at its core. In that sense, it represents a novel approach to analysis of supply chains, which serves as a starting point for further research in this direction, with the goal of eliminating the inertia-causing barriers and spurring the change towards circularity in supply chains.

6 Conclusions

This parts concludes this thesis by providing the answer to the main research question, which was formulated as follows: *"What are the underlying reasons for inertia in supply chains in relation to the change towards circularity?"*.

The notion of circular economy is gaining momentum in order to combat negativities of the current linear model and to ensure sustainable and prosperous future of humanity. However, because of its novelty, it is not precisely defined and it is possible to interpret it in a multitude of ways. With the knowledge that perceptions determine the reality, it is clear that this ambiguity of the notion of circular economy hinders its implementation. Furthermore, the hype surrounding circularity is supported by numerous plans and policies on (inter)national level. However, the actions that would reflect this hype are missing. Based on this, inertia was observed in supply chains when it comes to making the change towards circularity. The above-postulated main research question was formulated in order to help solve this problem. In order to achieve this, first, a literature review was conducted in order to provide further understanding of inertia and the concrete example of the stony materials supply chain, which, in turn, provided an answer to the first research sub-question. Second, based on the inputs from the literature review, a methodology, based on the SNA approach, was developed that enabled capturing and analyzing perceptions of the actors from supply chains, effectively answering the second research sub-question. Third, this methodology was applied to the concrete example of inertia in supply chains – the stony materials supply chain in the Netherlands. These results were postulated and interpreted, confirming the assumptions of existence of differences in perceptions between the actors in the supply chain and the phenomenon of diffusion of responsibility as the underlying reasons for the observed inertia. Furthermore, the observations were used to discuss the reasons underlying the emergence of differences of perceptions and diffusion of responsibility. This represents an answer to the third research sub-question. Fourth, a discussion about the specificities of the stony materials supply chain showed that these reasons can be generalized to the level of supply chains. This also represents the answer to the fourth research sub-question. Based on this the following conclusions are drawn.

Diffusion of responsibility and differences of perceptions are the underlying reasons for the manifestation of inertia in supply chains when it comes to making the change towards circularity. Furthermore, the main reasons for these two developments are:

- Lack of incentives for the companies in supply chains to make a change towards circularity.

  The companies within the supply chains do not see the benefits of becoming circular and therefore do not have interest in implementing circular practices. Furthermore, it was observed that the companies expect investors to spur this change by providing monetary incentives on the one hand, and the government to create a sustainable circular business models by introducing new laws, taxes and/or incentives on the other.

- High uncertainties and risks.

  Making the change towards circularity implies restructuring of the equilibrium existing in the current market. Furthermore, the notion of circular economy is ambiguous and open to interpretation. This results in high risks and high uncertainties for actors in supply chains that are discouraged to leave their "comfort zone" that they currently enjoy in the "linear" market.

- Lack of mutual interests between actors in supply chains.

  Following from the first conclusion actors do not have an interest in changing towards circularity because they cannot identify the benefits of doing so. Therefore, the common interest of changing

to circularity is non-existent between the actors in supply chains, which effectively hinders integration of supply chain that is the backbone of the notion of circular economy.

- Clashes of perceptions on all levels in supply chains, and especially between the supply chain and the government.

  Because of the lack of mutual interests in changing towards circularity, each actor focuses on its own, "linear", interests and engage in strategic behavior. These interests differ on every level, from in-between companies, over in-between branches to the level of supply chains. This results in clashes in perceptions, and therefore in perceived realities as well, of actors on every level in supply chains. Furthermore, there is a clash in perceptions of responsibilities between the supply chain as a whole and the government.

6.1 Limitations

During the course of formulation of this thesis, a couple of limitations regarding the conducted research became apparent. First, conclusions drawn on a general level of supply chains need to be validated and confirmed. Although the logic behind them is valid, they are a product of extrapolation from a specific case – the stony materials supply chain. Second, the scope of research was based on the flow of materials, with the recognition of DC, RC, PAP and CP as the actors that constitute the stony materials supply chain. However, from the results it is clear that there are a few more actors that should have been taken into consideration. Namely, based on Figure 21 and Figure 27 these are government and investor. Furthermore, the input of government would be even more relevant because of the identified clash of perceptions between it and the stony materials supply chain. If the government was included, the comparison of results would have been possible, as well as the validation of results. Third, time limitations limited the number of interviewees per branch for the second part of research to four. Although all of the findings were validated by the branch organizations, it is possible that by gathering inputs from a larger number of interviewees, the results would be different. However, considering the successful validation, the difference in results cannot be of that extent that it would influence the conclusions.

6.2 Recommendations

Based on the previous, limitations, part, the following recommendations for further research are formulated. First, there is a need of applying the methodology formulated in this thesis to different supply chains in order to acquire enough data to validate and confirm the conclusions on the general level that were drawn in this thesis. It is suggested to first analyze other supply chains from the construction sector because of the same, or similar, specificities as the stony materials supply chain (as deliberated in Chapter 5), and then to expand to other sectors. Second, expansion of research conducted in this thesis is needed. Namely, the inclusion of government and investor actors and reinterpretation of result with inclusion of their input.

In addition, each change that was perceived as needed in order to make a change to circularity entails research. It recognizes the current state as undesirable and proposes a change that has a goal of achieving the desired circular state. Furthermore, the fact that these changes are not incorporated yet indicates that there is a need for understanding of the underlying problems that are preventing that. Considering the conclusions of this thesis and the perceived importance of changes (Table 8), change number 27, which proposes creation of circular business models, is perhaps the most relevant one for further research.

Furthermore, on a general note, there is a need for research on all levels in regard to circular economy.

References

ABN AMRO, & Circle Economy. (2015). *Circular Construction. The foundation under a renewed sector*. Retrieved from https://www.circle-economy.com/wp-content/uploads/2016/06/Circle-Economy_2015_002_Rapport_Circulair-Construction_1-21.pdf

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). *Circular economy in construction: current awareness, challenges and enablers*. Paper presented at the Proceedings of the Institution of Civil Engineers-Waste and Resource Management.

BAM, & ARUP. (2017). *Circular business models for the built environment*. Retrieved from https://www.bam.com/sites/default/files/domain-606/documents/8436_business_models-606-1490949582322972999.pdf

Banerjee, S. B. (2012). A climate for change? Critical reflections on the Durban United Nations climate change conference. *Organization Studies, 33*(12), 1761-1786.

Batagelj, V. (2009). Social network analysis, large-scale. In *Encyclopedia of Complexity and Systems Science* (pp. 8245-8265): Springer.

Borgatti, S. P., & Halgin, D. S. (2011). Analyzing affiliation networks. *The Sage handbook of social network analysis, 1*, 417-433.

Breiger, R. L. (1974). The duality of persons and groups. *Social forces, 53*(2), 181-190.

Breiger, R. L. (1990). *Social mobility and social structure*: Cambridge University Press.

Broere, P. (2017, 10.09.2017) *Graduation topic discussion/Interviewer: U. Bukvic*.

Cagno, E., Trianni, A., Abeelen, C., Worrell, E., & Miggiano, F. (2015). Barriers and drivers for energy efficiency: Different perspectives from an exploratory study in the Netherlands. *Energy Conversion and Management, 102*, 26-38.

CBS, PBI, & Wageningen UR. (2017a). *Waste generation and treatment by sector, 1990-2014*. Retrieved from http://www.clo.nl/en/indicators/en0204-waste-generation-and-treatment

CBS, PBI, & Wageningen UR. (2017b). *Waste generation and treatment, 1985-2014*. Retrieved from http://www.clo.nl/en/indicators/en0204-waste-generation-and-treatment

CCICED. (2008). *Circular Economy Promotion Law of the People's Republic of China*. Retrieved from http://www.bjreview.com.cn/document/txt/2008-12/04/content_168428.htm

Circle Economy. (2018). Reports & insights. Retrieved from https://www.circle-economy.com/reports-insights/

Cohen, D., & Crabtree, B. (2006). Qualitative research guidelines project. In.

Cossu, R., & Williams, I. D. (2015). Urban mining: Concepts, terminology, challenges. *Waste Management, 45*, 1-3.

De Nooy, W., Mrvar, A., & Batagelj, V. (2011). *Exploratory social network analysis with Pajek* (Vol. 27): Cambridge University Press.

Deloitte. (2015). *Screening template for Construction and Demolition Waste management in the Netherlands*. Retrieved from http://ec.europa.eu/environment/waste/studies/deliverables/CDW_The%20Netherlands_Factsheet_Final.pdf

Di Maio, F., Rem, P. C., Baldé, K., & Polder, M. (2017). Measuring resource efficiency and circular economy: A market value approach. *Resources, Conservation and Recycling, 122*, 163-171. doi:https://doi.org/10.1016/j.resconrec.2017.02.009

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The qualitative research interview. *Medical education, 40*(4), 314-321.

Dobbs, R., Oppenheim, J., Thompson, F., Brinkman, M., & Zornes, M. (2011). Resource Revolution: Meeting the world's energy, materials, food, and water needs.

Einstein, A. (1905). On the electrodynamics of moving bodies.

Elia, V., Gnoni, M. G., & Tornese, F. (2017). Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production, 142*, 2741-2751.

Ellen MacArthur Foundation. (2015a). *Delivering Circular Economy: a toolkit for policymakers*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_PolicymakerToolkit.pdf

Ellen MacArthur Foundation. (2015b). *Towards the circular economy: business rationale for an accelerated transition*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf

Ellen MacArthur Foundation. (2018). Case studies. Retrieved from https://www.ellenmacarthurfoundation.org/case-studies

Ellen MacArthur Foundation, & Granta Design. (2015). *Circularity Indicators: An approach to measuring circularity*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Project-Overview_May2015.pdf

Ellen MacArthur Foundation, McKinsey Center for Business and Environment, & SUN. (2015). *Growth Within: A circular economy vision for competitive Europe*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf

European Commission. (2000). *Commission Decision on the European List of Waste COM 2000/532/EC*. Retrieved from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000D0532:20020101:EN:PDF

European Commission. (2015). *Closing the loop - An action plan for circular economy*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614

European Commission. (2016a). *Construction and Demolition Waste*. Retrieved from http://ec.europa.eu/environment/waste/construction_demolition.htm

European Commission. (2016b). *EU Construction and Demolition Waste Protocol*. Retrieved from http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8983

European Parliament, & Council of the European Union. (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directive (Text with EEA relevance). *Official Journal of the European Union L312/3*.

Florin, B. (2014). The European Economy: From a Linear to a Circular Economy. *Romanian Journal of European Affairs (RJEA), 14*(4), 78-91.

Freeman, L. C., Romney, A. K., & Freeman, S. C. (1987). Cognitive structure and informant accuracy. *American anthropologist, 89*(2), 310-325.

Geng, Y., Sarkis, J., Ulgiati, S., & Zhang, P. (2013). Measuring China's circular economy. *Science, 339*(6127), 1526-1527.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production, 114*, 11-32.

Greendeals.nl. (2017a). Green Deal approach. Retrieved from http://www.greendeals.nl/english/green-dealapproach/

Greendeals.nl. (2017b). Green Deals: Aanpak. Retrieved from http://www.greendeals.nl/green-deal-aanpak/

Greendeals.nl. (2017c). Overzicht alle Green Deals. Retrieved from http://www.greendeals.nl/greendeals/overzicht-green-deals/

Guerin, B. (2011). *Diffusion of responsibility*: Wiley Online Library.

Jones, C., Hesterly, W. S., & Borgatti, S. P. (1997). A general theory of network governance: Exchange conditions and social mechanisms. *Academy of management review, 22*(4), 911-945.

Keeble, B. R. (1988). The Brundtland report:'Our common future'. *Medicine and War, 4*(1), 17-25.

Lake, P., & Crowther, P. (2013). Data, an Organisational Asset. In *Concise Guide to Databases* (pp. 3-19): Springer.

Lippiatt, B. C., & Ahmad, S. (2004). *Measuring the life-cycle environmental and economic performance of concrete: the BEES approach*. Paper presented at the Proceedings of the International Workshop on Sustainable Development and Concrete Technology.

Marinković, S., Radonjanin, V., Malešev, M., & Ignjatović, I. (2010). Comparative environmental assessment of natural and recycled aggregate concrete. *Waste Management, 30*(11), 2255-2264.

McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., . . . Doménech, T. (2017). Circular economy policies in China and Europe. *Journal of Industrial Ecology*.

McPherson, J. M. (1982). Hypernetwork sampling: Duality and differentiation among voluntary organizations. *Social networks, 3*(4), 225-249.

Mendoza, J. M. F., Sharmina, M., Gallego-Schmid, A., Heyes, G., & Azapagic, A. (2017). Integrating Backcasting and Eco-Design for the Circular Economy: The BECE Framework. *Journal of Industrial Ecology*.

Ministerie van Infrastructuur en Milieu. (2014). *Landelijk afvalbeheerplan 2009-2021*. Retrieved from http://www.lap2.nl/beleidskader/

Ministerie van VROM. (2001). *Europese Afvalstoffenlijst (EURAL)*. Retrieved from https://www.rijksoverheid.nl/documenten/brochures/2010/11/23/europese-afvalstoffenlijst-eural

Mulders, L. (2013). *High quality recycling of construction and demolition waste in the Netherlands*. Retrieved from https://dspace.library.uu.nl/handle/1874/279530

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics, 140*(3), 369-380. doi:10.1007/s10551-015-2693-2

MVO Nederland. (2016). Het betonakkoord. Retrieved from https://mvonederland.nl/betonakkoord

Nasir, M. H. A., Genovese, A., Acquaye, A. A., Koh, S., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. *International Journal of Production Economics, 183*, 443-457.

Overheid.nl. (1997). *Wet- en regelgeving: Besluit stortplaatsen en stortverboden afvalstoffen*. Retrieved from http://wetten.overheid.nl/BWBR0009094/2016-04-01

Papachristos, G. (2014). Transition inertia due to competition in supply chains with remanufacturing and recycling: A systems dynamics model. *Environmental Innovation and Societal Transitions, 12*, 47-65.

Preston, F. (2012). *A Global Redesign?: Shaping the Circular Economy*: Chatham House London.

Rangan, B. V. (2008). Fly ash-based geopolymer concrete.

Rijkswaterstaat. (2013). *Nederlands afval in cijfers, gegevens 2006-2010*. Retrieved from https://www.afvalcirculair.nl/onderwerpen-1/helpdeskafvalbeheer/publicaties/downloads/afvalstoffenheffing-5/

Rijkswaterstaat, & National Institute for Public Health and the Environment. (2015). *Circular economy in the Dutch construction sector: A perspective for the market and government*. Retrieved from http://www.rivm.nl/bibliotheek/rapporten/2016-0024.pdf

Salas, D. A., Ramirez, A. D., Rodríguez, C. R., Petroche, D. M., Boero, A. J., & Duque-Rivera, J. (2016). Environmental impacts, life cycle assessment and potential improvement measures for cement production: a literature review. *Journal of Cleaner Production, 113*, 114-122.

Salo, E. (2016). Voluntary agreements for the achievement of sustainable development goals: Dutch Green Deals and WRAP agreements.

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development, 17*, 48-56.

Scott, J. (2017). *Social network analysis*: Sage.

Senge, P. M. (1990). *The fifth discipline : the art and practice of the learning organization*. New York, N.Y., [etc.] :: Doubleday Currency.

Shi, C., Jiménez, A. F., & Palomo, A. (2011). New cements for the 21st century: the pursuit of an alternative to Portland cement. *Cement and concrete research, 41*(7), 750-763.

SITRA. (2018). The most interesting companies in circular economy in Finland - business examples. Retrieved from https://www.sitra.fi/en/projects/interesting-companies-circular-economy-finland/#latest

Speth, J. G., & Zinn, D. (2008). *The bridge at the end of the world: Capitalism, the environment, and crossing from crisis to sustainability*: Yale University Press.

Stevenson, A. (2010). *Oxford dictionary of English*: Oxford University Press, USA.

Storm, S. (2011). WDR 2010: The World Bank's Micawberish Agenda for Development in a Climate-Constrained World. *Development and Change, 42*(1), 399-418.

The Ministry of Infrastructure and the Environment. (2016). *A circular Economy in the Netherlands by 2050 - Government-wide Programme for a Circular Economy*. Retrieved from https://www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050

The Netherlands Organisation for Applied Scientific Research (TNO). (2013). *Opportunities for a circular economy in the Netherlands*. Retrieved from https://www.tno.nl/media/8551/tno-circular-economy-for-ienm.pdf

Tisserant, A., Pauliuk, S., Merciai, S., Schmidt, J., Fry, J., Wood, R., & Tukker, A. (2017). Solid waste and the circular economy: A global analysis of waste treatment and waste footprints. *Journal of Industrial Ecology*.

Turner III, & Daniel, W. (2010). Qualitative interview design: A practical guide for novice investigators. *The qualitative report, 15*(3), 754.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol. 8): Cambridge university press.

Wijkman, A., & Skånberg, K. (2015). The circular economy and benefits for society. *Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and resource Efficiency*.

World Economic Forum. (2014). *Towards the Circular Economy: Accelerating the scale-up across global supply chains*. Retrieved from http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf

Appendices

Appendix A – further background information

Linear economic model

Current economic practices presuppose that raw materials and energy are abundantly, easily and cheaply available. Furthermore, it is assumed that the pollution and waste as the outputs of the economic activity are not endangering the world we live in (Storm, 2011). These assumptions characterize the economic model that is in use today – the linear economic model. It is best described with the "take, make, dispose" approach. Raw materials are taken from the earth, made into intended products and after they serve the intended purpose, their disposal takes place (Florin, 2014). Simply put, inputs of this model are raw materials, and the outputs are waste and pollution.

Although the assumptions underlying the linear economic model were applicable when it first emerged, it is clear that nowadays this is not the case (Sauvé et al., 2016). Generation of waste, pollution and other negative externalities cannot be ignored any more. As a consequence of the profit-driven, consumerism-oriented and capitalistic expansion of the current linear economic model in the XX century, the world scenario has changed from an empty-world to a full-world scenario (Storm, 2011). Empty-world scenario implies that the amount of used raw materials is negligible compared to the amount that is freely, easily and cheaply available in the world. It also assumes that waste and pollution, as the output components of the linear economic model, are of such quantity that they do not harm the Earth's ecosystem now, nor will they do so in the future (Storm, 2011). In other words, this model assumes that the consequences of linear economic activity, with its negative externalities, are inconsequential compared to the robustness and carrying capacity of the Earth. The full-world scenario, that is valid today, implies that the Earth is constrained with both the overuse of raw materials and energy, and excessive generation of waste and pollution (Storm, 2011). Raw materials and energy sources are becoming scarce and unevenly distributed throughout the world. This translates to the high supply risk of raw materials and energy and, therefore, to dependence on import, geopolitical situation and markets across the world (Ellen MacArthur Foundation, 2015b). In addition, pollution and waste generated in this economic model have evidently become a burden for our planet. Negative consequences of the linear economic model are best evidenced by climate change, extinction of species, air pollution and volatility in the energy and raw materials markets (Dobbs et al., 2011; Keeble, 1988; Speth & Zinn, 2008). Adding to the fire is the projected exponential rise of world population. More people imply the need for more production and economic activity in order to satisfy their needs. This translates to the use of more raw materials, generation of more waste and emission of more pollution in the future. Considering the projected exponential trend and the already excessive degradation of the Earth, it is clear that this approach is unsustainable and that it is only the question of time when the point of no return is reached.

In addition, the linear economic model fails to realize the full economic potential of products and materials by treating them as waste when they reach the end of their life cycles. Full economic potential is captured when the products and materials are reused throughout multiple life cycles (Ellen MacArthur Foundation et al., 2015). Moreover, the stress on ownership of the asset, integral in the linear economic model, leads to a considerable amount of "structural" waste (Ellen MacArthur Foundation, 2015b). Structural waste is represented by the time in which the intended function of the asset is not utilized because of the ownership. As an example, research encompassing the EU showed that the office spaces across the Europe are vacant (not used) 50% of the time (Ellen MacArthur Foundation, 2015b).

Considering the coupling of economic growth with resource constraints and degradation of the Earth, as well as the failure to capture the full economic potential of products and materials, it is clear that the linear economic model is unsustainable in the long run. New, fundamentally different approach is needed.

Circular economy

As a response to the negative trends of a linear economic model, a new economic approach is emerging – circular economy. Its main notion is decoupling of economic growth from resource constraints and degradation of the Earth's ecosystem (Ellen MacArthur Foundation, 2015a). The circular economy approach is still developing and, therefore, there is no widely-accepted or all-encompassing definition which precisely formulates it (Adams et al., 2017). This lack of unified view is recognized as the challenge for the implementation of circular economy practices (Cossu & Williams, 2015; Preston, 2012). This is even more true when focusing on the lower levels of economic system, such as: specific supply chains, national economies, etc. The reason for this is that each of these lower levels has its own specificities and characteristics which influence the appropriate interpretation of the notion of circular economy. Although not precisely defined, it is clear what the circular economy approach encompasses. Following are relevant definitions that are provided by the authorities on the subject.

Ellen MacArthur Foundation, probably one of the most important proponent of the circular economy, defines it as: *"an economy that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles."* (Ellen MacArthur Foundation, 2015b)

"The circular economy concept aims at extending the useful life of materials and promotes recycling to maximize material service per resource input, while lowering environmental impacts and resource use" (Tisserant et al., 2017)

"A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of life concept with restoration, shifts towards the use of renewable energy, eliminates toxic chemicals, which impair reuse and return to the biosphere, and aims for elimination of waste through superior design of materials, products, systems and business models." (World Economic Forum, 2014)

"A circular economy is an economic and industrial system based on the reuse of products and raw materials, and the restorative capacity of natural resources. It attempts to minimize value destruction in the overall system and to maximize value creation in each link of the system." (The Netherlands Organisation for Applied Scientific Research (TNO), 2013)

Although different, these definitions are characterized with the same general essence. This essence is reflected within integral characteristics of circular economy, as formulated by the Ellen MacArthur Foundation (2015b):

1. Designing out waste

There is no waste in circular economy. Biological materials are not toxic and can easily be returned to the soil. Technical materials are designed to be recovered, refreshed and upgraded, minimizing the energy input required and maximizing retention of value.

2. Strengthening the system with diversity

Diversity of economic system ensures higher resilience and versatility, similarly to nature's ecosystems.

3. Energy from renewable energy resources

By using renewable energy sources resource dependence is reduced and the resilience of the system is boosted. Implementation of circular economy reduces the energy demand and, therefore, facilitates the move towards renewable energy.

4. Systems thinking approach to markets and supply chains

All parts of markets and supply chains are interlinked and interdependent. In order for the notion of circular economy to be fully implemented, these need to be taken onto account. Therefore, taking a step back and applying the system thinking theory is crucial.

5. Prices reflect real costs

Prices act as signals for actors in circular economy and, therefore, they need to reflect the real costs. With the negative externalities incorporated into the full costs of materials/products/services, making of circular business decisions is boosted. Furthermore, transparency and trust are key aspects of circular economy.

Following from these characteristics are the three main principles governing the circular thinking (Ellen MacArthur Foundation, 2015b):

1. Control finite stock and balance flows of renewable resource flows in order to protect and boost natural capital.
2. Optimize resource yields by circulating products, components and materials at the highest quality at all times in both technical and biological cycles.
3. Boost system effectiveness by identifying and designing out negative externalities.

The notion of circular economy, with its main characteristics and principles, is graphically represented in Figure A1.

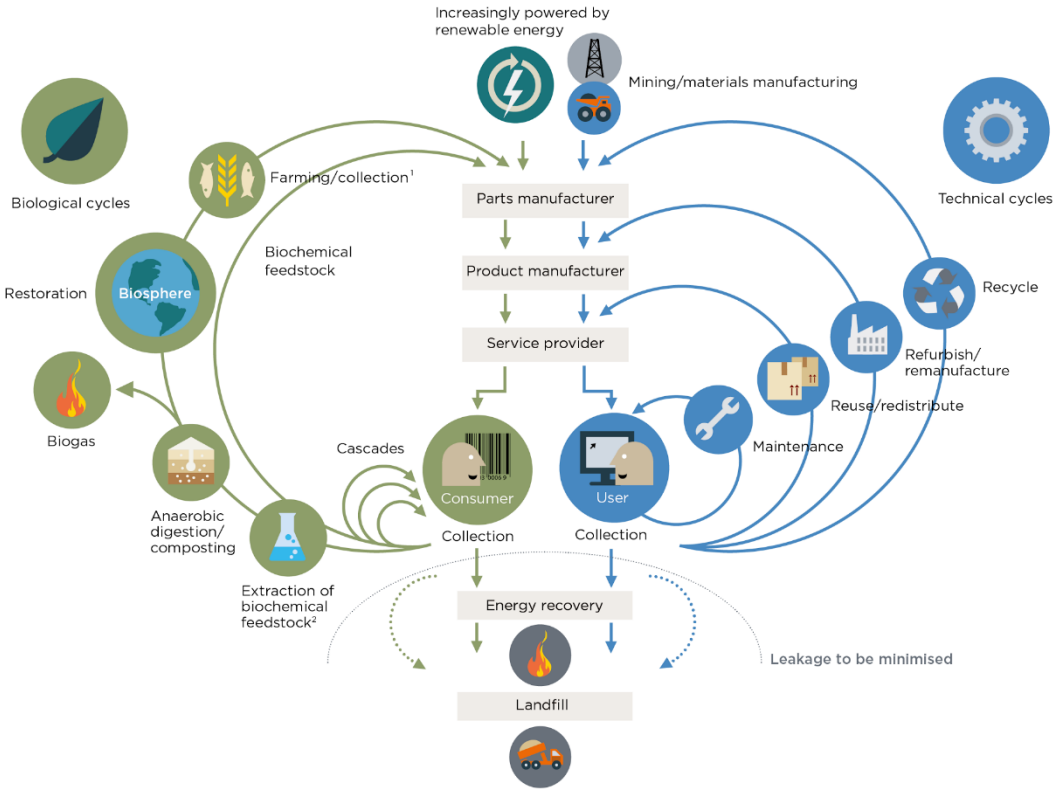


Figure A1: Circular economy – "Butterfly" diagram (Ellen MacArthur Foundation et al., 2015)

With the construction sector being the focal point of this research, focus is on technical cycles (on the right side of Figure A1). Main notions from Figure A1: Circular economy – "Butterfly" diagram (Ellen MacArthur Foundation et al., 2015)are keeping products and materials in closed loops, while prioritizing inner loops. According to this, the first loop proposes extending the service life of materials/products with maintenance. If that is not possible, then reuse on a product level is the next preferred option. After that,

refurbishing the product should be considered. The last resort, that is in accordance with the notions of circular economy, is recycling on a material level.

Besides battling with the negative effects of the linear economic model, the notion of circular economy entails many other potential benefits. From an economic viewpoint, implementing circularity will lead to a higher economic grow rate. In the circular scenario economic growth is expected to reach 27% by 2050, compared with 15% in the business as usual scenario (Ellen MacArthur Foundation, 2015a). Also, there will be substantial savings in net material costs. For example, Ellen MacArthur Foundation et al. (2015) found out that the European Union can create 0.9 trillion euros of additional net benefit by 2030. Furthermore, cost savings could amount to US$380 billion per year in transition scenario, and up to US$630 billion in a more advanced scenario within EU (Ellen MacArthur Foundation, 2015a). Moreover, research on the level of seven EU states concluded that the switch to circular economy would decrease each nation's greenhouse gas emissions by 70% and provide 4% more jobs (Wijkman & Skånberg, 2015).

The change towards the circular economy is gaining momentum throughout the world. This is evidenced by more and more (inter)national initiatives, actions, policies, legislations and authorities that endorse it (Ghisellini et al., 2016). Circular economy is perceived as the road that needs to be taken in order to deal with the current negative trends and ensure prosperous and sustainable future. China is one of the best examples, already implementing circular economy in their legislative system in 2008 (CCICED, 2008). There are numerous policies within EU that promote circular economy, with perhaps the most significant one being the freshly instituted action plan – Closing the loop (European Commission, 2015; McDowall et al., 2017). The Netherlands is also one of the pioneers in the field of circular economy, which is witnessed by a government wide program for achieving 100% circularity in 2050, with a stepping stone of 50% in 2030 (The Ministry of Infrastructure and the Environment, 2016). All of these pinpoint the worldwide relevance of the circular economy approach.

To conclude, the circular economy approach is on the rise with the prospect of considerable benefits and backing of international authorities.

Construction sector in the Netherlands

The Netherlands is one of the most advanced countries in the world when it comes to recycling, and the construction sector is no different. More than 95% of materials in the construction sector are currently recycled, implying an already high level of circularity of the sector (ABN AMRO & Circle Economy, 2015). However, 85% of these materials are cascaded into the civil engineering sector as base materials for roads, development of new residential areas and water management (Rijkswaterstaat & National Institute for Public Health and the Environment, 2015). In this way, these materials are cascaded into a lower level function reuse – down-cycled. This down-cycling is not in line with the notions of circular economy. Furthermore, in the civil engineering sector 100% of materials are already recycled into the same functional level – up-cycled (Rijkswaterstaat & National Institute for Public Health and the Environment, 2015). Current trends show that less and less new structures are built within the civil engineering sector and, therefore, that the market for secondary materials is becoming saturated, hindering even the above-mentioned "down-cycling" (ABN AMRO & Circle Economy, 2015). Furthermore, recycling is seen as the least favorable, but acceptable, option within the notion of circular economy. Therefore, although a high percentage of materials is recycled, the construction sector in the Netherlands cannot be considered circular.

The construction sector in the Netherlands is responsible for 50% of the totally used raw materials, 40% of total energy consumption, 40% of generated waste, 35% of CO2 emissions and 30% of total water consumption (BAM & ARUP, 2017; The Ministry of Infrastructure and the Environment, 2016). Furthermore, harvesting of raw materials for the construction sector is responsible for 4,5% of total primary energy use, 5% of total national greenhouse emissions and 20% of total goods transportation in the

Netherlands (ABN AMRO & Circle Economy, 2015). Taking into account that the construction sector contributed 4,8% of added value to the Dutch economy in 2013, it is clear that the implementation of the notion of circular economy would yield significant benefits, both economical and environmental (ABN AMRO & Circle Economy, 2015).

Products of the construction sector are buildings and structures. They are characterized with the long service life, which usually ranges from 50 to 250 years. This specificity of the construction sector is a challenge for application of circular practices for a number of reasons. First, the circular economy favors paying for the function when needed, rather than owning the asset that provides that function. Based on the function over ownership principle, ideally, producer of the building/structure would lease it, take it back after the lease period and assume responsibility for circulating it. However, the above-mentioned longevity implies many uncertainties for the producers, which makes application of this ownership model unattractive (Rijkswaterstaat & National Institute for Public Health and the Environment, 2015). This is further supported by the short-term planning of companies in the current linear economic model, which usually spans up to 10 years in advance. It follows that the full life-cycles of buildings/structures are not taken into account in the strategic plans of the companies. This contradiction hints at the changes that are needed on all levels of the current linear economic system in order for the circular economy to take place. Furthermore, it is challenging to design product elements in a way that ensures functionality of product reuse after such a long period (Rijkswaterstaat & National Institute for Public Health and the Environment, 2015). The needs of the owners/users are changing along with their life styles and the design trends and regulations within the sector. Another implication of longevity of structures is that the today's waste comes from materials that were used to build structures 50-250 years ago. Those structures were not designed with circularity in mind and, therefore, the waste materials coming from them are challenging for reinsertion into the supply chain at any level (material or product). Also, because of longevity, there is a disbalance between the available end-of-life materials and the needed raw materials for construction of new structures. This is because 50-250 years ago considerably less structures were constructed than it is the case today. Following from the growing economies and the number of people, this disbalance will remain in the future as well, and as such needs to be taken into account. Therefore, there are two lines of actions needed for achieving circularity in the construction sector:

1. Acknowledging existing structures, that were not designed with the circular approach in mind, as material banks and enabling circulation of materials from them back into the supply chain.
2. Implementing a way of designing and building that will enable application of circular practices at the end of service life of new structures.

Rounding it off, there is an interesting implication stemming from this. If, theoretically, the second line of action is executed as of today, the soonest that the construction sector can hope to achieve circularity is in 50-250 years.

In order for successful closure of material loops to take place, integration of supply chains is essential (Ellen MacArthur Foundation, 2015a). Enabling free flow of information and knowledge between the actors in the supply chain is crucial. This also entails a change in the mindset of actors, as well as different relations between them. Current outlook at the data as the strategic asset, which leads to unavailability of important data (Lake & Crowther, 2013), has to transition to a "data as a common good" perspective. This is particularly observable in the construction sector, where a specific engineering knowledge is what separates the two companies in the market. In order to achieve this, cooperation between actors needs to be focused on joint long-term goals, mutual trust and transparency. In the language of the theory of organizational structure, this translates to a switch from the current "market" relations between the actors to the "network", which entails long term cooperation between the actors motivated by matching interests. (Jones et al., 1997).

Circular approach implies closing the material loops. Looking into the materials used in the construction sector, one isolates itself based on its implications for the change towards the circularity – concrete. Concrete is the most used material in the construction sector (Marinković et al., 2010). Worldwide consumption of concrete is holding the second place, with only consumption of water being higher (Rangan, 2008). This averages to the annual production of 1 ton of concrete per inhabitant of the Earth (Lippiatt & Ahmad, 2004). Concrete is a monolith, stone-like material, made by mixing water, aggregate (sand and gravel) and cement. Water, sand and gravel are not renewable, but are abundantly available. However, excavation and transport of those materials result in landscape mutilation, energy consumption and pollution. Cement is considered the most polluting part of the concrete, contributing around 7% of total anthropogenic (man-made) CO2 emissions (Salas et al., 2016; Shi, Jiménez, & Palomo, 2011). Currently, only around 2% of concrete is "up-cycled". It is clear from here that the concrete material loop is not closed yet, as well as that there are significant benefits to be gained if the notion of circular economy is implemented. Furthermore, it is a challenge to up-cycle it because of its monolithic structure and the irreversible hydration of cement. Moreover, on a product level it is challenging to accomplish design which will support reuse while keeping the concrete's ability to conform to any shape it is poured into. Other widely used construction materials – steel and wood – are almost 100% recyclable, reusable or treatable in line with the notion of circular economy. Therefore, the concrete is the most challenging construction material for achieving circularity in the construction sector and it is of interest for further research.

Construction and Demolition Waste (CDW) – stony materials

Definition of waste used in the Netherlands is: *"All substances, preparations or objects which the owner is disposing, planning to dispose or is obliged to dispose"* (Deloitte, 2015; European Parliament & Council of the European Union, 2008). Construction and demolition waste (CDW) is formulated as: *"Waste which is generated in construction, renovation and demolition of buildings and other edifices, including road and water constructions."* (Ministerie van Infrastructuur en Milieu, 2014).

CDW stream is the largest by volume in the EU (European Commission, 2016b). It is responsible for approximately a third of all generated waste (European Commission, 2016a). Zooming in to the Netherlands, in 2015, a total of 59.54 Mt of waste was generated (CBS et al., 2017b). CDW stream was the largest contributor, adding 23.83 Mt, or 40%, to the total (CBS et al., 2017a). Furthermore, it is projected that this contribution will rise to 31 Mt in 2021 (Ministerie van Infrastructuur en Milieu, 2014). Overview of the CDW generation in the Netherlands from 2006 to 2014 can be observed in Figure A2.

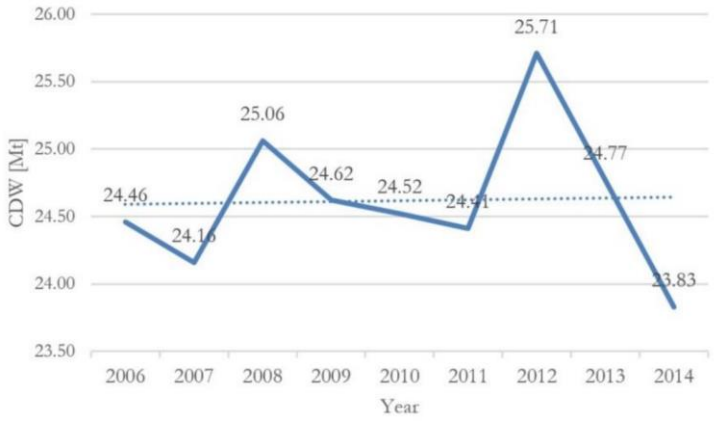


Figure A2: CDW generation in the Netherlands for the period 2006-2014, based on data from (CBS et al., 2017a; Deloitte, 2015; Rijkswaterstaat, 2013)

In the Netherlands, sub-streams of the CDW stream are identified according to the "Europese afvalstoffenlijst" since 2002 (Ministerie van VROM, 2001), which is in accordance with the EU's

classification - the "List of Waste" (LoW) (European Commission, 2000). Within this classification the stony materials waste stream consists of concrete, bricks, rubble (mixture of stony materials), tiles and ceramics, and gypsum based materials. Stony materials constitute the largest share of CDW stream, with the share of around 65% (Mulders, 2013). This translates to the 26% of the total waste generation in the Netherlands. Table A1 provides an overview of the amount that every sub-group of the stony materials waste stream contributes. In addition, waste treatment for each of those sub-groups is specified. As can be seen, the largest part of the stony materials is rubble, with a share of 87%. Most of the stony materials, around 93%, is recycled into the base materials. This means that biggest chunk of stony materials is retrieved and processed together, and then down-cycled into the base materials. Although recycling is better than land filling or incineration, down-cycling is not preferential in circular economy. Therefore, there is a potential for considerable benefits by introducing the notion of circular economy to the stony materials.

The Netherlands is considered one of the leaders in the amount of materials that are recycled. As it was shown, with 93% recycle rate, the stony materials CDW stream is in line with this. The underlying reason for this high percentage of recycling is the landfill ban which was set up in 1997 (Overheid.nl, 1997). It forbids land filling of, amongst others, CDW stream, except for some hazardous materials like asbestos. As a consequence, stony materials waste stream had to be recycled or reused.

	Stony materials CDW stream											
	Concrete		Bricks		Tiles and ceramics		Gypsum		Rubble		Total	
Waste treatment	kt	%	kt	%	kt	%	kt	%	kt	%	kt	%
Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	117.00	0.86	117.00	0.75
Landfill	129.00	7.97	1.00	0.29	0.00	0.00	0.00	0.00	94.00	0.69	224.00	1.44
Recycling - concrete	300.00	18.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	300.00	1.92
Recycling - base materials	1190.00	73.50	0.00	0.00	0.00	0.00	0.00	0.00	13321.00	98.25	14511.00	93.07
Recycling - gypsum	0.00	0.00	0.00	0.00	0.00	0.00	26.00	40.00	26.00	0.19	52.00	0.33
Unknown	0.00	0.00	341.00	99.71	8.00	100.00	39.00	60.00	0.00	0.00	388.00	2.49
Total	1619.00	100.00	342.00	100.00	8.00	100.00	65.00	100.00	13558.00	100.00	15592.00	100.00
%	10.38		2.19		0.05		0.42		86.95			

Table A1: Structure of the CDW stream and waste treatment, adapted from (Mulders, 2013)

Appendix B – full transcripts of interviews with branch organizations

Demolition companies

Prior to the interview the interviewee approved of recording the interview and using it for thesis research.

UB: To begin with, what is your company about?

DC: My company is the national association of demolition contractors and also the asbestos removal companies. We are representing with VERAS around 100 demolition companies and 22 suppliers. Suppliers are law firms, education institutes and machine deliverance. Our core business are defending the interests of demolition companies. We represent them and we have an office in the middle of the country, in Meteren.

UB: What is your role within it?

DC: My role is association manager and I am doing that job with at least one colleague. We have divided some dossiers, some things concerning demolition matters. That is an important thing. And we are talking of course a lot with policy officials, but also colleague associations and organizations, like BRBS, but also other contracting association. One of our tasks is also to give our members information about changing legislations, but also when they have some individual problems, for example with neighbors or with maintenance, we try to solve their problems together. The most important thing is that we are defending their interests.

UB: I have seen on your website that one of the main things that you are committed to is actually promoting high quality recycling of materials in order to support circular economy.

DC: That is correct. We have a couple of years ago set up a policy document in which we stated about 5 goals. One of the goals is to stimulate the role of the demolition contractors within the circular economy, and the most important element of that goal is to talk with customers, but also with policy officials in order to make it clear to them that the demolition contractor is the supplier of material. When there is a renovation or demolishing the building then there is the material created by dividing the materials by applying different demolition methods. Then we discuss that we think that they should take care of the role of the demolition contractor.

UB: What is your view on the notion of circular economy? Do you see benefits in becoming 100% circular?

DC: We think that it is very important in our economy that it becomes circular because this is a way to prevent exhaustion of primary resources, primary and scarce materials. So, I think that you cannot cover it for the whole 100%, but I think you have to do at least your best to get that goal. It is important to know that also for image reasons it is important for the customer to know that the demolishing company not only demolishes the building but also takes care of putting the materials into new materials.

UB: What are the criteria that need to be met in order for the stony materials supply chain to be considered 100% circular? (Example: Betonakkoord)

DC: I think that one of the most important criteria is that you use a Pre-Demolition Audit. It is also one of the measures proposed in the Concrete Agreement. It should be an obligation for each demolition contractor to use that instrument because then you have a good view of the consistence of materials in that building and so it is much easier to separate them at the source and then also to put them on a new materials market. In case of the stony fractions to replace gravel and sand. Also the customer should describe the Pre-Demolition Audit for each demolition and renovation project.

UB: The audit encompasses figuring out which materials are in the building before it is demolished?

DC: Yeah. You need a kind of passport. You walk through the building and investigate together with the customer of which materials the building is made. In general it is really important to provide demolishing contractors time, space and money to do their job well. In practice the situation is, and I know because we are also member of the European association, that every customer has a need to do the demolishing work as soon as possible. This is because it is important to build a new object in its place. There are high investments, but you also need to take care of the demolishing process before that. That is what we always say to policy officials and contractors and of course customers, or our clients to say it like that. They have to give us more time and more space. The space to separate the materials. Time to have a careful demolishing process. And money to recover also difficult materials, like insulation that is really difficult to recycle. Then you need more money to reach that goal. And that is also in favor of circular economy. From the technical point of view you can say that the demolishing contractor is able to do any job you want. Every fraction, every material can be separated. The only factor for that is that he needs time to do that. And money and space. That is the triangle.

UB: Going back to the criteria, could you think of any?

DC: I think when you are able to produce material which is also recyclable, and so on and so on. Every building you demolish the stony fraction should be kept inside the chain by making them profitable but also you need to take care of the quality of the material by separation at source and also then the customers should prescribe a kind of recyclable fraction into new products. Like the Concrete Agreement wants to reach.

UB: You already mentioned the pre-demolition audit. Are there any other changes that need to occur within the stony materials supply chain in order to achieve circularity along these criteria?

DC: The behavior of the customer is very important for that purpose.

UB: Could you define who do you mean when you say the customer?

DC: These are the clients of our demolishing companies who are looking for their buildings to be demolished. For example, the owners of the houses or the municipalities. [Continuing..] They need to change their behavior in general, because there are the good ones and the bad ones, to say it like that. It has to be put in the procurement procedures. They have to prescribe some separation at source into the fractions with which you can have very good use in the circular economy. They have to think more about that. Now, the emphasis in projects is mostly on costs. The goal is to have the lowest costs as possible. But sometimes for fulfilling the circular economy it is not only about costs but also about quality.

UB: But how would they recognize it as beneficial?

DC: By telling them of course, or by law change. By prescribing it by law. Like the goals from the Concrete Agreement. They could be copied into the law and then the customers is obliged to do so.

UB: Any other change? You said changes in behavior.

DC: Yes, and the pre-demolition audit. I think that is also an important change. Also in the Netherlands guidelines on how to do a demolition process. We also think that these guidelines should be implemented into the projects.

UB: What are the perceived needed changes within the companies in your branch for becoming more circular?

DC: I think that they should look more carefully for possibilities for bringing the material away for better recycling. I think that there is an opportunity in our sector.

UB: Could you elaborate on that? Maybe give an example?

DC: For example, this is more about the marketing I think. The point is that now companies have contracts with delivery companies. But sometimes it is 50-60 kilometers from their plant. There was a company recently and they said, but in the neighborhood of our company there are other companies that can take care of our materials. But, they did not know that. So that is I think important issue, that they have to take care more carefully of the supply of the materials. The other thing is that they should tell their customers more about the possibilities of circular economy.

UB: The example that you gave, some far away company was contracted for demolishing but they did not know about the company that was close by, right? Do you mean to single out the transport as an important parameter?

DC: Yes. Considering that the stony materials are rather heavy, transport is particularly relevant. But now the company have some stable contracts with some delivery companies, or recycling companies. But I think that they need to look further around to see other possibilities.

UB: Do you see any changes in the role of the company from your branch in the market as a consequence of becoming more circular?

DC: I think that we as an association should promote more the role of the demolition company within the supply chain in line the circular economy. We deal with a lot of customers, policy officials and organizations in that field and we can make a difference by repeating. We have a good story, and we have to tell it.

UB: You already mentioned earlier that the demolishing companies will became providers of raw materials. Do you consider this an opportunity?

DC: Yes, I think that that is the strongest point in the marketing, a really big opportunity.

Recycling companies

Prior to the interview the interviewee approved of recording the interview and using it for thesis research.

UB: To begin with, what is your company about?

RC: My company is a waste management company, located in the harbor region of Amsterdam. We are mostly processing two types of waste. Mixed construction and demolition waste that we sort out in different types, and rubble, the debris waste that we crush, screen and wash. Then it depends on the type where it is used. Especially, the concrete rubble we screen and wash so that it can be used in new concrete. We process approximately about 600000 tons per year of debris waste. The concrete part of that is about 150000 tons.

UB: The concrete part. Does it go back to the concrete industry?

RC: Yes, in different sizes. For example, 4/60 mm diameter fraction is produced for reuse in new concrete – circular. And the fines, smaller than 4 mm, go into the construction industry.

UB: What is it used for in the construction industry?

RC: For foundations.

UB: What is your role within the company?

RC: My role is that of the managing director. I am responsible for the functioning of the company. Also, I am responsible for investments and innovation.

UB: What is your view on the notion of circular economy? Do you see benefits in becoming 100% circular?

RC: Becoming circular. I was wondering what is circular economy? That is an interesting question. I think that we as a society do not have a choice on whether or not to implement circular economy. It is necessary to us to move on to the circular economy. Because of all the primary materials that we use are ending.

Therefore, if we want to give our children or grandchildren a future that has to be a topic for us, so that they can live as good as we are living. My opinion is that we do not have the choice. Circular economy has to be realized. That is the first part of it. The second part is that there are business opportunities. For example, if we look at our activities, in some way they are circular. What I mean is that our business model is to take waste and to make a product out of it. And I expect expansion in that field. In the end, for demographic reasons it is a must for everything to become circular and it will rise the opportunities to make living out of it.

UB: What are the criteria that need to be met in order for the stony materials supply chain to be considered 100% circular?

RC: First, more awareness that all things of the stony materials around us are in the basis valuable for us to be reused. And the awareness of the owner of the building, government, all the parties in the value chain. That is the first step that is important. There has to be more awareness to that point. Second, you have to make it transparent. We have to make it transparent. The process. For example, we are talking to this people from Schiphol, from the biggest airport in the Netherlands. Next year, 2018, they will have 2000 projects. Small and large. Projects of demolition, buildings, constructions, etc. We are discussing with them on the subject of how to handle and maintain all of the stony materials demolition. In our opinion, you have to maximize the upcycling. You have to explain what our possibilities are to contribute to that upcycling. It is our responsibility to make it clear what is possible at the moment. Third, this is the part related to pricing. To ensure that during the demolition, all of the materials are separated in a good way. It is a matter of pricing because demolition company has to do their job for a small amount of money. Therefore, they are not really interested in separating in a good way all of the materials. We have problems because of that. We have to make more effort to separate and to prepare the material for getting the new life.

UB: Basically, what you are saying is that the demolition companies need to do a better job so that you can do yours in a better way?

RC: Yes. So all parties have to contribute. The energy to clean the material and to prepare it is much less. And that all starts with the owner of the building or the construction. Everything is connected. You have to overlook the whole chain. The whole chain has to be leveled on this at that point. When that is achieved, then it will work.

UB: What do you think about the future buildings, should they be built in a way that is facilitating reuse in the end?

RC: Absolutely. In my opinion, in about 30 or 40 years, the recycling that we are doing now, does not exist any more. Everything will be reused on a product level. That is what the ultimate goal has to be. This will happen in 40 years if all parties are going to put a lot of effort in it. Owners, investors, if they require that sort of goals, then it will happen. That is the ultimate goal in being circular. Maybe you have a minor part of it, 10 to 20 %, that you cannot reuse. Maybe for that part is there some kind of recycling that looks like what we are doing at the moment. But, in the end, there have to be material passports for each building, and demolition and reuse has to be in components.

UB: You said that the whole supply chain has to work on that. Do you see that happening?

RC: It is very difficult. Because we are thinking in the ways of the old economy and everybody has their own interests. It would be ideal that, for example, the government has the role in that by putting it in law. We see that from our participation in different working groups. For example, the Concrete Agreement, where all of the actors sit together, around 8 to 10 parties. We have been talking now for more than 3 years with each other and, in my opinion, we did not reach anything. Because everybody is still looking at their own interests. This is a serious problem for the acceleration of the circular economy.

UB: For you the solution to that problem is the involvement of the government in a way of prescribing what has to be done?

RC: Yes. Or if you take the investment company, that invests in real estate. And they say what is the policy of the investment company for the real estate for the next 10, 20, 30, 40 years. For example, if there is a large office building that has to be built. What do I expect in the life cycle analysis of that building? I do not think that we are going to build for the life cycle of the new building. This is 30 or 40 years. And then at the end it is taken apart and the components are reused in a new building or in a new construction. It is important that the investor wants that to happen. Because the demand of users is also shifting more frequently. And that is the way to respect that. And that creates value for the investor. There are some investors that are thinking in that way, not really acting yet in that way. I think in 5 to 10 years it is coming.

UB: What are the perceived needed changes within the companies in your branch for becoming more circular?

RC: First of all, I think that recycling companies will not exist anymore in about 30 – 40 years. In the way that we are organized at the moment. We have to, somehow, shift in our business models. Until that happens, we have to introduce new techniques that will perfect the recycling process. And we need to seek to work together with the whole value chain. To listen carefully to what is expected and what the demands are, and to react on them. On the one hand innovate, and on the other hand participate actively in the whole value chain. This year, we have invested in a new installation, which can process broken concrete in a way that the product is very clean. We can also offer different sizes. Any size that the concrete factory wants. Whatever they ask, we can deliver. On their specifications and on their demands.

UB: Do you see any changes in the role of the companies from your branch in the market as a consequence of becoming more circular?

RC: As I already said, I do not think that there would be recycling companies as they are today in 30 – 40 years and that because of that we have to change our business model. I think that we are shifting to, instead of processing waste, becoming more of a producer of end products. We are all shifting in the chain, from preparing for reuse to production of actual products. That will be the shift.

UB: That means that you will be competing with the concrete producers then?

RC: Yes, but we are merging with concrete producers. Everything in the whole process is in one company, under one roof. Now you have, as an example, 100 recycling companies and 14 concrete producers in the Netherlands. But in the next 30 – 40 years, there will be no recycling companies and no concrete companies. The most of them are merged or they have died, and they keep it all under one roof. The integration of the chain is unstoppable. You will have 5 or 6 huge companies that do most of the work.

Primary aggregates producers

Prior to the interview the interviewee approved of recording the interview and using it for thesis research.

UB: To begin with, what is your company about?

PAP: I am the director of the association of the aggregates industry. The primary aggregates. Cascade, that is my association, has a lot of members in the Netherlands. They work in the Netherlands but also in Germany and Belgium. We are trying to do good things for the primary aggregates. That is the main thing that I do. Circular economy is important. Ensuring that there are new projects in the Netherlands (extraction of aggregates). Making it easy for the members.

UB: How about the aggregates industry? Are there many places where you can extract them?

PAP: Yes, we have many places because we are lucky. There is a large market demand for aggregates, for the building industry. A few years back, the building industry was very bad, there was a big crisis because of which nobody wanted to build. There was no money and there was almost no demand for aggregates. But, today it is different. We cannot come up with enough aggregate production projects. The lucky thing in the Netherlands is that we are living in the Delta. We have a lot of water coming from the Netherlands and from the Belgium. And what we need to do in the Netherlands, and we are working full on it, is making the river wider (country-wide "Room for the rivers" project. Most of the primary aggregates are found near rivers, in their basins. What we do is that we make the river wider because of the safety; we take all of the aggregates and sell them. Therefore we contribute to the water safety with our projects and this is paid by the industry and not by the taxpayers, which is good. But we also make a lot of natural and recreation areas. Because many areas next to the rivers were used for agriculture, where they use a lot of fertilizers which is considered very bad in the Netherlands. Therefore, we buy the land, we make the project and we transform these areas into nature and recreational areas with a lot of water and birds. Summing it up, our business is good for water safety, nature and we extract the aggregates in the process. This is the specificity in the Netherlands, the fact that we need more room for rivers. In addition, how we can pay for that by extracting and selling the aggregates. It is different than, for example, steel. If you need steel, you go and dig it up, and you sell it because a customer needs it. Of course, in our industry, we produce when there are buyers, but the underlying reason why we can work on these projects is water safety and nature areas. A win-win. I am a biologist, and when I started to work here as a director I ordered reports for analyzing the quality of the nature that we produced in our process. The butterfly foundation, a critical NGO, did the research [Copy of the research given to the interviewer]. The outcome indeed was comparable to the best nature areas in the Netherlands. That is because we replace the fertilized ground with the soil that is good for nature. There was also another research into what did we as the industry do for the nature as the byproduct of getting the aggregates. Alterra, Wageningen University, did it and the results were great. A lot of people say that we have to stop with the primary aggregates.

UB: To be honest, I was not aware of this part.

PAP: I know, we try to tell, but it is difficult because a lot of people say: "No, we want circular economy. We do not need aggregates anymore. We can do everything with recycled materials. Please, industry, go away." During the crisis in the Netherlands we were almost the only industry that was still working on producing the nature, biodiversity, natural capital, which I find really good. But if you talk to BRBS [just an example, given only because PAP knew the research was supported by them], they would not tell you. And of course, I understand that because we are all lobbyists. We all tell the stories that we really like to tell. Everybody does it.

UB: The second question, what is your role within the company?

PAP: I am director of the association and what I do is if there is something that is bad for my members, primary aggregates producers, then I will go and try to do something about it. And that can be related to laws in Europe. I am also in the board of the European association. If it is necessary, I go to Brussels to try to influence laws that are not good for my members. It can be about health and safety. It can be related to the environment, technical issues, or economic issues like taxes. That is at the European level. A lot of things come from Brussels to The Hague and I try to get involved in them, on a national level. Also, a lot of law making responsibilities transferred from the central government to the provinces. We have 12 provinces in the Netherlands, which is a lot. However, there are only 4 provinces that are important for the aggregates industry. Those are the provinces with rivers, because that is where the aggregates are mostly, Limburg, Gelderland, Brabant and Overijssel a little bit. The most important ones are Limburg and Gelderland. Therefore, I also interfere on the level of provinces. It can also be, and that is why we should talk about circular economy, about the market. If no one wants to buy sand and gravel anymore, my members will have a problem. The reason that we are involved in circular economy is that we started having

difficulties in doing business. For example, one day I noticed that when we went to get a permit from the province of Gelderland the process was more difficult. When I asked for a reason for this, they said that there is no need for primary aggregate no more because there is circular economy. Those people think that if you have a house, you take it down and you buy a new house. However, if you know a bit about the volumes and how much we can be reused as the aggregate for new houses. It is not much. Also people, even people in The Hague, they think it is very difficult to talk about volumes, about tonnage, etc. They do not listen, but say that the circular economy is in place and that everything can be built with recycled materials. I always say that they will have to stop building very quickly because they do not have the aggregate. Or maybe you can build a lot of houses, but very small ones [joke]. Tiny houses maybe. I had to make it easier for them to understand. Therefore, I made an image showing what is possible. Here, you have houses that can be demolished. The problem is that we want to sell sand and gravel for the concrete for new houses. But, the members of BRBS want to sell their secondary product. A few weeks ago we were in Tallinn (Estonia) because of the conference on sustainable supply of aggregates in Europe. Estonia is chairing the European Commission at the moment. We had a very interesting congress and we tried in a few points to say how it is, what can we do with circular economy, what is our place as the primary aggregates association members. What is our place in this circular economy? We know about the volumes. First we tried to make kind of a position paper, together with BRBS, because I said that we have to do sustainable things, so let us make together a very good position paper on volumes and how to do it. We worked on it for 3 years, but in the end the BRBS said that they had to write down that the secondary aggregates are the best, use them always and after all of them are used maybe you can use primary aggregates. They were scared and they had members stating that their only goal is to sell as much as possible of secondary materials. Then my board decided that it was a waste of time. The time was not right. We were at the point of singing it when it happened, with a lot of energy invested. Now, there are some bad feelings between us. But, it will change again. Of course, every association has their own interest, and that is why you have to turn to facts. In my opinion these are the facts. It is not like when you have an old house, you brake it down and take everything and build a new one. Because all of the houses that were built were not built with circularity in mind. Everything is glued together, like this building, and it is very difficult to reuse everything again. If you look at the demand, we can, maybe, if we do everything we can with smart breaking and smart demolition, get 20% from the old houses. It was also said on the European level that 1/5 of everything we need can come from demolition. So, if you have only 20% from the recycled aggregates, you need 80% primary aggregates. But still, the people in The Hague say that they do not need the primary aggregates because of the circular economy. Then I say that it is fine if they do not need us, but you have to know that if you want to build using concrete we can, if we are lucky, get 20% of the needed materials from the demolition. The rest need to come from our industry. On top of that we provide water safety and produce natural area. You have to think before you say that you will stop this industry. We have this Concrete Agreement [Betonakkoord]. I made it not happen (in the form proposed at that time) because they think that we should try to put as much recycled aggregate in the concrete. As much as possible. We have to put everything in it. But the problem is the following. If we use recycled aggregates for the roads than we also use broken bricks, gypsum, etc. [stony materials – rubble] You can take clean material out of it, as long as there is a little left. And there is a big demand for the foundation of the roads. And this stuff (rubble) that comes out of the demolition process. All the stony like material together, because it is too difficult to get them clean. It is difficult because we did not build with separating and treating them afterwards in mind, it is too costly. If you want to use it in concrete, it is not too much, but you can clean it and mix it with the primary aggregates. But, there is also very big demand for the road foundation. If you want to build the road in the Netherlands, you have to make a very good layer of foundation. Or if you want to develop houses, they also need a foundation. There are 2 benefits for this use. The first is that if you put this under the road you can also use broken bricks [as a part of the the rubble]. At the moment we cannot use them for any other purpose. However, if it is combined with secondary concrete [rubble] it is excellent for roads as these aggregates are angular (as opposed to the round road materials). If we do not

use this rubble for the road foundation, but take out concrete for reuse in the new concrete, then we are left with a mountain of bricks. Furthermore, what will we put in the road foundations instead of the rubble? BRBS says that it should be primary aggregates, because the secondary aggregates you always have to put in new concrete. The other benefit is that you need a thinner layer of asphalt and less cement for roads. This is because it has angular shape and it is very stable. Therefore, this is an excellent material for foundations. But the problem is that if you can clean it, if you can get it out, if you put it in the law, the people who are building need to buy it. Because it is in the law. It is not good for sustainability, it is not good for anything, but it is very good for the price. We are working on the Betonakkoord and first they wanted to build houses only from the recycled materials, completely excluding the raw materials. Now they understand and they are a bit flexible. Now, we have a MIA/VAMIL, which is a governmental tax rule, which says that you have tax benefit if you make concrete with more than 30% of recycled aggregates. Consequently, we see companies importing recycled concrete materials from east Germany, because we do not have it enough, in order to get this benefit. They say that it is circular, but they use trucks to get it here and in the end, it is worse from the viewpoint of sustainability. If you look at the LCA, you just want to cry. However, people say circularity, circularity. They put it above sustainability. When I say it, they say that they know that I am saying it only to boost the sale of primary aggregates. And that is true, I do want to sell it, but I also want it to be sustainable. This is what you should do if you want to make it very good. You want to make a house. You say ok, let's make it from the concrete. What you should not do is to think tomorrow I need concrete. This is the way it is today in the building industry. We need to forget this. We have to know what kind of aggregates, secondary or primary, does not matter, what is in the neighborhood. Because transport is a big polluter and it has a big footprint. Do I know about the building that is to be demolished and that has a lot of materials that can be used to this end. Or there, I have a river. We have to look for the optimum mix. That is what you should do. That is circular a bit, but it is sustainable. And that is the main goal. Because if you only look at circularity this will happen [relating to the example of importing stony materials]. It is very difficult to reach it, even people from Delft. Elphie Nelissen, you know her maybe. She is a professor at TU Eindhoven and she made the Bouw Agenda, the Circular Bouw Economie Agenda. She thinks that the goal is to make new houses all made of circular, secondary materials. The problem for my members, the primary aggregate producers is the following. They say Leonie, let them because if they want to make houses from the secondary aggregates and they make concrete after one life cycle they cannot use it anymore. And they will still want to build houses in concrete, so they will come to us. Because they made a mess out of it, they mixed all kinds of stuff in the concrete. Very circular, but you can never use it again. So I am always like ok, we have built for 40-50 years houses without thinking about the next life cycles. We have to deal with that. The houses are there and we have to do something with the stuff [demolished materials]. As good as possible. Under roads, maybe some other things. Maybe innovate some new techniques to do better demolition. I do not know what, but do something about it. Now we know that we have to be careful with the aggregates and to make very good decisions. We need to immediately stop to build like we did for 40 years. From now on we must build with elements which after the end-of-life of the house can be taken out and reused, and keep the elements as clean as possible. Make it as clean as possible because then you can reuse and reuse and reuse. If you put all kinds of stuff in it, ASE granulate [blast furnace], a new society word, it is terrible because after one life cycle it is poisonous. I think that is not so good. We should think about clean materials that we can reuse endlessly and we have to build in a way that you can reuse all of the materials. Recycling is your last option. We need to try to build in a way that nothing is recycled in the future. We must reuse it. But what we now see is because of making the concrete very dirty using circularity as an excuse, we will need the primary aggregates forever. Very good for my members, but I do not think that it is good. There is so much power and money involved, and lobbying, and people that are making these agendas they do not know exactly how it is and they think lets do this, I have 2 weeks to finish. Then there is the agenda, and then people from the government say lets make new rules. And the problem is that they all want to do a right thing, but what they do not know is that they do the wrong thing. And it will not help. I know it, you know it, and it will not change.

Sometimes when I speak to the policy makers I say ok, I cannot convince you because I am from the wrong kind of industry. But please, if you in thirty years figure out that you did the wrong thing, please remember that somebody already told you this thirty years ago. That is all that I can do. But now I have told you and maybe you have a fresh look. Maybe they will believe you if you write something down in your report. Maybe it helps a bit in the right way. I hope it will.

UB: You have mentioned the road base, and that there is high demand for it. However, I have looked into some research on that, and they say that the road network in Netherlands is very advanced already and that there is no need for a lot of new roads. Furthermore, the existing aggregate from the road base can be almost completely reused..

PAP: Almost. You can reuse a lot. But we will build a lot. If you look at the demand for housing, roads, everything needs foundation. But this is good, if there is already a road you can really reuse everything. You can raise the foundation. You can reuse the asphalt. A little bit you have to put extra because you always lose something. But the roads that are now there and the places where the houses are we can reuse some 80-90%. But, you will see that we will need a lot of new areas where we can build houses. Especially, in the certain parts where the ground lowers [sinking]. We have to fill it up with good materials, and it must also be safe material because we do not want dirty stuff that is leaching in the ground water.

UB: You mentioned the Concrete Agreement. You are a part of it?

PAP: In the Concrete Agreement, they want change, which is very good. If you look at concrete, you have sand, gravel, water and cement normally. If you look at the production, sand, gravel and water have no footprint. But cement, it is responsible for a big footprint. Therefore, we have to look at the good ways to produce cement. Maybe some substitution. What we should not do is what we do now. When you have asphalt you put it in the oven, you burn everything and then in the end you have some stuff which has somehow the same aspects as cement. You can use it in concrete to glue everything together. But if you look at what is in that stuff after burning all of the house materials, it is terrible. All kinds of toxic stuff which we put in the concrete, because we do not need cement anymore. But you can never reuse it. It is too dangerous. We produce a lot of stuff that we cannot reuse, so we should stop it. We do not do it only for the waste from the Netherlands, we get it from Italy, Greece. It is because we have built these very good furnaces. We need more fuel than it is available in the Netherlands. So we take it from the whole Europe and put it in our Dutch furnaces. And it is already very polluted here. Bring everything to the Netherlands. Put it in our beautiful ovens and put it in the concrete. Not so wise in my opinion. The problem is that it is difficult for people to look in an integrated way. So we are not doing so good. We want to be sustainable, but we are not. And that is a pity, because it is also my country. Do not this in your country, say this is bad practice.

UB: You have already said a lot, but how would you describe your view on circular economy?

PAP: You have to put sustainability as the highest goal.

UB: Sustainability is really vague term, and circular economy as well. And the relation between the two is also undefined. Circular economy is not only about circulating the materials at any cost. It says that we should value negative externalities as well.

PAP: Everything should be in the LCA.

UB: So, you think that that is the best way to do it?

LA: Yes. We have to use methods of LCA. In the Netherlands we have our building law, Bouwbesluit, and in this law it says that you have to do an MPG [Milieuprestatie Gebouw = Environmental performance of buildings]. If you want to build the house, the architect or the one that wants to build it goes to the municipality and says here is the calculation of the environmental performance for the proposed object.

You need to calculate this because of the law, but nobody really did it. They can calculate something and say here it is. But it does not make any sense because there is no limit. You say I did the calculations. I know the wood, glass, concrete and the answer is 5. Bye, thank you. Next time, the answer is 8. Ok, bye thank you. There was no limit. You only had to calculate it. But now, they have put a limit in the Bouwbesluit that will come into use from the first of January. MPG must be 1 or lower. If you calculate and it is higher you cannot get the permit. Which is good. But now, how do you calculate the MPG. It consists of all materials that are in the building. Every association and company calculates the LCA of its product, also sand and gravel, and they put it in the Nationale Milieudatabase [National Environmental Database]. Then the architects get information from this database. The database is not complete, but we are working on that. However, it is very expensive. You need an institute that does the LCA. Then you go to another institute to check it. Institutes need to have certificate to perform an LCA, so you cannot go just anywhere. But LCA is developed by people from Delft. They are the technical people. They know about the fuel, about the emissions. So, everything in this LCA is about this kind of technical things. What is not measured is production of water safety and nature, and the soft values in general. We have the LCA, it is a start, but we should put other stuff than this Delft stuff in it. Is it fair? I do not think so? One day, because I was so tired of BRBS. I said lets calculate and compare the LCAs of both the primary and secondary aggregates. The BRBS finished first and they would not show their report, but only the conclusion. I did it for all of the four types that we do. The outcome was almost the same. I thought how this is possible. We scoop it up from the river. It is clean and ready. It turns out that they did not consider the demolition process with the excuse that that is not part of what they do. And it was done by one institute, and checked by another. So it is good. I said this is not fair. We need more rules for the LCA. What goes in and what does not. What we are doing is crazy actually, but at the moment we have to do it because we need the National Environmental Database, we need to calculate it, and of course we all want very low footprint because of the better position in the market. This is a rat race. I do not think that it is a good way, but it is the best that we have at the moment. I know that the BRBS does not like this because nobody is buying their products to make concrete. This is because the quality can never be compared with the primary aggregates. Another problem is also the quantity. If I am a builder, I want to make sure that you are producing quality and quantity on a regular basis. Therefore, I can imagine that the builders say that they would always use the primary materials. It is easy. It is always there. It is clean. We know the quality. For my members it is very nice, but I think that we should always look at what is there, and on time. We need a big database where we know what is in the urban mine. Where it is. When it will be ready for use again. And we need to think about it in advance, and not like I need the concrete tomorrow. Sometimes it is possible to reuse as much as possible concrete from the house that is nearby and that is really clean. Even if it is 80%. But, if we put 80% in the law, we do not have it. We have 20%. It depends a bit on where you are. If you want to build a house in Zeeland, and you know that the secondary aggregate is available tomorrow in Groningen, maybe it is not such a good idea. At the moment the government is stimulating this with the tax benefit.

UB: Ok, this is the current situation. Do you see it developing in the future?

PAP: Yes. We are developing it a bit. There is a new approach in the making. Of course, I am not in favor of making buildings with not clean aggregates because it is not healthy and because you cannot reuse it at the end-of-life. But, they are developing something very interesting. Maybe it will help us. It is called Module D. You have modules A,B,… All kinds of things that you can calculate from the numbers in the National Environmental Database. Module D also looks at, if you build the building and you want to know what is in the building. What kind of materials. Madaster (www.madaster.com/nl), it is a place with all the information about the buildings. It is a new thing and they want to do it. They want to have material passports and they want to use Module D. And Module D says we want to know what kind of materials do you use in your new building. And also what is the value of the materials for the next life cycle. If you build something with clean materials you get plus because you can use it for the next house. If you make a house with a lot of rubbish, you get a minus. So they want to calculate the value of the material that you are using

in your house with taking into account what can you do with it in the next life cycle. I think that this is a beginning of thinking in the right way.

UB: Ok, so you said that the current LCA is not the best option for evaluating, and that the new one is needed?

PAP: Yes. And we will get the new one. The Netherlands is currently the only country in Europe that has it in the law that you need to make these calculations with the LCA. The only country with the National Environmental Database. And also the only country that has the limit value, from January. If I tell my colleagues from the rest of Europe they think that we are crazy. Now in Europe they are developing a similar tool, called PEF [Product Environmental Footprint]. It is the European LCA. I think that it is already better because they say something about the land use. They also tackle toxicity. It is bigger than our LCA. In a few years, PEF will replace the LCA. In this PFA you have one parameter called land use. And they say that it is always negative. This is not fair. I am very much lobbying in the European Union to say that the land use is a very good parameter, but it must be to have both negative and positive value. Because for us, it is not fair. The problem is that the situation in the Netherlands is specific. We extract primary aggregates from the rivers and contribute to water safety and nature. In the rest of Europe this is different, because they blow up hills and mountains. I tried to put in the Concrete Agreement that you have to give priority to the materials that produce natural capital.

UB: Do you expect the Concrete Agreement to go through? And when?

PAP: Yes. I think in February. But at the moment it has changed a bit. It is now the ambition document, and before it was a document with the goals. It is changing bit by bit. Why do we need the Concrete Agreement? Because the concrete industry is losing it to wood and steel because of all of the rubbish that is put in it. Then we looked at wood and they have the FSC [Forest Stewardship Certificate], and we do not have anything. We also need a certificate. For cement, because it is a big thing. There is a very clever consultant and he is the mind behind the Concrete Agreement. He thinks in a very good and wise way, especially when it comes to his own money. He made this huge Concrete Agreement. He made huge CSC [Concrete Sustainability Council] certificate that says that all of the aggregates are produced in a good way for the environment and with good goals. If you do not have this certificate, the people from the concrete industry, they do not get points. It is a huge administrative burden now to get this certificate and the only use is that this smart consultant gets a lot of money. It will not change the way in which we work.

UB: Do you see it as beneficial in a way of industry coming together and discussing?

PAP: I think it will help a bit. The problem in The Hague is that they want the change. They do not ask associations because associations are putting the brakes on everything. This is because associations represent a large number of different members. Some of them are front-runners, some are in the middle and some are late comers. ME as the association person, I have to be in the middle in order to take care of everyone. As an association, I cannot run as fast as the best boys in the class, because I will lose my other members. And if they go away, we cannot do anything. People in The Hague want to go fast, so they ask the front-runners, and not the associations. They are in the working group. I understand why they invite the front-runners. But I say that they should not forget us, because if they all run very far, very hard, the people that are in this working group, they are companies and they always move because of the two reasons. The first reason is if they must because of the law. The second reason is that they can earn money. Do you really think that if they know what is going, they are coming to their competitors to tell them all about it? I do not think so. They do not and here is what happened. We know that few things that will be in the Concrete Agreement, the people from the working group, they already accomplished them. I do not think that that is fair and they do not want to listen. I am angry with them. Now, they are coming to the point when they need all companies and suddenly I am welcome again. It is wrong. But I will try to convince my

members to sign it. We are not so happy with how the process is going, but for the outside world, it is good that we have a certification. Positive press. The Minister is happy.

UB: Would you say that the main point of the Concrete Agreement is the certification?

PAP: No. The problem is that they want in the law the percentage of how much secondary aggregate has to be used in new concrete. That is not good. Because in one place it can be 80%, it depends on what is around. And in the other way it is 0%. I am always against putting percentages in the law, because people think circular is sustainable. At the moment it will be 5% and that is not a problem because you can always put 5%. We have also put in the Concrete Agreement that no more than 20% of the demand is available. They will start at 5%, but that will go up because they think that it is more sustainable. But it is not. As long as you want to build as much as we are building now, we cannot get this materials because then you pressure the companies to get it from far away or to put things that are not clean. It is very short-term thinking. There is the example of the garage in Eindhoven, very sustainable with large balls in it, but it collapsed before it started to work.

UB: What do you think that has to change in the supply chain of stony or concrete materials?

PAP: We have to know about volumes.

UB: Would you then say that we need to be aware of the reality?

PAP: Yes. The problem is that the people in the Hague do not know and are not interested in the facts. Here is an example of the bridge in Nijmegen. The municipality official was bragging how he has the most sustainable bridge in the world because it was completely made out of secondary aggregates. However, he was unaware of the two important things. That the secondary aggregates were imported from far away and that just below the bridge there was a primary aggregates extraction project. When he realized this, he was shocked because he told the contractor that he wanted a sustainable bridge. If we, as the building industry, are not careful in the future, we might get the same name as the banks. You cannot believe them. They say anything that you want to hear. But when it comes to the facts, it is all wrong.

UB: Let us go back to the changes in the supply chain.

PAP: We have primary and secondary aggregates. They are both good, if they are clean. But we have to work together. At the moment we do not. In other countries, people do work together. I lately discovered why it is like this in the Netherlands. If you look at the machinery, in other countries the same machinery is used for both demolition and the primary aggregates extraction. But, in the Netherlands, with our rivers and clean aggregates that are abundantly available, you just scoop it up, the machinery is completely different. Because of that we are competitors in the market. My members do not do demolition. There are two completely separate sectors. It is very difficult. And then they started to hate each other because they were competitors. The thing is that we have to work together, make one story. And for that we need very good information about the urban mine. What is realistic? When are the secondary materials available? When do we need certain rivers made wider? If we cannot dig up the aggregates, we wish everyone good luck with the river widening. We will not do it anymore. And the only place where we can produce the aggregates is near the river. We cannot do it somewhere else. And also, we cannot take out more aggregates from the rivers than there is demand in the market. Now there is a lot of demand for aggregates, but there were years with very little demand. However, our members are all family companies that use their money to prevent the company to shut down. And there are only 14 big companies. Therefore, we know exactly what is going on here. Demolition industry has hundreds of companies, small ones, big ones. Good ones, not so good ones. They have no idea about the volumes. BRBS also has no numbers. They say circular economy is good and it is sustainable. Do as much as you can. Put it in the law. And people in The Hague listen to that because they think they need to do the circular economy because of the Brussels.

Concrete producers

Prior to the interview the interviewee approved of recording the interview and using it for thesis research.

UB: To begin with, what is your company about?

CP: This is not, to say, a company. This is a group of producers of concrete. I am working for BFBN, which is the association of the precast concrete producers. In this building, from the 1.12.2017 we are talking about the BetonHuis. It is an association of not only the producers of precast concrete, but also the producers of ready-mix concrete and cement. Therefore, there is a joint association, the BetonHuis, which is the association for all the concrete producers and cement producers in the Netherlands, so it is quite large. We have about 90 members that are into the production of precast concrete which are the member of this association. And there are about between 20 and 25 producers of ready-mix concrete and there are 3 cement producers. But there is only 1 in Holland which is near the Maastricht, at Sint-Pietersberg. They are finishing their production there, I think, in 2018. Rather soon. After that they will produce cement from the raw materials imported from Belgium. They mill it and they make the cement still, but not the Portland Clinker, which is the basis of all cement. It will not be produced any more in the Netherlands, which is good.

UB: Moving on, what is your role within the company?

CP: I am involved in all issues like durability, sustainability, health and environment issues and safety issues. So, what I do is that I help our members concerning the questions of sustainability, durability, or that kind of issues. And I am involved in a governmental guidelines concerning sustainability and trying to see how we can influence this part in order for the members to be satisfied.

UB: Circular economy is then definitely a part of your role?

CP: Yes.

UB: Have you been dealing with it so far?

CP: Quite a lot at the moment. Especially the last couple of years of course. We have for about 10 years now, or maybe even before that, talk about flexible construction, industrial construction. So, when the construction is made that flexible and that easy to deconstruct. Take the parts of it back in order to reuse it again afterwards. Therefore, you have to be very flexible in your design, and in that way that the design has to be made so that indeed after the end of life of the construction you may be able to take parts of it back again and reuse it. So, when, in your design, you take that into account, then it is up to the people after 50 or 100 years when the deconstruction takes place. There is a possibility of using part of it again, so the thinking process has to start already now. So, we were involved, especially from the producers of precast concrete that are very interested in that. Because you have the possibility very much with this precast concept of taking it back again after the end of life. And when you use ready mix concrete, you should also think of possibilities in your design detail that there is also the possibility to take it apart after the end of life. Think it through before you design it and that is the whole thing that we are involved in at the moment. There are quite a few steps in the circularity that you have to take into account. I would say that, to begin with, not building any houses or whatever should be the best for circular economy and durability and sustainability. But I do not think that people would like that. Therefore, there is a large task for us to build and construct. And when you do that, you have to take into account how, for example, the foundation structure, or piles, or floors, or the skeleton of the building could last again for another reuse. Here (in Woerden), for example we have the mayor house which was in the old building of Ericcson. They wanted to build a new building because the old one was too large and not usable. They decided to build the new building around the existing skeleton of the old one. And that is a possibility. But, when you take it into account in the beginning, before constructing it, that makes it much easier for the one in the end to reuse it. And that is the same on every level. You can think of good possibilities of reusing. We have so many

different products that we make. There is: with all the paving blocks and flags; with concrete piles, walls, floors, roof tiles… Everything is made of concrete. It is much easier for, for example paving blocks and flags, because you pick them up after 40 years and put them somewhere else. And you can use it again for the new pavement. But it is getting more difficult when you use a certain pattern for the floor of the building that has been made specifically for that building, and it is sometimes more difficult to reuse it again because it is specifically made for that one building. So, when you think of it in the beginning, then you can probably use it again. You always have to think in a certain way. First of how can I design so that we can reuse afterwards, either a skeleton base or a part of the building. And if that is not possible, then how can we keep the quality of the concrete such that when it is not possible to reuse it again, that you can crush it and use the aggregate again. Or even if you have an aggregate that you can crush it down further into different parts like the gravel and the sand and the cement. So it is a whole system of thinking circularity in order to be able to become circular. It becomes very clear that everyone has to be circular. We can not continue in a linear economy so we have to think how to do that. It gives quite good possibilities of… I think that we are circular already, but you can always improve of course.

UB: You said circular already, how come?

CP: It depends on the definition you have of it of course.

UB: Do you refer to the use of mineral [stony] materials as aggregates for roads?

CP: At the moment, yes. I think it is about 98% of all the concrete that gets a good application afterwards. The most of it goes into the foundation layers for road construction. But, for us that is still a very good possibility of being circular, or becoming even more circular. It is just a different application. And when you see this road foundations as a new system within system boundaries… You can after maybe 30-40 years or so when the road has to be dug up again and used again, you can still say there is a foundation containing concrete aggregates together with masonry aggregates, you can still say that it is a very limited package of aggregates. In 30-40 years when you pick it up again and you start separating concrete and masonry and start reusing concrete again, maybe you can use it for (new) concrete or maybe you can use it for a new foundation. It is a very limited way of application (use for road base), but I see it also as a part of circular economy. It is not gone, it is not thrown away, it is refined into a certain foundation.

UB: Better than putting it into a landfill, you mean?

CP: Yes. But even for landfill you can say it is not gone and that it stays there. But you have to have much more energy before getting it out of there of course. It is done at the moment. Some of the old landfills we have here are picked up again and mineral [stony] material is taken out and separated, sorted and used again.

UB: Basically, it is like a material bank?

CP: Yes. Kind of material bank, yes.

UB: The same as for the (road) foundation?

CP: Yes. The foundation is more defined of course and the materials are still used for some function. It is of course always the definition that you use. Up-cycling, down-cycling, that discussion about the high value, of course. There is a nice example of the beer bottle labels. A year ago I was at a congress and there was a presentation by someone who gathered all the labels from the beer bottles and he made a very nice, new, toilet paper from that. Everyone was applauding and supportive. But we do not do different things in the concrete industry. So you make the concrete first and then you crush it down to an aggregate and use it again as a foundation of a road construction, where it also replaces the primary raw materials. It replaces sand and gravel there, so talking about the value of concrete and concrete aggregate that you use, it is difficult to see what the real value is. There is a need for a new way of seeing how much the value really is there.

UB: Regarding the road structures, less and less roads are being built because there is already extensive road network in the Netherlands. And, as you can reuse all of the aggregate in the existing roads, the space for stony materials is getting scarce. That is why it could be a problem.

CP: Yes, that could be eventually. I am not sure whether it really diminishes a lot. Again, I think there will be less applications in the road constructions in the future. Although we said the same thing 30 years ago and still there is a lot of aggregate going into the road construction. I cannot really judge whether it will be much less in the future than now. It is a possibility that it will be less. We should do more something in using the aggregates in concrete again, where at the moment 600000-700000 tons will be used for into concrete today, I think, I don't have the exact numbers. So, that is not too much. That is maybe 4-5% of all the total concrete rubble becoming available. So, it can become better.

UB: You have already told me a bit, but now officially, what is your view on the notion of circular economy? What is it for you? And do you see benefits in becoming 100% circular?

CP: Sure. We have to do that. We have to try to see how we can reuse our old concrete in the best way and using this ladder (like a ladder of Lansink) we can very much see how to do this. First of all, reusing the products themselves and then afterwards if it is not possible or it is less feasible then using it on an aggregate scale. I think that we are all obliged to do such things. It is almost impossible to not do. Only using linear economy is not an option anymore.

UB: What are the criteria that need to be met in order for the stony material supply chain to be considered 100% circular. For example we have the "Betonakkoord" with 7 goals that promise 100% circularity. What are those criteria in your opinion?

CP: First of all, we have to have a good discussion about the value of reusing the concrete. Not all concrete is the same. So, there are so many different types of concrete. In the pavement structures, the blocks and flags, it is much easier to use secondary raw materials again. That is much easier than in other products. In some of the products it is very difficult to use concrete aggregates again. Some of our members, they make kitchen surfaces. Those are very nice, shiny and polished. So you do not want any aggregates in there. You need natural materials in there in for it to be very durable and not to have any holes, porous things in there. In the sewer pipes and manholes, it is a very, very special market also, where you want to have very pure materials which are very tight and not porous. So, when there is a piece of wood in the sewer system, or the piece of gypsum, or a cellular concrete in there, you have a big problem. So they do not want to have that. So, in many products you can use the secondary raw materials, but not all of them. So, you have to make differences in there. That is why I think that in the Betonakkoord where it says that the 100% of the old concrete goes back to the concrete industry, that is the first thing where something can go wrong, because not all the concrete is clean enough that it can go back. For example, when you have pavement stones or flags and they are full of oil, you do not use them again. It is impossible to do that. You cannot even use it as a foundation because there is too much oil in there. You cannot do that. So, you have to have a possibility of putting such bricks somewhere else. Sometimes it is too much contaminated with plastics or other masonry products. You should have the possibility before to separate everything again and if you do not have that then you should use it maybe only as a foundation in road construction or something like that. Not all concrete can go back to concrete again. You can maybe try to do that, but you always find limits that you cannot pass anymore. And the same thing is for the minimum content of concrete aggregates for concrete (Betonakkord) is 5 % for all concrete. It is not possible. You cannot do that for all types of concrete. There are many differences, many variances in types of concrete. In some cases you can do 15 or 20 or even 30 %, but in some cases you stick to zero. You can think of how we can improve that and maybe augment it in future of course, but at the moment that is not possible. Those are two points that I have against the Betonakkoord.

UB: Did you participate in it so far?

CP: As an association we are not a front runner. Our members are front runners. They participate also in the table discussions. We are just advising them how they could do that That is the only thing we do as an association. There are also many types of members that we have. Some of the members have their own products where it is difficult to implement it. And there are other members that are a part of the front runners and they want it done as quickly as possible. As an association you have members to take into account.

UB: Going back to the criteria from the previous question. What are they?

CP: First take into account that you have lots of variation of certain products where you can use it. That is the first thing we have to take into account. One of the other parts is the value of reusing it and the value of recycling it has to become clear. What is the value of the concrete aggregates in the road base? Is that maybe lower value than using the concrete right away from the construction and what is the level of it. So, try to get a value clearly, kind of a value indicator. That is not easy at all. The thing with circularity is that it should not become an ideological item. It is very nice to talk about circularity in the way of we are going to make things in a way that everything goes back, everything is inserted into one circle and it easily becomes ideological. And we should really consider that the circularity is not a goal by itself. Circularity for us is a way of thinking and acting such that we are able to get sustainable society and sustainable applications of our products. That is the main goal that we have. And once circularity can become part of that goal then I am for it. It is good, it is very good, but do not let the circularity become the main goal. Because if something has to be circular and there is no other way that you can do that. For example, when there is a building becoming available in Amsterdam and there is no construction at that point in Amsterdam, and you have to use the building somewhere in Rotterdam. Then you have to transport the building, or the construction product or the aggregate from one city to another city and then that is not sustainable anymore. You have such a high CO2 emissions from the transport which incurs a lot of cost. That is maybe circular anymore, but it is not sustainable anymore.

UB: Is storage perhaps an option in that case?

CP: Maybe you could. But then also you should take care that maybe you have to store it somewhere in Amsterdam or somewhere in Hague and in the end it will be used somewhere in Utrecht or in Rotterdam. Also then you have to consider the sustainability side of it. Make a life-cycle analysis of the system that you are going to look at. It should become part of the life-cycle analysis, and not only the circularity as the main goal. That is maybe the most important message that I want to give you.

UB: What you are saying is that whenever you have some end-of-life concrete you should make a decision based on all relevant factors. And that sometimes this decision is in contrast with circular approach?

CP: First you have to look at what is the value of the construction that is there. So there is a construction that has reached the end of life. So you consider what is the value of construction. The skeleton, the parts of concrete and the parts of masonry, and wood, and so forth. What is the value of it? The value of it in terms of how it can be used or reused. If it is very difficult to give the value to that, maybe you should consider to not use the parts of the construction, but to bring it to the recycling site where it becomes recycled into the small aggregates. Then again, you can use the aggregates for new concrete, or road construction, or whatever. The whole system of reusing construction or building has to be done based on a kind of life-cycle analysis. What about the cost? What about the value of reusing it? I think that there should be much more attention paid to this fact. Because at the moment it is not done. It can be the best option, but the options should be evaluated and that is not done at the moment. We should do more.

UB: What are the changes that need to occur within the stony materials supply chain in order to achieve circularity along these criteria?

CP: At the moment the people that make new constructions (investors and construction companies) could give more attention to circularity. But, keep it also in the total of sustainability, please. They should consider sustainability first and the circularity as the part of sustainability. They should not put circularity as the first goal. It does not happen that often, but you get the impression. If you want you can do that, but stick to the couple of projects where you ask for the circularity to be the main item. And then you learn a lot from that because you cannot always do everything as circular as possible because you have higher costs of removing some materials or there is no way to reuse the foundation for example that is there. Then you need to get the new foundation in there. So, some projects can be done and you learn a lot from those projects, but do not do it on a large scale, too much forced by circularity, but keep sustainability always in mind.

UB: Any other changes that you can think of?

CP: You need to start asking for sustainable construction much more, instead on focusing on costs only. Cost of construction is, at the moment the main factor. When sustainability is valued more than the costs, then you have a good advance there.

UB: What would make it more valuable (than looking solely at costs)?

CP: Getting the awareness on sustainable construction more clear to the investors. Of course, it costs money and that is it. Sometimes, the more sustainable the more it costs. It has to do with awareness. Augmenting the awareness of circularity and sustainability, with the people from the whole chain involved. I have been busy doing that. Everyone is busy doing that. Also, with the Betonakkoord we are doing that. I would prefer seeing much more call for sustainable construction in the future than what we do at the moment. You have to do it in the whole chain.

UB: You said in the whole chain. What did you mean by that?

CP: It is collaboration and it is when the awareness of all parties in the chain is at the certain level. Everyone has to be involved. In that case, the Betonakkoord is a good development.

UB: What are the perceived needed changes within the companies in your branch for becoming more circular?

CP: There is a very large variety in concrete producers. The main thing is that, together with the investors, together with the construction companies,…, we start thinking much more on how our products could be reused again after their end of life. That is the whole thing to do. In the design, discuss with the supply chain what are the best solutions to implement all kinds of measures in the design in order for the people in 40-50 years to reassemble the construction. Also, in this chain think of possibilities for design for reassembly. That is the main thing. There are all kinds of possibilities. But you do not know what happens after 50 years. 50 years ago, 1950-60s, people would never have thought that buildings today would be reassembled again. Maybe we are talking now about something that will not happen after 50 years, but when we do think about reassembly now, we give them a possibility after 50 years. We should start thinking much more of design for reassembly now, giving the possibility of reassembly and deconstruction after the end of life. I think that it is an obligation that every one of us has.

UB: However, concrete is very specific. Even with the precast elements, which are easy for reassembly, you need to join them somehow on site and still ensure that they will not be damaged during deconstruction. On the other hand, in situ cast concrete is an even greater challenge. How about that?

CP: Yes, but you can have construction detailing in such a way that there is no really tight connection. Think of flexible connections or something like that in order to be able to reassemble it again. Think in possibilities, not problems. We should not be too tight in our own way of construction. Think of new ways. I am not sure how to do it, but think of it.

UB: Recently the required height of the ceiling changed in the Netherlands. What if this happens in the future? It can possibly damage the efforts to design for reassembly.

CP: Maybe in 30 years we find out that the people got taller again and we have to change the height also. But, if you do nothing at the moment that is not good either, so think of possibilities. And even if you see that in 50 years it is not possible to use a wall system again. You have to be able to bring it to a recycling plant and recycle it again. And there is a possibility for maybe not only make the aggregates of it, but maybe reassemble the concrete again in the different parts, sand, gravel or cement that can be reused. On all scale, there are possibilities of this example. All kinds of parts. So many different possibilities. Even possibilities that we cannot think of now.

UB: Do you see any changes in the role of the companies from your branch in the market as a consequence of becoming more circular?

CP: What happens is that many of our producers are making houses in total, with all the amenities incorporated, as a box. If you want a bigger house you just join a few boxes together. There is a shift from making small parts for housing and connecting them on the building site to more and more making complete walls with windows in there, with everything together as housing units. Or even there are 4 or 5 of our members that make complete houses together with everything in there, kitchen and everything.

UB: Are there any of your members that offer service instead of ownership?

CP: I think that it is ownership at the moment still, but it is a possibility in the future. You lease your house or something.

CP: There is another thing that I would like to say. Now, we have two separate ways of thinking about the sustainability. One is via the life-cycle analysis, and the other is circularity. The best way is to join both into certain system. So, when there is an LCC made for the product or construction, you should have the circularity part added to total study. There are some developments here already.

Appendix C – cards representing changes that were used in the second part of research

Developing new ways of appraising value that will support circular business decisions

The actors within the supply chain fail to identify the added value of the circular approach. Therefore, they have no incentive to make circular decision. The goal of this change is to provide a way of identifying the value of adopting the notions of circular economy.

Defining the notion of circular economy in the stony materials supply chain

Actors in the supply chain have different views on the notion of circular economy. In order to enable the implementation of the circular approach, these views have to be aligned. That is, a single definition of the circular economy within the stony materials supply chain has to be agreed on in the whole supply chain.

Accounting for real costs of transport

Transport was recognized as part of the reuse/ recycle process that is often overlooked although it can lead to significant external costs that make the whole process pointless.

Integrating actors within the supply chain

The actors perceive the current level of collaboration within the supply chain as not sufficient for implementation of the circular approach.

Raising awareness about the potential of the notion of circular economy within the supply chain

Currently, not all actors within the supply chain are aware of the potential benefits of the circular approach. This needs to change, if the notions of circular economy are to be implemented.

Conducting research across the supply chain with the goal of identifying and enabling all possible reuses of concrete products and materials

It is perceived that current reusing and recycling options are not enough and that there are many more possibilities if the research is conducted on the level of supply chain.

Introducing the concept of geographical distribution of the market areas in which a company can operate

Geographical distribution implies creating dedicated areas in which one company operates. In this way negative externalities of the transport are kept under control, which is the reason why this change was perceived.

Standardizing of concrete products

Concrete is the most used construction material. It is everywhere around us. Naturally, there is a great variety of concrete products. In order to boost recycling and reusing of concrete products, there needs to be standardization of concrete products (reduction of variety).

Using the waste treatment hierarchy (ladder of Lansink) when making decision about the stony materials waste
Although postulated in the law as a guideline, the waste treatment hierarchy is not used. It is perceived that by using the waste treatment hierarchy (ladder of Lansink) the circularity of the supply chain would be boosted.

Incorporating value of reuse/recycling in the Life Cycle Assessment
LCA is a tool which has to be used for almost all new construction developments. However, there is no way of appraising value of reuse or recycling within it. Therefore, incorporating a way to do that into the LCA would be beneficial for the circularity of the supply chain.

Developing new value indicators
Currently there are no indicators in use that take into account circularity aspects of products in the supply chain. These are needed in order to enable making of circular decisions.

Developing a tool for assessing the most beneficial treatment of end of life products and materials
Taking all of the options into account when deciding about the treatment of the end of life materials is hard and time consuming. Particularly because there needs to be a free flowing information and knowledge sharing across the supply chain, which is currently not the case. Therefore, developing a tool that will help with this decision will greatly enhance circularity.

Appreciating road foundations as material banks
Down-cycling most ofthe stony materials into the road base material is recognized as a bad practice in the circular approach. However, implementation of the notions of circular economy is a process that takes time. Therefore, road foundations should be viewed as material banks Materials that are put in road bases remain clean during their life cycle and can be recycled / reused again.

Acknowledging the differences in quality requirements between different concrete products and their impact on the amount of secondary materials that can be used for the production of those products
There is a wide variety of concrete products on the market. Some of those products have limits on how much secondary materials can be used for their production. The others are contaminated during their life-cycle to the point that it is impossible to reuse them again. It is important to acknowledge these potential limitations.

Planning and designing with future in mind
Longevity of structures implies that actions taken today will dictate the circularity of the construction sector in 50 or more years. Therefore, it is important to take this into account when planning and designing new constructions today.

Designing for reassembly
In theory of circular economy reuse at the product level is more valuable than reuse at the material level. Therefore, it is important to design for reassembly in order to enable this higher value to be captured.

Designing modular constructions

It is hard to predict the needs of people and society in 50 years time. Therefore, it is important to design modular constructions that will allow for easy change of the intended function of the construction.

Keeping quality of the stony materials at the high level by separation at the source

With separation at source, the demolition process would have higher quality stony materials as output, which supports the notions of circular economy. Therefore this part of the process should become standard part of demolition companies' job.

Prescribing separation at the source and the minimum amount of demolished materials that have to be recycled in the procurement procedure

In order to ensure separation at the source and recycling of end of life materials and therefore support the circularity of the supply chain, these should become part of the standard demolition procurement procedure.

Enabling high value demolishing, reuse and recycling by providing more time, more space and more time for the demolition companies

Currently demolition process is not given enough credit. The highest value of end of life materials is ensured with a well planned and executed demolition. In order to achieve this, demolition process needs to be allowed enough time, space and money.

Incorporating Pre-Demolition Audit in demolition process

Pre-Demolition Audit encompasses creation of the inventory of materials used in the structure that is to be demolished prior to the demolition. With this knowledge the demolition process can be planned in such a way that it yields the most value out of the end of life materials. Therefore, introduction of the Pre-Demolition Audit in the demolition process would boost the notions of the circular economy.

Raising the awareness of the supply chain about the new role of the demolition companies as materials providers

Implementation of circular approach has disruptive effect on the supply chain, with changing roles for all of the actors. In that sense, the demolition companies will become "raw" materials providers. The sooner the whole supply chain becomes aware of this, the sooner the notions of circular economy may be implemented.

Introducing new technologies that will make the recycling process better

The better the recycling technologies, there are more and better options for reuse of recycled materials.

Making the process fully transparent - in terms of information and knowledge gathering and sharing across the supply chain

In order for the best choice of the treatment of end of life materials to take place, the decision makers need to be fully aware about all options for treatment, reuse and recycling of those materials. Therefore, free information and knowledge flow across the supply chain is mandatory.

Incorporating adequate pricing for demolition companies	Putting the notions of circular economy in the law
Current pricing for demolition companies does not provide incentive for them to opt for a high value demolition process.	*Voluntary agreements between parties are perceived as ineffective. An example of the Concrete Agreement is given, within which nothing was accomplished although there were talks between parties for 3 years. Therefore, government action, in terms of prescribing in law what needs to be done for circularity to be achieved, is needed.*
Creating new business models that will allow for transitioning to circular economy	**Aligning the theory, perceptions and reality regarding the possibilities in realizing the notion of circular economy**
Circular economy will disrupt current roles and business models for the actors in the stony materials supply chain. Therefore, it would be beneficial to formulate new business models that will correspond to this new situation. In this way, actors will have a clearer picture of what the future holds, and could adjust accordingly.	*Theory identifies how fully circular supply chain functions. However, implementation of a circular approach is a lengthy process. Reality encompasses knowledge of the current state of circularity, and also awareness about what is possible at which point in time. Perceptions of the actors lie somewhere in between. These three need to be aligned.*
Ensuring that everybody in the supply chain is knowledgeable about the circular economy and the real situation regarding its possibilities in the stony materials supply chain	**Relieving political pressure on government officials**
Everybody involved in the stony materials supply chain should have enough knowledge and understanding of the notions of circular economy and specificities of the supply chain. Only in this way can there be a constructive progress towards circularity.	*Currently, some government officials, under pressure from the hype around the notion of circular economy, are insisting on 100% circularity, although it is not possible to achieve that at this moment. This is having adverse effect on the actors in the supply chain in terms that they are expected to deliver something that they are not, yet, able to, or their current business models are under pressure.*
Taking into account the gap between the supply of secondary aggregates and demand for aggregates in the building industry. And, therefore, the need for primary aggregates in the years to come	**Not reusing and recycling at any cost**
Some actors are insisting on 100% circularity, although it is not possible at the moment, nor in the foreseeable future. The reason for this is longevity of structures. First, in order to be able to achieve full circularity the amount of end of life materials needs to match that of the materials needed for new developments. Second, buildings built 50 years ago were not designed for circularity. Third, this material gap will remain.	*Insisting on circularity at any cost may prove to be disadvantageous in the end. An example was given of importing large quantities of recycled materials, which incurred significant real costs because of the transport involved.*

Addressing and analyzing the implications of the notion of circular economy for the quality of the stony materials' rubble and its usability	**Stopping the use of "dirty" aggregates in production of new concrete because it hinders its reuse in the next life cycles**
Rubble has great characteristics for use in road foundations. If concrete fraction is taken out of this rubble, its characteristics are diminished. Furthermore, other fractions, like masonry, are unusable in any other way than as part of the rubble. Circularity implies return of the end of life materials to their respective waste streams, and therefore the removal of rubble, potentially creating a bigger problem.	*When waste from other industries (e.g. ash) is used for production of concrete it disables reinserting of that concrete in the next life cycle, hindering the notions of circular economy in the long term.*
Changing the laws that are stimulating import of recycled aggregates [MIA/VAMIL law]	**Deciding on the optimum mix of aggregates based on the time of their availability, whether they are primary or secondary, location and needed transport, quality, possibility for re-circulation, needs of projects in the vicinity**
MIA/VAMIL law states that anyone that uses more than 30 % of recycled aggregates gets a tax benefit. This law should in theory boost circularity, but in reality it lead to excessive import of recycled aggregates. This import implies transport which makes the whole point of using recycled aggregates obsolete because of massive negative externalities.	*There are not enough secondary aggregates to completely replace primary aggregates. This implies use of mixed aggregates. However, the most beneficial mixture is to be determined on the case basis, taking into account the above postulated parameters.*
Planning ahead - allow enough time for taking all of the options into account when ordering concrete	**Creating a database that contains all materials and products that are available in the urban mine**
Current practices encompass ordering of concrete needed for the construction process in almost a " I need it today" fashion. This disables the process of analyzing all of the options available and deciding on the most beneficial one.d.	*In order to boost reuse and recycling there has to be a register of the available products for reuse and materials for recycling in the urban environment. In that way, it is possible to plan and design with circularity in mind.*
Using material passports (e.g. Madastar)	**Adopting the way of building that ensures reuse on a product level and eliminates the need for recycling completely**
Material passport of a building encompasses details about all of the materials that were used for its construction. In this way, valuable information are gathered and made available to the supply chain, which can, than, plan accordingly.	*In order for the notions of circular economy to be implemented completely, a new way of building needs to be introduced which supports it. According to the circular approach this encompasses creating structures that are reusable on a product level. The sooner this new approach to building is incorporated the sooner the circular economy will be possible within the stony materials supply chain.*

Appendix D – perceptions of responsible actors on the level of individual companies

Branch	Demolition Companies											Codename	DC1										
Company												Location											
Interviewee												Date and time											
Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	EU	Des	BO	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	EU	Des	BO	Rank
1	0	0	0	0	1						0	21	1	0	0	0							0
2	0	0	0	0				1			0	22	1	0	0	0							7
3	0	0	0	0				1			0	23	0	0	0	0			1				9
4	0	0	0	0			1				0	24	0	0	0	0			1				0
5	0	0	0	0			1				0	25	0	0	0	0			1				0
6	0	0	0	0			1				0	26	0	0	0	0	1						4
7	0	0	0	0							0	27	0	0	0	0			1				0
8	0	0	0	0				1			0	28	0	0	0	0			1				0
9	1	0	0	0							0	29	0	1	0	0							0
10	0	0	0	0	1						0	30	0	0	0	0						1	0
11	1	0	0	0							0	31	0	0	0	0			1				0
12	0	1	0	0							0	32	0	0	0	0	1						0
13	0	0	0	0			1				0	33	0	1	0	0							8
14	0	0	0	0				1			0	34	0	0	0	0	1						2
15	0	0	0	0			1				1	35	0	0	0	0	1						5
16	0	0	0	0					1		0	36	0	0	0	0					1		0
17	0	0	0	0					1		0	37	0	0	0	1							0
18	1	0	0	0							10	38	1	0	0	0							0
19	0	0	0	0		1					0	39	0	0	0	0	1						3
20	1	0	0	0							0	40	0	0	0	0		1					6
Sum	4	1	0	0	2	1	5	4	2	0		*Sum*	3	2	0	1	5	1	6	0	1	1	
Total	DC	RC	PAP	CP	Gov	Inv	SC	EU	Des	BO	*Sum*												
	7	3	0	1	7	2	11	4	3	1	39												
%	17.95	7.692	0	2.564	17.95	5.128	28.21	10.26	7.692	2.564	100												

Table D1: Perception of responsible actors, interviewee DC1

Branch	Demolition companies											Codename	DC2										
Company												Location											
Interviewee												Date and time											
Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	Rank
1	0	0	0	0			1				0	21	0	0	0	0	1						0
2	0	0	0	0			1				0	22	1	0	0	0							0
3	0	0	0	0							0	23	0	0	0	0			1				0
4	0	0	0	0			1				0	24	0	0	0	0	1						0
5	0	0	0	0	1						0	25	0	0	0	0			1				0
6	0	0	0	0			1				0	26	0	0	0	0	1						0
7	0	0	0	0							0	27	0	0	0	0			1				0
8	0	0	0	0				1			0	28	0	0	0	0			1				0
9	0	0	0	0			1				0	29	0	0	0	0			1				0
10	0	0	0	0	1						0	30	0	0	0	0	1						0
11	0	0	0	0					1		0	31	0	0	0	0	1						0
12	0	0	0	0			1				0	32	0	0	0	0							0
13	0	0	0	0			1				0	33	0	0	0	1							0
14	0	0	0	0							0	34	0	0	0	1							0
15	0	0	0	0					1		0	35	0	0	0	0	1						0
16	0	0	0	0				1			0	36	0	0	0	0			1				0
17	0	0	0	0				1			0	37	0	0	0	0			1				0
18	0	0	0	0		1					0	38	1	0	0	0							0
19	0	0	0	0	1						0	39	0	0	0	0						1	0
20	0	0	0	0		1					0	40	0	0	0	0		1					0
Sum	0	0	0	0	3	2	7	3	2	0		*Sum*	2	0	0	2	6	1	7	0	0	1	
Total	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	*Sum*												
	2	0	0	2	9	3	14	3	2	1	36												
%	5.556	0	0	5.556	25	8.333	38.89	8.333	5.556	2.778	100												

Table D2: Perception of responsible actors, interviewee DC2

Branch	Demolition companies								Codename	DC3							
Company									Location								
Interviewee									Date and time								
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Des	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Des	Rank
1	0	0	0	0		1		0	21	0	0	0	0	1			8
2	0	0	0	0		1		0	22	0	0	0	0		1		0
3	0	0	0	0		1		0	23	0	0	0	0		1		0
4	0	0	0	0		1		0	24	0	0	0	0		1		0
5	0	0	0	0	1			6	25	0	0	0	0		1		0
6	0	0	0	0		1		0	26	0	0	0	0	1			1
7	0	0	0	0				0	27	0	0	0	0		1		0
8	0	0	0	0	1			10	28	0	0	0	0	1			5
9	0	0	0	0	1			7	29	0	0	0	0		1		0
10	0	0	0	0		1		0	30	0	0	0	0	1			0
11	0	0	0	0	1			9	31	0	0	0	0	1			0
12	0	0	0	0		1		0	32	0	0	0	0	1			0
13	0	0	0	0		1		0	33	0	0	0	0		1		0
14	0	0	0	0	1			0	34	0	0	0	0	1			4
15	0	0	0	0	1			0	35	0	0	0	0	1			2
16	0	0	0	0		1		0	36	0	0	0	0		1		0
17	0	0	0	0			1	0	37	0	0	0	0		1		0
18	1	0	0	0				0	38	0	0	0	0	1			3
19	0	0	0	0	1			0	39	0	0	0	0		1		0
20	0	0	0	0	1			0	40	0	0	0	0		1		0
Sum	1	0	0	0	8	9	1		*Sum*	0	0	0	0	9	11	0	
Total	DC	RC	PAP	CP	Gov	SC	Des	*Sum*									
	1	0	0	0	17	20	1	39									
%	2.564	0	0	0	43.59	51.28	2.564	100									

Table D3: Perception of responsible actors, interviewee DC3

Branch	Demolition companies											Codename	DC4									
Company												Location										
Interviewee												Date and time										
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	Des	Sci	Con	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	Des	Sci	Con	Rank
1	0	0	0	0			1				0	21	1	0	0	0							4
2	0	0	0	0		1					0	22	1	0	0	0							2
3	0	0	0	0		1					0	23	0	1	0	0							7
4	0	0	0	0		1					0	24	0	0	0	0			1				0
5	0	0	0	0		1					1	25	0	0	0	0			1				8
6	0	0	0	0					1		0	26	0	0	0	0	1						0
7	0	0	0	0							0	27	1	0	0	0							3
8	0	0	0	1							0	28	0	0	0	0	1						0
9	1	0	0	0							0	29	0	0	0	0	1						0
10	0	0	0	0	1						0	30	0	0	0	0		1					0
11	0	0	0	0			1				0	31	0	0	0	0	1						0
12	1	0	0	0							0	32	0	0	0	0				1			0
13	0	1	0	0							0	33	0	1	0	0							0
14	0	0	0	1							0	34	0	1	0	0							0
15	0	0	0	0				1			0	35	0	0	0	0	1						0
16	0	0	0	0				1			0	36	0	1	0	0							0
17	0	0	0	0				1			9	37	0	0	0	0						1	0
18	1	0	0	0							0	38	0	0	0	0				1			0
19	0	0	0	0							5	39	0	0	0	0				1			10
20	0	0	0	0			1				6	40	0	0	0	0				1			0
Sum	3	1	0	2	1	4	3	3	1	0		*Sum*	3	4	0	0	5	1	2	4	0	1	
Total	DC	RC	PAP	CP	Gov	SC	Inv	Des	Sci	Con	*Sum*												
	6	5	0	2	6	5	5	7	1	1	38												
%	15.79	13.16	0	5.263	15.79	13.16	13.16	18.42	2.632	2.632	100												

Table D4: Perception of responsible actors, interviewee DC4

Branch	Recycling companies													Codename	RC1											
Company														Location												
Interviewee														Date and time												
Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	IC	Sci	CC	Des	Con	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	IC	Sci	CC	Des	Con	Rank
1	0	1	0	0									0	21	0	0	0	0	1								7
2	0	1	0	0									0	22	0	0	0	0									0
3	0	1	0	0									0	23	0	0	0	0				1					1
4	0	0	0	0			1						0	24	0	0	0	0			1						0
5	0	0	0	0	1								0	25	1	0	0	0									0
6	0	0	0	0					1				0	26	0	0	0	0	1								0
7	0	0	0	0									0	27	0	0	0	0				1					2
8	0	0	0	1									0	28	1	0	0	0									0
9	0	0	0	0	1								10	29	0	1	0	0									0
10	0	0	0	0	1								0	30	0	0	0	0				1					0
11	0	0	0	0	1								0	31	0	0	0	0			1						0
12	0	0	0	0						1			0	32	0	0	0	0		1							9
13	0	1	0	0									0	33	0	0	0	0				1					0
14	0	0	0	1									0	34	0	0	0	1									0
15	0	0	0	0							1		5	35	0	0	0	0	1								0
16	0	0	0	0					1				0	36	0	1	0	0									0
17	0	0	0	0							1		3	37	0	0	0	0								1	6
18	0	1	0	0									4	38	0	0	0	0	1								0
19	0	0	0	0	1								0	39	0	0	0	0			1						8
20	0	0	0	0		1							0	40	0	0	0	1									0
Sum	0	5	0	2	5	1	1	0	2	1	2	0		*Sum*	2	2	0	2	4	1	3	4	0	0	0	1	
Total	DC	RC	PAP	CP	Gov	Inv	SC	IC	Sci	CC	Des	Con	*Sum*														
	2	7	0	4	9	2	4	4	2	1	2	1	38														
%	5.263	18.42	0	10.53	23.68	5.263	10.53	10.53	5.263	2.632	5.263	2.632	100														

Table D5: Perception of responsible actors, interviewee RC1

Branch	Recycling Companies										Codename	RC2									
Company											Location										
Interviewee											Date and time										
Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	EU	IP	Des	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	EU	IP	Des	Rank
1	0	0	0	0	1					0	21	0	0	0	0		1				0
2	0	0	0	0	1					0	22	0	0	0	0		1				0
3	0	0	0	0		1				0	23	0	1	0	0						5
4	0	0	0	0	1					0	24	0	0	0	0		1				0
5	0	0	0	0	1					0	25	1	0	0	0						0
6	0	1	0	0						0	26	0	0	0	0	1					3
7	0	0	0	1						0	27	0	0	0	0	1					0
8	0	0	0	0				1		0	28	0	0	0	0			1			0
9	0	0	0	0	1					1	29	0	0	0	0	1					0
10	0	0	0	0			1			2	30	0	0	0	0	1					0
11	0	0	0	0				1		0	31	0	0	0	0	1					0
12	0	0	0	0						9	32	0	1	0	0						0
13	0	0	0	0	1					8	33	0	1	0	0						0
14	0	0	0	0						0	34	0	0	0	0			1			4
15	0	0	0	0	1					7	35	0	0	0	0						0
16	0	0	0	0		1				0	36	0	0	0	0		1				0
17	0	0	0	0		1				10	37	0	1	0	0						0
18	1	0	0	0						0	38	0	0	0	0	1					6
19	0	0	0	0		1				0	39	0	0	0	0						0
20	1	0	0	0						0	40	0	0	0	0					1	0
Sum	2	1	0	1	7	4	1	2	0		*Sum*	1	4	0	0	6	4	2	0	1	
Total	DC	RC	PAP	CP	Gov	Inv	EU	IP	Des	*Sum*											
	3	5	0	1	13	8	3	2	1	36											
%	8.333	13.89	0	2.778	36.11	22.22	8.333	5.556	2.778	100											

Table D6: Perception of responsible actors, interviewee RC2

Branch	Recycling Companies									Codename	RC3								
Company										Location									
Interviewee										Date and time									
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	IP	Con	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	IP	Con	Rank
1	0	0	0	0	1				0	21	0	0	0	0	1				0
2	0	0	0	0	1				10	22	1	0	0	0					0
3	0	0	0	0	1				0	23	0	1	0	0					8
4	0	0	0	0		1			9	24	0	1	0	0					4
5	0	0	0	0		1			0	25	0	0	0	0	1				0
6	0	0	0	0		1			0	26	0	0	0	0	1				0
7	0	0	0	0					0	27	0	1	0	0					1
8	0	0	0	0	1				0	28	0	0	0	0		1			0
9	0	0	0	0	1				0	29	0	0	0	0	1				0
10	0	0	0	0			1		5	30	0	0	0	0	1				0
11	0	0	0	0			1		0	31	0	1	0	0					0
12	0	1	0	0					3	32	0	0	0	0	1				0
13	0	0	0	0	1				0	33	1	0	0	0					0
14	0	0	0	0			1		0	34	0	0	0	0	1				7
15	0	0	0	0				1	0	35	0	0	0	0	1				0
16	0	0	0	0				1	2	36	0	0	0	1					0
17	0	0	0	0				1	0	37	0	0	0	1					0
18	1	0	0	0					0	38	0	0	0	0	1				0
19	0	0	0	0	1				0	39	0	0	0	0	1				6
20	0	0	0	0	1				0	40	0	0	0	0		1			0
Sum	1	1	0	0	8	3	3	3		*Sum*	2	4	0	2	10	2	0	0	
Total	DC	RC	PAP	CP	Gov	SC	IP	Con	*Sum*										
	3	5	0	2	18	5	3	3	39										
%	7.692	12.82	0	5.128	46.15	12.82	7.692	7.692	100										

Table D7: Perception of responsible actors, interviewee RC3

Branch	Recycling Companies										Codename	RC4									
Company											Location										
Interviewee											Date and time										
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Con	Inv	BO	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Con	Inv	BO	Rank
1	0	0	0	0	1					0	21	0	0	0	0	1					3
2	0	0	0	0	1					0	22	0	0	0	0	1					0
3	0	0	0	0	1					0	23	0	1	0	0						5
4	0	0	0	0	1					0	24	0	0	0	0					1	2
5	0	0	0	0	1					0	25	0	0	0	0	1					0
6	0	0	0	0	1					0	26	0	0	0	0	1					1
7	0	0	0	0						0	27	0	0	0	0		1				0
8	0	0	0	0						0	28	0	0	0	0	1					0
9	0	0	0	0	1					4	29	0	0	0	0	1					0
10	0	0	0	0	1					7	30	0	0	0	0						0
11	0	0	0	0		1				0	31	0	0	0	1						0
12	0	0	0	0	1					0	32	0	0	0	0	1					0
13	0	0	0	0			1			0	33	0	0	0	0				1		8
14	0	0	0	0						0	34	0	0	0	0	1					0
15	0	0	0	0	1					0	35	0	0	0	0	1					0
16	0	0	0	0			1			0	36	0	0	0	1						9
17	0	0	0	0				1		0	37	0	0	0	0		1				6
18	1	0	0	0						0	38	1	0	0	0						10
19	0	0	0	0	1					0	39	0	0	0	0				1		0
20	0	0	0	0				1		0	40	0	0	0	0			1			0
Sum	1	0	0	0	11	1	2	2	0		*Sum*	1	1	0	2	9	2	1	2	1	
Total	DC	RC	PAP	CP	Gov	SC	Con	Inv	BO	*Sum*											
	2	1	0	2	20	3	3	4	1	36											
%	5.556	2.778	0	5.556	55.56	8.333	8.333	11.11	2.778	100											

Table D8: Perception of responsible actors, interviewee RC4

Branch	Primary aggregates producers										Codename	PAP1									
Company											Location										
Interviewee											Date and time										
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	IP	Des	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	IP	Des	Rank
1	0	0	0	0		1				0	21	1	0	0	0						0
2	0	0	0	0	1					0	22	0	0	0	0			1			0
3	0	0	0	0	1					6	23	0	1	0	0						0
4	0	0	0	0		1				0	24	0	0	0	0	1					7
5	0	0	0	0		1				8	25	1	0	0	0						0
6	0	0	0	0		1				0	26	0	0	0	0	1					0
7	0	0	0	0						0	27	0	0	0	0		1				0
8	0	0	0	1						0	28	0	0	0	0		1				1
9	0	0	0	0	1					0	29	0	0	0	0		1				4
10	1	0	0	0						0	30	0	0	0	0						0
11	0	0	0	0		1				0	31	0	0	0	0	1					2
12	0	0	0	0				1		0	32	0	0	0	0		1				5
13	0	1	0	0						0	33	0	0	0	0	1					0
14	0	0	0	1						0	34	0	0	0	1						9
15	0	0	0	0					1	0	35	0	0	0	0	1					10
16	0	0	0	1						0	36	0	0	0	1						3
17	0	0	0	0					1	0	37	0	0	0	0			1			0
18	1	0	0	0						0	38	1	0	0	0						0
19	0	0	0	0	1					0	39	0	0	0	0	1					0
20	0	0	0	0	1					0	40	0	0	0	0		1				0
Sum	2	1	0	3	5	5	0	1	2		*Sum*	3	1	0	2	6	5	2	0	0	
Total	DC	RC	PAP	CP	Gov	SC	Inv	IP	Des	*Sum*											
	5	2	0	5	11	10	2	1	2	38											
%	13.16	5.263	0	13.16	28.95	26.32	5.263	2.632	5.263	100											

Table D9: Perception of responsible actors, interviewee PAP1

Branch	Primary aggregates producers											Codename	PAP2									
Company												Location										
Interviewee												Date and time										
Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	EU	SC	BO	Des	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	EU	SC	BO	Des	Rank
1	0	0	0	0					1		0	21	1	0	0	0							0
2	0	0	0	0	1						1	22	1	0	0	0							0
3	0	0	0	0				1			0	23	0	1	0	0							7
4	0	0	0	0	1						0	24	0	0	0	0			1				0
5	0	0	0	0	1						0	25	0	0	0	0		1					0
6	0	0	0	0				1			0	26	0	0	0	0	1						6
7	0	0	0	0							0	27	0	1	0	0							0
8	0	0	0	1							5	28	0	0	0	0	1						0
9	0	1	0	0							0	29	0	0	0	0	1						0
10	0	0	0	0		1					0	30	0	0	0	0					1		4
11	0	0	0	0					1		0	31	0	0	0	0	1						0
12	0	1	0	0							0	32	0	0	0	0					1		0
13	0	0	0	0				1			0	33	0	1	0	0							0
14	0	0	0	0			1				0	34	0	0	0	1							2
15	0	0	0	0						1	3	35	0	0	0	0	1						0
16	0	0	0	0						1	0	36	0	0	0	1							0
17	0	0	0	1							10	37	0	0	0	1							0
18	1	0	0	0							0	38	0	0	0	0	1						9
19	0	0	0	0		1					0	39	0	0	0	0	1						8
20	0	0	0	0		1					0	40	0	0	0	1							0
Sum	1	2	0	2	3	3	1	3	2	2		*Sum*	2	3	0	4	7	1	1	0	2	0	
Total	DC	RC	PAP	CP	Gov	Inv	EU	SC	BO	Des	*Sum*												
	3	5	0	6	10	4	2	3	4	2	39												
%	7.692	12.82	0	15.38	25.64	10.26	5.128	7.692	10.26	5.128	100												

Table D10: Perception of responsible actors, interviewee PAP2

Branch	Concrete producers	Codename	CP1
Company		Location	
Interviewee		Date and time	

Perceived change nr.	DC	RC	PAP	CP	Inv	Gov	Con	IP	Rank	Perceived change nr.	DC	RC	PAP	CP	Inv	Gov	Con	IP	Rank
1					1					21					1				
2						1				22						1			
3				1					7	23		1							
4						1			4	24				1					9
5						1				25	1								
6				1						26						1			
7						1				27							1		6
8				1					10	28								1	
9						1				29								1	
10					1				3	30						1			
11						1				31						1			
12								1		32							1		1
13						1				33				1					
14							1		5	34				1					
15							1			35						1			
16							1			36				1					8
17							1			37							1		2
18		1								38								1	
19					1					39						1			
20	1									40							1		
Sum	1	1	0	3	3	7	4	1		*Sum*	1	1	0	4	1	6	4	3	

Total	DC	RC	PAP	CP	Inv	Gov	Con	IP	*Sum*
	2	2	0	7	4	13	8	4	40
%	5	5	0	17.5	10	32.5	20	10	100

Table D11: Perception of responsible actors, interviewee CP1

Branch	Concrete producers	Codename	CP2
Company		Location	
Interviewee		Date and time	

Perceived change nr.	DC	RC	PAP	CP	Sci	Inv	Gov	IP	Des	Con	Rank	Perceived change nr.	DC	RC	PAP	CP	Sci	Inv	Gov	IP	Des	Con	Rank
1					1							21						1					
2						1						22		1									
3		1										23					1						
4							1					24							1				
5		1										25						1					
6				1								26							1				
7		1										27		1									
8				1								28		1									
9					1							29				1							
10								1				30							1				
11								1				31							1				
12							1					32				1							
13						1						33		1									
14		1										34		1									
15									1			35							1				
16						1						36				1							
17						1						37										1	
18	1											38							1				
19						1						39							1				
20						1						40						1					
Sum	1	4	0	2	2	6	2	2	1	0		*Sum*	0	5	0	3	1	3	7	0	0	1	

Total	DC	RC	PAP	CP	Sci	Inv	Gov	IP	Des	Con	*Sum*
	1	9	0	5	3	9	9	2	1	1	40
%	2.5	22.5	0	12.5	7.5	22.5	22.5	5	2.5	2.5	100

Table D12: Perception of responsible actors, interviewee CP2

Branch	Concrete producers										Codename	CP3								
Company											Location									
Interviewee											Date and time									
Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	RB	Ind	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Inv	RB	Ind	Rank
1					1						21							1			
2					1					1	22	1									9
3					1						23		1								
4						1					24	1									
5					1						25				1						
6						1					26					1					
7					1						27									1	
8				1							28					1					
9							1				29						1				
10					1					5	30					1					10
11					1					6	31					1					8
12						1					32					1					7
13					1						33		1								
14								1			34				1						
15							1			3	35					1					
16				1						4	36				1						
17							1			2	37							1			
18							1				38		1								
19							1				39					1					
20						1					40							1			
Sum	0	0	0	2	8	4	5	1	0		*Sum*	2	3	0	3	7	1	3	0	1	

Total	DC	RC	PAP	CP	Gov	SC	Inv	RB	Ind	*Sum*
	2	3	0	5	15	5	8	1	1	40
%	5	7.5	0	12.5	37.5	12.5	20	2.5	2.5	100

Table D13: Perception of responsible actors, interviewee CP3

Branch	Concrete producers									Codename	CP4								
Company										Location									
Interviewee										Date and time									
Perceived change nr.	DC	RC	PAP	CP	Gov	Ban	SC	Inv	Rank	Perceived change nr.	DC	RC	PAP	CP	Gov	Ban	SC	Inv	Rank
1					1					21								1	
2						1				22									8
3							1			23				1					
4										24					1				
5							1			25	1								
6					1				1	26					1				4
7										27							1		
8				1					5	28					1				
9					1					29					1				
10					1					30									
11					1				3	31								1	
12				1						32					1				
13					1					33					1				
14							1			34		1							
15				1					6	35					1				
16					1				2	36									
17				1					7	37								1	
18	1									38								1	
19								1		39								1	
20								1		40				1					
Sum	1	0	0	4	7	1	3	2		*Sum*	1	1	0	2	7	1	1	4	

Total	DC	RC	PAP	CP	Gov	Ban	SC	Inv	*Sum*
	2	1	0	6	14	2	4	6	35
%	5.714	2.857	0	17.14	40	5.714	11.43	17.14	100

Table D14: Perception of responsible actors, interviewee CP4

Appendix E – aggregated perceptions on branch level and normalization

Demolition companies

Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Des	Inv	Con	EU	BO	IP	Sci	Total
1	0	0	0	0	1	2	0	1	0	0	0	0	0	4
2	0	0	0	0	0	3	0	0	0	1	0	0	0	4
3	0	0	0	0	0	2	0	0	0	1	0	0	0	3
4	0	0	0	0	0	4	0	0	0	0	0	0	0	4
5	0	0	0	0	2	2	0	0	0	0	0	0	0	4
6	0	0	0	0	0	3	0	0	0	0	0	0	1	4
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	1	1	0	1	0	0	1	0	0	0	4
9	2	0	0	0	1	1	0	0	0	0	0	0	0	4
10	0	0	0	0	3	1	0	0	0	0	0	0	0	4
11	1	0	0	0	1	0	0	1	0	0	0	1	0	4
12	1	1	0	0	0	2	0	0	0	0	0	0	0	4
13	0	1	0	0	0	3	0	0	0	0	0	0	0	4
14	0	0	0	1	1	0	0	0	0	1	0	0	0	3
15	0	0	0	0	1	1	1	0	0	0	0	1	0	4
16	0	0	0	0	0	1	3	0	0	0	0	0	0	4
17	0	0	0	0	0	0	4	0	0	0	0	0	0	4
18	3	0	0	0	0	0	0	1	0	0	0	0	0	4
19	0	0	0	0	2	0	0	1	0	0	0	0	0	3
20	1	0	0	0	1	0	0	2	0	0	0	0	0	4
21	2	0	0	0	2	0	0	0	0	0	0	0	0	4
22	3	0	0	0	0	1	0	0	0	0	0	0	0	4
23	0	1	0	0	0	3	0	0	0	0	0	0	0	4
24	0	0	0	0	1	2	0	1	0	0	0	0	0	4
25	0	0	0	0	0	3	0	1	0	0	0	0	0	4
26	0	0	0	0	4	0	0	0	0	0	0	0	0	4
27	1	0	0	0	0	3	0	0	0	0	0	0	0	4
28	0	0	0	0	2	2	0	0	0	0	0	0	0	4
29	0	1	0	0	1	2	0	0	0	0	0	0	0	4
30	0	0	0	0	2	1	0	0	0	0	1	0	0	4
31	0	0	0	0	3	1	0	0	0	0	0	0	0	4
32	0	0	0	0	2	0	1	0	0	0	0	0	0	3
33	0	2	0	1	0	1	0	0	0	0	0	0	0	4
34	0	1	0	1	2	0	0	0	0	0	0	0	0	4
35	0	0	0	0	4	0	0	0	0	0	0	0	0	4
36	0	1	0	0	0	2	1	0	0	0	0	0	0	4
37	0	0	0	1	0	2	0	0	1	0	0	0	0	4
38	2	0	0	0	1	0	1	0	0	0	0	0	0	4
39	0	0	0	0	1	1	1	0	1	0	0	0	0	4
40	0	0	0	0	0	1	1	2	0	0	0	0	0	4
Total	DC	RC	PAP	CP	Gov	SC	Des	Inv	Con	EU	BO	IP	Sci	Total
Sum	16	8	0	5	39	50	14	10	2	4	1	2	1	152
%	10.53	5.26	0.00	3.29	25.66	32.89	9.21	6.58	1.32	2.63	0.66	1.32	0.66	100

Perceived change nr.	DC	RC	PAP	CP	Gov	SC	Des	Inv	Con	EU	BO	IP	Sci	Total
1	0	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0	1
2	0	0	0	0	0	0.75	0	0	0	0.25	0	0	0	1
3	0	0	0	0	0	0.667	0	0	0	0.333	0	0	0	1
4	0	0	0	0	0	1	0	0	0	0	0	0	0	1
5	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0.75	0	0	0	0	0	0	0.25	1
7														0
8	0	0	0	0.25	0.25	0	0.25	0	0	0.25	0	0	0	1
9	0.5	0	0	0	0.25	0.25	0	0	0	0	0	0	0	1
10	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	1
11	0.25	0	0	0	0.25	0	0	0.25	0	0	0	0.25	0	1
12	0.25	0.25	0	0	0	0.5	0	0	0	0	0	0	0	1
13	0	0.25	0	0	0	0.75	0	0	0	0	0	0	0	1
14	0	0	0	0.333	0.333	0	0	0	0	0.333	0	0	0	1
15	0	0	0	0	0.25	0.25	0.25	0	0	0	0	0.25	0	1
16	0	0	0	0	0	0.25	0.75	0	0	0	0	0	0	1
17	0	0	0	0	0	0	1	0	0	0	0	0	0	1
18	0.75	0	0	0	0	0	0	0.25	0	0	0	0	0	1
19	0	0	0	0	0.667	0	0	0.333	0	0	0	0	0	1
20	0.25	0	0	0	0.25	0	0	0.5	0	0	0	0	0	1
21	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	1
22	0.75	0	0	0	0	0.25	0	0	0	0	0	0	0	1
23	0	0.25	0	0	0	0.75	0	0	0	0	0	0	0	1
24	0	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0	1
25	0	0	0	0	0	0.75	0	0.25	0	0	0	0	0	1
26	0	0	0	0	1	0	0	0	0	0	0	0	0	1
27	0.25	0	0	0	0	0.75	0	0	0	0	0	0	0	1
28	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	1
29	0	0.25	0	0	0.25	0.5	0	0	0	0	0	0	0	1
30	0	0	0	0	0.5	0.25	0	0	0	0	0.25	0	0	1
31	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	1
32	0	0	0	0	0.667	0	0.333	0	0	0	0	0	0	1
33	0	0.5	0	0.25	0	0.25	0	0	0	0	0	0	0	1
34	0	0.25	0	0.25	0.5	0	0	0	0	0	0	0	0	1
35	0	0	0	0	1	0	0	0	0	0	0	0	0	1
36	0	0.25	0	0	0	0.5	0.25	0	0	0	0	0	0	1
37	0	0	0	0.25	0	0.5	0	0	0.25	0	0	0	0	1
38	0.5	0	0	0	0.25	0	0.25	0	0	0	0	0	0	1
39	0	0	0	0	0.25	0.25	0.25	0	0.25	0	0	0	0	1
40	0	0	0	0	0	0.25	0.25	0.5	0	0	0	0	0	1
Total	DC	RC	PAP	CP	Gov	SC	Des	Inv	Con	EU	BO	IP	Sci	Sum
Sum	4.00	2.00	0.00	1.33	10.17	12.67	3.58	2.58	0.50	1.17	0.25	0.50	0.25	39
%	10.26	5.13	0.00	3.42	26.07	32.48	9.19	6.62	1.28	2.99	0.64	1.28	0.64	100

Figure E1: Responsibility aggregated on a demolition companies' branch level, before (left) and after (right) the normalization

Recycling companies

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	Con	SC	Des	IP	IC	Sci	CC	EU	BO	Total
1	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	4
2	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	4
3	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	4
4	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	4
5	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	4
6	0	1	0	0	1	0	0	1	0	0	0	1	0	0	0	4
7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
8	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	3
9	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
10	0	0	0	0	2	0	0	0	0	1	0	0	0	1	0	4
11	0	0	0	0	1	0	0	1	0	2	0	0	0	0	0	4
12	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	3
13	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	4
14	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
15	0	0	0	0	2	0	1	0	1	0	0	0	0	0	0	4
16	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0	4
17	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	4
18	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	4
20	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	4
21	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	4
22	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3
23	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	4
24	0	1	0	0	0	1	0	1	0	0	0	0	0	0	1	4
25	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4
26	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
27	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	4
28	1	0	0	0	1	0	0	1	0	0	0	0	0	1	0	4
29	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	4
30	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	3
31	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4
32	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	4
33	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	4
34	0	0	0	1	2	0	0	0	0	0	0	0	0	1	0	4
35	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
36	0	1	0	2	0	1	0	0	0	0	0	0	0	0	0	4
37	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	4
38	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	4
39	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	3
40	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	4
Total	DC	RC	PAP	CP	Gov	Inv	Con	SC	Des	IP	IC	Sci	CC	EU	BO	Total
Sum	10	18	0	9	60	14	7	12	3	5	4	2	1	3	1	149
%	6.71	12.08	0.00	6.04	40.27	9.40	4.70	8.05	2.01	3.36	2.68	1.34	0.67	2.01	0.67	100

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	Con	SC	Des	IP	IC	Sci	CC	EU	BO	Total
1	0	0.25	0	0	0.75	0	0	0	0	0	0	0	0	0	0	1
2	0	0.25	0	0	0.75	0	0	0	0	0	0	0	0	0	0	1
3	0	0.25	0	0	0.5	0.25	0	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	0	1
5	0	0	0	0	0.75	0	0	0.25	0	0	0	0	0	0	0	1
6	0	0.25	0	0	0.25	0	0	0.25	0	0	0	0.25	0	0	0	1
7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
8	0	0	0	0.333	0.333	0	0	0	0	0.333	0	0	0	0	0	1
9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
10	0	0	0	0	0.5	0	0	0	0	0.25	0	0	0	0.25	0	1
11	0	0	0	0	0.25	0	0	0.25	0	0.5	0	0	0	0	0	1
12	0	0.333	0	0	0.333	0	0	0	0	0	0	0	0.333	0	0	1
13	0	0.25	0	0	0.5	0	0.25	0	0	0	0	0	0	0	0	1
14	0	0	0	0.5	0	0	0	0	0	0.5	0	0	0	0	0	1
15	0	0	0	0	0.5	0	0.25	0	0.25	0	0	0	0	0	0	1
16	0	0	0	0	0	0.25	0.5	0	0	0	0	0.25	0	0	0	1
17	0	0	0	0	0	0.5	0.25	0	0.25	0	0	0	0	0	0	1
18	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	1
20	0.25	0	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	1
22	0.333	0	0	0	0.333	0.333	0	0	0	0	0	0	0	0	0	1
23	0	0.75	0	0	0	0	0	0	0	0	0.25	0	0	0	0	1
24	0	0.25	0	0	0	0.25	0	0.25	0	0	0	0	0	0	0.25	1
25	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	1
26	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
27	0	0.25	0	0	0.25	0	0	0.25	0	0	0.25	0	0	0	0	1
28	0.25	0	0	0	0.25	0	0	0.25	0	0	0	0	0	0.25	0	1
29	0	0.25	0	0	0.75	0	0	0	0	0	0	0	0	0	0	1
30	0	0	0	0	0.667	0	0	0	0	0	0.333	0	0	0	0	1
31	0	0.25	0	0.25	0.25	0	0	0.25	0	0	0	0	0	0	0	1
32	0	0.25	0	0	0.5	0.25	0	0	0	0	0	0	0	0	0	1
33	0.25	0.25	0	0	0	0.25	0	0	0	0	0.25	0	0	0	0	1
34	0	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0.25	0	1
35	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
36	0	0.25	0	0.5	0	0.25	0	0	0	0	0	0	0	0	0	1
37	0	0.25	0	0.25	0	0	0.25	0.25	0	0	0	0	0	0	0	1
38	0.25	0	0	0	0.75	0	0	0	0	0	0	0	0	0	0	1
39	0	0	0	0	0.333	0.333	0	0.333	0	0	0	0	0	0	0	1
40	0	0	0	0.25	0	0	0.25	0.25	0.25	0	0	0	0	0	0	1
Total	DC	RC	PAP	CP	Gov	Inv	Con	SC	Des	IP	IC	Sci	CC	EU	BO	Sum
Sum	2.58	4.58	0.00	3.33	15.75	3.67	1.75	3.08	0.75	1.58	1.08	0.50	0.33	0.75	0.25	40.00
%	6.46	11.46	0.00	8.33	39.38	9.17	4.38	7.71	1.88	3.96	2.71	1.25	0.83	1.88	0.63	100

Figure E2: Responsibility aggregated on a recycling companies' branch level, before (left) and after (right) the normalization

Primary aggregates producers

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	EU	BO	Total
1	0	0	0	0	0	0	1	0	0	0	1	2
2	0	0	0	0	2	0	0	0	0	0	0	2
3	0	0	0	0	1	0	1	0	0	0	0	2
4	0	0	0	0	1	0	1	0	0	0	0	2
5	0	0	0	0	1	0	1	0	0	0	0	2
6	0	0	0	0	0	0	2	0	0	0	0	2
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	2	0	0	0	0	0	0	0	2
9	0	1	0	0	1	0	0	0	0	0	0	2
10	1	0	0	0	0	1	0	0	0	0	0	2
11	0	0	0	0	0	0	1	0	0	0	1	2
12	0	1	0	0	0	0	0	0	1	0	0	2
13	0	1	0	0	0	0	1	0	0	0	0	2
14	0	0	0	1	0	0	0	0	0	1	0	2
15	0	0	0	0	0	0	0	2	0	0	0	2
16	0	0	0	1	0	0	0	1	0	0	0	2
17	0	0	0	1	0	0	0	1	0	0	0	2
18	2	0	0	0	0	0	0	0	0	0	0	2
19	0	0	0	0	1	1	0	0	0	0	0	2
20	0	0	0	0	1	1	0	0	0	0	0	2
21	2	0	0	0	0	0	0	0	0	0	0	2
22	1	0	0	0	0	1	0	0	0	0	0	2
23	0	2	0	0	0	0	0	0	0	0	0	2
24	0	0	0	0	1	0	0	0	0	1	0	2
25	1	0	0	0	0	1	0	0	0	0	0	2
26	0	0	0	0	2	0	0	0	0	0	0	2
27	0	1	0	0	0	0	1	0	0	0	0	2
28	0	0	0	0	1	0	1	0	0	0	0	2
29	0	0	0	0	1	0	1	0	0	0	0	2
30	0	0	0	0	0	0	0	0	0	0	1	1
31	0	0	0	0	2	0	0	0	0	0	0	2
32	0	0	0	0	0	0	1	0	0	0	1	2
33	0	1	0	0	1	0	0	0	0	0	0	2
34	0	0	0	2	0	0	0	0	0	0	0	2
35	0	0	0	0	2	0	0	0	0	0	0	2
36	0	0	0	2	0	0	0	0	0	0	0	2
37	0	0	0	1	0	1	0	0	0	0	0	2
38	1	0	0	0	1	0	0	0	0	0	0	2
39	0	0	0	0	2	0	0	0	0	0	0	2
40	0	0	0	1	0	0	1	0	0	0	0	2
Total	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	EU	BO	Total
Sum	8	7	0	11	21	6	13	4	1	2	4	77
%	10.39	9.09	0.00	14.29	27.27	7.79	16.88	5.19	1.30	2.60	5.19	100

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	EU	BO	Total
1	0	0	0	0	0	0	0.5	0	0	0	0.5	1
2	0	0	0	0	1	0	0	0	0	0	0	1
3	0	0	0	0	0.5	0	0.5	0	0	0	0	1
4	0	0	0	0	0.5	0	0.5	0	0	0	0	1
5	0	0	0	0	0.5	0	0.5	0	0	0	0	1
6	0	0	0	0	0	0	1	0	0	0	0	1
7												0
8	0	0	0	1	0	0	0	0	0	0	0	1
9	0	0.5	0	0	0.5	0	0	0	0	0	0	1
10	0.5	0	0	0	0	0.5	0	0	0	0	0	1
11	0	0	0	0	0	0	0.5	0	0	0	0.5	1
12	0	0.5	0	0	0	0	0	0	0.5	0	0	1
13	0	0.5	0	0	0	0	0.5	0	0	0	0	1
14	0	0	0	0.5	0	0	0	0	0	0.5	0	1
15	0	0	0	0	0	0	0	1	0	0	0	1
16	0	0	0	0.5	0	0	0	0.5	0	0	0	1
17	0	0	0	0.5	0	0	0	0.5	0	0	0	1
18	1	0	0	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0.5	0.5	0	0	0	0	0	1
20	0	0	0	0	0.5	0.5	0	0	0	0	0	1
21	1	0	0	0	0	0	0	0	0	0	0	1
22	0.5	0	0	0	0	0.5	0	0	0	0	0	1
23	0	1	0	0	0	0	0	0	0	0	0	1
24	0	0	0	0	0.5	0	0	0	0	0.5	0	1
25	0.5	0	0	0	0	0.5	0	0	0	0	0	1
26	0	0	0	0	1	0	0	0	0	0	0	1
27	0	0.5	0	0	0	0	0.5	0	0	0	0	1
28	0	0	0	0	0.5	0	0.5	0	0	0	0	1
29	0	0	0	0	0.5	0	0.5	0	0	0	0	1
30	0	0	0	0	0	0	0	0	0	0	1	1
31	0	0	0	0	1	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0.5	0	0	0	0.5	1
33	0	0.5	0	0	0.5	0	0	0	0	0	0	1
34	0	0	0	1	0	0	0	0	0	0	0	1
35	0	0	0	0	1	0	0	0	0	0	0	1
36	0	0	0	1	0	0	0	0	0	0	0	1
37	0	0	0	0.5	0	0.5	0	0	0	0	0	1
38	0.5	0	0	0	0.5	0	0	0	0	0	0	1
39	0	0	0	0	1	0	0	0	0	0	0	1
40	0	0	0	0.5	0	0	0.5	0	0	0	0	1
Total	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	EU	BO	Sum
Sum	4.00	3.50	0.00	5.50	10.50	3.00	6.50	2.00	0.50	1.00	2.50	39
%	10.26	8.97	0.00	14.10	26.92	7.69	16.67	5.13	1.28	2.56	6.41	100

Figure E3: Responsibility aggregated on a primary aggregates producers' branch level, before (left) and after (right) the normalization

Concrete producers

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	Con	IP	SC	Sci	Des	RB	Ind	Ban	Total
1	0	0	0	0	2	1	0	0	0	1	0	0	0	0	4
2	0	0	0	0	2	1	0	0	0	0	0	0	0	1	4
3	0	1	0	1	1	0	0	0	1	0	0	0	0	0	4
4	0	0	0	0	2	0	0	0	1	0	0	0	0	0	3
5	0	1	0	0	2	0	0	0	1	0	0	0	0	0	4
6	0	0	0	2	1	0	0	0	1	0	0	0	0	0	4
7	0	1	0	0	2	0	0	0	0	0	0	0	0	0	3
8	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
9	0	0	0	0	2	1	0	0	0	1	0	0	0	0	4
10	0	0	0	0	2	1	0	1	0	0	0	0	0	0	4
11	0	0	0	0	3	0	0	1	0	0	0	0	0	0	4
12	0	0	0	1	1	0	0	1	1	0	0	0	0	0	4
13	0	0	0	0	3	1	0	0	0	0	0	0	0	0	4
14	0	1	0	0	0	0	1	0	1	0	0	1	0	0	4
15	0	0	0	1	0	1	1	0	0	0	1	0	0	0	4
16	0	0	0	1	1	1	1	0	0	0	0	0	0	0	4
17	0	0	0	1	0	2	1	0	0	0	0	0	0	0	4
18	2	1	0	0	0	1	0	0	0	0	0	0	0	0	4
19	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
20	1	0	0	0	0	2	0	0	1	0	0	0	0	0	4
21	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
22	1	1	0	0	1	0	0	0	0	0	0	0	0	0	3
23	0	2	0	1	0	0	0	0	0	1	0	0	0	0	4
24	1	0	0	1	2	0	0	0	0	0	0	0	0	0	4
25	2	0	0	1	0	1	0	0	0	0	0	0	0	0	4
26	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
27	0	1	0	0	0	0	1	0	0	0	0	0	1	1	4
28	0	1	0	0	2	0	0	1	0	0	0	0	0	0	4
29	0	0	0	1	1	0	0	1	1	0	0	0	0	0	4
30	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
31	0	0	0	0	3	0	0	0	1	0	0	0	0	0	4
32	0	0	0	1	2	0	1	0	0	0	0	0	0	0	4
33	0	2	0	1	1	0	0	0	0	0	0	0	0	0	4
34	0	2	0	2	0	0	0	0	0	0	0	0	0	0	4
35	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
36	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
37	0	0	0	0	0	2	2	0	0	0	0	0	0	0	4
38	0	1	0	0	1	1	0	1	0	0	0	0	0	0	4
39	0	0	0	0	3	1	0	0	0	0	0	0	0	0	4
40	0	0	0	1	0	2	1	0	0	0	0	0	0	0	4
Total	DC	RC	PAP	CP	Gov	Inv	Con	IP	SC	Sci	Des	RB	Ind	Ban	Total
Sum	7	15	0	23	51	27	9	6	9	3	1	1	1	2	155
%	4.52	9.68	0.00	14.84	32.90	17.42	5.81	3.87	5.81	1.94	0.65	0.65	0.65	1.29	100

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	Con	IP	SC	Sci	Des	RB	Ind	Ban	Total
1	0	0	0	0	0.5	0.25	0	0	0	0.25	0	0	0	0	1
2	0	0	0	0	0.5	0.25	0	0	0	0	0	0	0	0.25	1
3	0	0.25	0	0.25	0.25	0	0	0	0.25	0	0	0	0	0	1
4	0	0	0	0	0.667	0	0	0	0.333	0	0	0	0	0	1
5	0	0.25	0	0	0.5	0	0	0	0.25	0	0	0	0	0	1
6	0	0	0	0.5	0.25	0	0	0	0.25	0	0	0	0	0	1
7	0	0.333	0	0	0.667	0	0	0	0	0	0	0	0	0	1
8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0.5	0.25	0	0	0	0.25	0	0	0	0	1
10	0	0	0	0	0.5	0.25	0	0.25	0	0	0	0	0	0	1
11	0	0	0	0	0.75	0	0	0.25	0	0	0	0	0	0	1
12	0	0	0	0.25	0.25	0	0	0.25	0.25	0	0	0	0	0	1
13	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	1
14	0	0.25	0	0	0	0	0.25	0	0.25	0	0	0.25	0	0	1
15	0	0	0	0.25	0	0.25	0.25	0	0	0	0.25	0	0	0	1
16	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	1
17	0	0	0	0.25	0	0.5	0.25	0	0	0	0	0	0	0	1
18	0.5	0.25	0	0	0	0.25	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
20	0.25	0	0	0	0	0.5	0	0	0.25	0	0	0	0	0	1
21	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
22	0.333	0.333	0	0	0.333	0	0	0	0	0	0	0	0	0	1
23	0	0.5	0	0.25	0	0	0	0	0	0.25	0	0	0	0	1
24	0.25	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0	1
25	0.5	0	0	0.25	0	0.25	0	0	0	0	0	0	0	0	1
26	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
27	0	0.25	0	0	0	0	0.25	0	0	0	0	0	0.25	0.25	1
28	0	0.25	0	0	0.5	0	0	0.25	0	0	0	0	0	0	1
29	0	0	0	0.25	0.25	0	0	0.25	0.25	0	0	0	0	0	1
30	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
31	0	0	0	0	0.75	0	0	0	0.25	0	0	0	0	0	1
32	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0	0	0	1
33	0	0.5	0	0.25	0.25	0	0	0	0	0	0	0	0	0	1
34	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	1
35	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
36	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
37	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	1
38	0	0.25	0	0	0.25	0.25	0	0.25	0	0	0	0	0	0	1
39	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	1
40	0	0	0	0.25	0	0.5	0.25	0	0	0	0	0	0	0	1
Total	DC	RC	PAP	CP	Gov	Inv	Con	IP	SC	Sci	Des	RB	Ind	Ban	Sum
Sum	1.83	3.92	0.00	6.00	13.42	6.75	2.25	1.50	2.33	0.75	0.25	0.25	0.25	0.50	40
%	4.58	9.79	0.00	15.00	33.54	16.88	5.63	3.75	5.83	1.88	0.63	0.63	0.63	1.25	100

Figure E4: Responsibility aggregated on a concrete producers' branch level, before (left) and after (right) the normalization

Appendix F – aggregated perceptions on the level of the stony materials supply chain

Perceived change nr.	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	Sci	EU	BO	RB	Ind	Ban	IC	CC	Total
1	0	0.25	0	0	1.5	0.5	1	0	0	0	0.25	0	0.5	0	0	0	0	0	4
2	0	0.25	0	0	2.25	0.25	0.75	0	0	0	0	0.25	0	0	0	0.25	0	0	4
3	0	0.5	0	0.25	1.25	0.25	1.42	0	0	0	0	0.33	0	0	0	0	0	0	4
4	0	0	0	0	1.67	0	2.33	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0.25	0	0	2.25	0	1.5	0	0	0	0	0	0	0	0	0	0	0	4
6	0	0.25	0	0.5	0.5	0	2.25	0	0	0	0.5	0	0	0	0	0	0	0	4
7	0	0.33	0	1	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	2
8	0	0	0	2.58	0.58	0	0	0.25	0.33	0	0	0.25	0	0	0	0	0	0	4
9	0.5	0.5	0	0	2.25	0.25	0.25	0	0	0	0.25	0	0	0	0	0	0	0	4
10	0.5	0	0	0	1.75	0.75	0.25	0	0.5	0	0	0.25	0	0	0	0	0	0	4
11	0.25	0	0	0	1.25	0.25	0.75	0	1	0	0	0	0.5	0	0	0	0	0	4
12	0.25	1.08	0	0.25	0.58	0	0.75	0	0.75	0	0	0	0	0	0	0	0	0.33	4
13	0	1	0	0	1.25	0.25	1.25	0	0	0.25	0	0	0	0	0	0	0	0	4
14	0	0.25	0	1.33	0.33	0	0.25	0	0.5	0.25	0	0.83	0	0.25	0	0	0	0	4
15	0	0	0	0.25	0.75	0.25	0.25	1.75	0.25	0.5	0	0	0	0	0	0	0	0	4
16	0	0	0	0.75	0.25	0.5	0.25	1.25	0	0.75	0.25	0	0	0	0	0	0	0	4
17	0	0	0	0.75	0	1	0	1.75	0	0.5	0	0	0	0	0	0	0	0	4
18	3	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0	0	0	1.92	2.08	0	0	0	0	0	0	0	0	0	0	0	0	4
20	0.75	0	0	0	1	2	0.25	0	0	0	0	0	0	0	0	0	0	0	4
21	1.5	0	0	0	1.25	1.25	0	0	0	0	0	0	0	0	0	0	0	0	4
22	1.92	0.33	0	0	0.67	0.83	0.25	0	0	0	0	0	0	0	0	0	0	0	4
23	0	2.5	0	0.25	0	0	0.75	0	0	0	0.25	0	0	0	0	0	0.25	0	4
24	0.25	0.25	0	0.25	1.25	0.5	0.75	0	0	0	0	0.5	0.25	0	0	0	0	0	4
25	1.5	0	0	0.25	0.5	1	0.75	0	0	0	0	0	0	0	0	0	0	0	4
26	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
27	0.25	1	0	0	0.25	0	1.5	0	0	0.25	0	0	0	0	0.25	0.25	0.25	0	4
28	0.25	0.25	0	0	1.75	0	1.25	0	0.25	0	0	0.25	0	0	0	0	0	0	4
29	0	0.5	0	0.25	1.75	0	1.25	0	0.25	0	0	0	0	0	0	0	0	0	4
30	0	0	0	0	2.17	0	0.25	0	0	0	0	0	1.25	0	0	0	0.33	0	4
31	0	0.25	0	0.25	2.75	0	0.75	0	0	0	0	0	0	0	0	0	0	0	4
32	0	0.25	0	0.25	1.67	0.25	0.5	0.33	0	0.25	0	0	0.5	0	0	0	0	0	4
33	0.25	1.75	0	0.5	0.75	0.25	0.25	0	0	0	0	0	0	0	0	0	0.25	0	4
34	0	0.75	0	2	1	0	0	0	0	0	0	0.25	0	0	0	0	0	0	4
35	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
36	0	0.5	0	2.5	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	4
37	0	0.25	0	1	0	1	0.75	0	0	1	0	0	0	0	0	0	0	0	4
38	1.25	0.25	0	0	1.75	0.25	0	0.25	0.25	0	0	0	0	0	0	0	0	0	4
39	0	0	0	0	2.33	0.58	0.58	0.25	0	0.25	0	0	0	0	0	0	0	0	4
40	0	0	0	1	0	1	1	0.5	0	0.5	0	0	0	0	0	0	0	0	4
Total	DC	RC	PAP	CP	Gov	Inv	SC	Des	IP	Con	Sci	EU	BO	RB	Ind	Ban	IC	CC	Total
Sum	12.4	14	0	16.2	49.8	16	24.6	6.58	4.08	4.5	1.5	2.92	3	0.25	0.25	0.5	1.08	0.33	158
%	7.86	8.86	0.00	10.23	31.54	10.13	15.56	4.17	2.58	2.85	0.95	1.85	1.90	0.16	0.16	0.32	0.69	0.21	100

Figure F1: perceptions of responsibility aggregated on the stony materials supply chain level

Appendix G – perceptions of importance of changes

Final rank	SC		DC		RC		PAP		CP	
	Nr.	Change	Nr.	Change	Nr.	Change	Nr.	Change	Nr.	Change
1	23	New recycling technologies	26	Law on circular economy	23	New recycling technologies	34	No to "dirty" aggregates	15	Plan and design for future
2	26	Law on circular economy	35	No laws stimulating import of secondary	9	Ladder of Lansink	2	Formulating circular economy	22	New role of demolition companies
3	15	Plan and design for future	39	Material passports	10	Reuse/recycling in the LCA	28	Aligning theory, perceptions and reality	6	Conducting research across the supply chain
4	34	No to "dirty" aggregates	23	New recycling technologies	27	Circular business models	31	Gap between secondary and needed materials	32	Not reusing and recycling at any cost
5	17	Modular constructions	5	Raising awareness	26	Law on circular economy	15	Plan and design for future	16	Design for reassembly
6	39	Material passports	34	No to "dirty" aggregates	24	Fully transparent process	36	Allowing enough time for best choice	17	Modular constructions
7	27	Circular business models	22	New role of demolition companies	21	Pre Demolition audit	29	Knowledge about circular economy	10	Reuse/recycling in the LCA
8	9	Ladder of Lansink	38	Urban mine database	12	Tool for best treatment	30	Relieving political pressure	11	New value indicators
9	10	Reuse/recycling in the LCA	21	Pre Demolition audit	17	Modular constructions	8	Standardization of products	27	Circular business models
10	22	New role of demolition companies	9	Ladder of Lansink	34	No to "dirty" aggregates	32	Not reusing and recycling at any cost	36	Optimum aggregate mix - taking everything into account
11	38	Urban mine database	18	Separation at the source	15	Plan and design for future	3	Real costs of transport	8	Standardization of products
12	8	Standardization of products	8	Standardization of products	37	Allowing enough time for best choice	26	Law on circular economy	1	New ways of appraising value
13	2	Formulating circular economy	15	Plan and design for future	39	Material passports	23	New recycling technologies	2	Formulating circular economy
14	32	Not reusing and recycling at any cost	2	Formulating circular economy	38	Urban mine database	24	Fully transparent process	18	Separation at the source
15	5	Raising awareness	27	Circular business models	16	Design for reassembly	5	Raising awareness	37	Allowing enough time for best choice
16	35	No laws stimulating import of secondary	19	Separation at the source and minimum amount of recycling in procurement procedure	18	Separation at the source	39	Material passports	23	New recycling technologies
17	24	Fully transparent process	28	Aligning theory, perceptions and reality	13	Roads as material banks	38	Urban mine database	4	Integration of the supply chain
18	18	Separation at the source	20	More time, space and money	33	Quality of rubble without concrete	17	Modular constructions	26	Law on circular economy
19	21	Pre Demolition audit	40	Build for product level reuse	4	Integration of the supply chain	35	No laws stimulating import of secondary	14	Different quality requirements
20	36	Allowing enough time for best choice	25	Adequate pricing for demolition companies	32	Not reusing and recycling at any cost	1	New ways of appraising value	29	Knowledge about circular economy

21	16	Design for reassembly	33	Quality of rubble without concrete	36	Optimum aggregate mix - taking everything into account	4	Integration of the supply chain	3	Real costs of transport
22	37	Allowing enough time for best choice	11	New value indicators	2	Formulating circular economy	6	Conducting research across the supply chain	31	Gap between secondary and needed materials
23	11	New value indicators	17	Modular constructions	1	New ways of appraising value	7	Geographical distribution	24	Fully transparent process
24	3	Real costs of transport	3	Real costs of transport	3	Real costs of transport	9	Ladder of Lansink	5	Raising awareness
25	28	Aligning theory, perceptions and reality	1	New ways of appraising value	5	Raising awareness	10	Reuse/recycling in the LCA	30	Relieving political pressure
26	6	Conducting research across the supply chain	4	Integration of the supply chain	6	Conducting research across the supply chain	11	New value indicators	7	Geographical distribution
27	31	Gap between secondary and needed materials	6	Conducting research across the supply chain	7	Geographical distribution	12	Tool for best treatment	9	Ladder of Lansink
28	12	Tool for best treatment	7	Geographical distribution	8	Standardization of products	13	Roads as material banks	12	Tool for best treatment
29	29	Knowledge about circular economy	10	Reuse/recycling in the LCA	11	New value indicators	14	Different quality requirements	13	Roads as material banks
30	4	Integration of the supply chain	12	Tool for best treatment	14	Different quality requirements	16	Design for reassembly	19	Separation at the source and minimum amount of recycling in procurement procedure
31	30	Relieving political pressure	13	Roads as material banks	19	Separation at the source and minimum amount of recycling in procurement procedure	18	Separation at the source	20	More time, space and money
32	33	Quality of rubble without concrete	14	Different quality requirements	20	More time, space and money	19	Separation at the source and minimum amount of recycling in procurement procedure	21	Pre Demolition audit
33	1	New ways of appraising value	16	Design for reassembly	22	New role of demolition companies	20	More time, space and money	25	Adequate pricing for demolition companies
34	14	Different quality requirements	24	Fully transparent process	25	Adequate pricing for demolition companies	21	Pre Demolition audit	28	Aligning theory, perceptions and reality
35	19	Separation at the source and minimum amount of recycling in procurement procedure	29	Knowledge about circular economy	28	Aligning theory, perceptions and reality	22	New role of demolition companies	33	Quality of rubble without concrete
36	20	More time, space and money	30	Relieving political pressure	29	Knowledge about circular economy	25	Adequate pricing for demolition companies	34	No to "dirty" aggregates
37	40	Build for product level reuse	31	Gap between secondary and needed materials	30	Relieving political pressure	27	Circular business models	35	No laws stimulating import of secondary
38	13	Roads as material banks	32	Not reusing and recycling at any cost	31	Gap between secondary and needed materials	33	Quality of rubble without concrete	38	Urban mine database
39	25	Adequate pricing for demolition companies	36	Allowing enough time for best choice	35	No laws stimulating import of secondary	37	Allowing enough time for best choice	39	Material passports
40	7	Geographical distribution	37	Allowing enough time for best choice	40	Build for product level reuse	40	Build for product level reuse	40	Build for product level reuse

Table G1: perceptions on importance of changes