



Market prospects of secondary construction aggregates in Sweden

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ABSTRACT

The transition towards a circular economy is being increasingly envisaged in Europe. Increased utilisation of secondary construction aggregates poses a great opportunity in this regard given its potential to avoid waste disposal, natural resource extraction, and reduce costs. Nevertheless, the Swedish construction aggregates market is dominantly characterised by primary aggregates utilisation. This study employs a qualitative approach to analyse the Swedish construction aggregates market from the user perspective in order to identify the challenges of increased utilisation of secondary aggregates. The dominant and systematic utilisation of primary aggregates is chiefly driven by market processes allowing economic advantages and convenience for the users in doing so, whereas the situational and non-systematic utilisation of secondary aggregates is opportunistically driven by different actors in order to seize opportunities such as avoided costs and improved environmental performance. The realisation of increased secondary aggregates utilisation needs to be first facilitated via changes to the institutional structure that makes such materials a priority issue for the supply chain actors, which necessitates national-level policy interventions and supply chain actor collaborations. Second, the competitiveness of secondary aggregates needs to be lifted to a comparable state to that of primary aggregates, which necessitates the development of specific sectoral application standards and vertical integration of secondary aggregates supply by construction corporations.

1. Introduction

The need for a circular economy, a strategy to restore the environmental and economic balance of industrial activity (Ghisellini et al., 2016), is becoming ever more important in today's societies. The European Union (EU) has officially announced its vision to become a recycling society in the long term (European Commission, 2005) and put forward many targets that abide its member states to improve their resource efficiencies. Yet, the current handling of materials in the region involves considerable losses of potential resources, especially in relation to the management of industrial residues (Material Economics, 2020).

Various industries related to production (e.g. steel and cement) as well as waste treatment (e.g. municipal waste incineration and end-of-life vehicle shredding) generate millions of tonnes of heterogeneous residues such as slag (Branca et al., 2020), bottom ash (Dou et al., 2017), and shredder residues (Vermeulen et al., 2011) in the European region. The material complexity and the small particle size render the resource recovery and recycling of such residues technically and economically challenging, and hence, they are often disposed of in landfills (ibid.). A

widely proposed potential solution to this disposal problem is to reutilise these residues as secondary aggregates in various construction-related applications such as filling, constructing foundation layers, and producing asphalt and concrete (ibid.). This solution, given the large scale of construction aggregates utilisation (European Aggregates Association, 2020), would provide an opportunity to reutilise large quantities of such residues. It would also avoid the environmental burdens of primary aggregates production such as groundwater depletion, land-use change, and climate impact (Miliutenko, 2009). Additionally, secondary aggregates utilisation could potentially reduce the cost of sourcing aggregates, which shares a significant portion of the total costs of construction projects (Sobotka et al., 2012).

In Sweden, the current utilisation of construction aggregates is dominated by primary materials, whereas sourcing secondary aggregates are apparently confined to construction and demolition (C&D) residues. Given the national circular economy strategy's specific focus on increased resource efficiency in the construction sector (Swedish Government Offices, 2020), a great need for increased secondary aggregates utilisation is soon expected. However, the current C&D residue

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reutilisation in the country already surpassed 70% several years ago (Jepsson and Nyberg, 2017), and the potential to further increase mostly lies with external industrial residues. Several countries in the region with similar socio-economic contexts to Sweden (e.g. Denmark, the Netherlands, Belgium, and Finland) have already adopted external industrial residues such as incineration bottom ash and steel slag in various construction applications (Branca et al., 2020; Dou et al., 2017). Yet, applications of construction aggregates derived from external industrial residue are currently quite limited in Sweden.

In order for secondary aggregate utilisation to increase in Sweden, such materials need to compete with and replace primary aggregates in a marketplace that has evolved and been established to facilitate the utilisation of the latter. That would necessitate in-depth knowledge on the processes and the underlying structures of the prevailing market (Desrochers, 2000) for construction aggregates. Previous studies have investigated the potential utilisation of different types of industrial residues such as municipal bottom ash (Lam et al., 2010), steel slag (Dhoble and Ahmed, 2018), shredder fines (Péra et al., 2004), and glass (Adhikary et al., 2021) as secondary aggregates in several of the aforementioned construction-related applications. However, such studies are chiefly focused on the technical aspects such as material compositions and mechanical properties pertaining to different applications, whereas the market context in which the technical solutions have to be developed and implemented remain unaddressed. A few studies have investigated the markets for secondary construction aggregates, yet they are chiefly confined to selected aspects related to market structures – that is, stakeholders and their roles (Mele et al., 2015) – such as supply and demand (Bertils and Elvingsson, 2019), user and regulatory requirements (Johansson et al., 2017), and policy instruments (Dubois et al., 2015). Such studies, on the one hand, fail to provide a cohesive overview of the market structure, whereas investigations on market processes – that is to say, actor actions and interactions (Mele et al., 2015) – are lacking on the other. The lack of knowledge concerning market processes, and market structures that facilitate them, which are crucial to understanding how a given market is organised (Aspers, 2009), renders initiating change towards increased secondary aggregates utilisation more difficult.

The overall aim of this study is to analyse the Swedish construction aggregates market in relation to main market processes and the underlying structures in order to facilitate changed practices and initiate increased utilisation of secondary aggregates. In doing so, the following research questions are addressed: Why are primary construction aggregates utilised to the extent they currently do? And: What conditions determine the utilisation of secondary construction aggregates?

2. Method

A qualitative empirical approach (Fig. 1) was employed to analyse the Swedish construction aggregates market. In accordance with the contemporary literature in the context of sustainability, the market was recognised as an integrated part of the wider socio-technical context, that is, actors, governing institutions, and interrelations between them (Geels, 2004; Margallo et al., 2015), where multiple actors contribute in creating and exchanging value (Ottosson et al., 2020). A qualitative approach was opted for as it could refer to meanings, descriptions, and characteristics (Bell et al., 2019) and thus capture how different actors perceive the market and act in it. Such knowledge is essential for assessing the market potential of secondary construction aggregates (Anderson and Dower, 1978). Semi-structured face-to-face interviews were deemed most appropriate to capture the idiosyncrasies and complex perceptions associated with the issue at question (Miles and Huberman, 1994). The collected data was thematically analysed, an approach that facilitates the aggregation of data scattered throughout the interviews and building a storyline. Based on these findings, the challenges of and possible measures for facilitating increased utilisation of secondary construction aggregates were discussed.

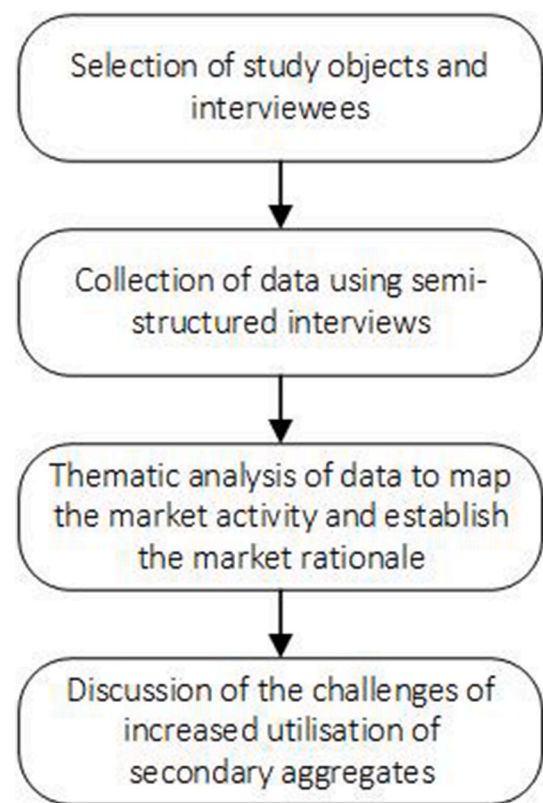


Fig. 1. Overall methodological approach of the study.

2.1. Selection of study objects and interviewees

The study focused chiefly on the perspective of the user (i.e. companies that purchase and utilise aggregates in different construction-related applications) because it is the most central actor in the aggregates supply chain and also has a prominent role in the selection of materials. Any changes towards an increased utilisation of secondary aggregates will thus have to be implemented by them. The users' perspective was also complemented with the customer (i.e. companies and organisations that order and own the completed construction) and supplier (i.e. companies that produce and sell construction aggregates) perspectives. The customer perspective was addressed particularly because the users' raw material choice for aggregates, in general, is presumably influenced by various aspects related to the customers' practices and requirements. The supplier perspective was addressed particularly because the users' material choice concerning secondary aggregates is most likely influenced by various aspects related to the quality and availability of such materials.

In addressing the user perspective, the three largest construction corporations in Sweden (PEAB, SKANSKA, and NCC) were selected because the large-scale and wide-spanned operations would make them have a vast amount of experience and knowledge and cover the possible variance regarding different market aspects. The corporations collectively account for 55% of the country's construction sector by turnover (Flanders Investment & Trade, 2019) and are operational throughout the country. Regarding construction-related applications, the main focus was put on ground constructions (such as filling, preparing foundation layers, and laying ballast), which account for the largest share of aggregates utilisation (Swedish Geological Survey, 2019). Asphalt production and concrete production were also considered as considerable amounts of aggregates are utilised in them (Jepsson and Nyberg, 2017). These three applications mostly occur as part of infrastructure constructions, whereas concrete production is also accounted for by building constructions. Consequently, three infrastructure constructors, one

asphalt producer, and one concrete producer that are subsidiaries of one of the aforementioned corporations were selected. In addressing the customer perspective, the Swedish Transport Administration (STA), which owns all the state roads and railways and is the largest customer for infrastructure projects in the country, was selected, as it would have the most profound influence on the users and could cover the possible variance regarding different projects. In addressing the supplier perspective, a major supplier, a subsidiary of one of the construction corporations mentioned above and also operational in all the regions of the country, was selected, as it would have wide experience and knowledge concerning the issues associated with sourcing different types of secondary raw materials. Regarding the interviews, regional managers were selected because they are responsible for large-scale and wide-spanned operations, and they would have a vast amount of experience and knowledge and cover the possible variance regarding different aspects.

2.2. Data collection

Empirical data were collected via semi-structured face-to-face interviews (interview guides are provided as supplementary material). The interviews were audio-recorded and lasted from 60 to 75 min. Follow-up interviews were held regarding further clarifications and additional information. Three interview guides were developed regarding the user, customer, and supplier perspectives (Table 1). The general structure of the interview guides targets three main aspects. The current practice regarding aggregate utilisation in terms of market processes and the formal institutions supporting them was chiefly addressed in order to establish how the market is organised today and identify what needs to be addressed to initiate change. Challenges of continuing the current practice were addressed to identify actor incentives and necessary conditions for change. Future developments regarding secondary aggregate utilisation were addressed to identify the drivers and barriers of change and the context in which change has to be implemented.

Questions targeting specific issues regarding the current market situation were added in order to gain further insights on the aforementioned general issues related to the different actors. Regarding users, the physical flows of aggregates were addressed to map the extent of market activity in terms of types and quantities of different aggregates supplied and utilised in different applications. The organisation of project procurement and aggregates sourcing were addressed to establish the factors creating motives for the current material choices and the supplier selection and purchasing, respectively. The questions also targeted the comparison between primary and secondary aggregates, as such a comparison is key in assessing the marketability of residue-derived resources (Lupton, 2017). Regarding customers, procurement was addressed given that the involved customer is a state-owned organisation, and that public procurement is governed by strict rules and practices, which could potentially influence the use of specific types of material in their infrastructure. Regarding suppliers, secondary

aggregates utilisation was addressed to complement the aforementioned material flows, because they are the ones mostly driving such initiatives. The production of secondary aggregates was addressed to establish the influence of the waste regulation, which has a profound influence on the Swedish waste reutilisation (Johansson, 2018).

2.3. Data analysis

The collected data were thematically analysed in accordance with the process of tagging (data reduction), theme development (data display), and interpretation (conclusion drawing) (Miles and Huberman, 1994), as illustrated in Fig. 2. The recorded interviews were transcribed and processed with tags, which represent a gross list of aspects of relevance and potential significance to the aggregates market, by referring to specific statements and information from the interview respondents (Bell et al., 2019). Subsequently, themes that represent implicit topics characterised by a group of tags (Patton, 2002) were formulated to identify factors related to material, actor, and institution-related aspects that could potentially influence the different market processes. Tagging was revisited iteratively as the themes were evolving until saturation was reached. A detailed overview of the themes and corresponding tags are provided as supplementary materials.

These themes were then interpreted to map the market activity and establish the market rationale. The market activity was mapped in terms of the current physical flows of aggregates across the supply chain, thereby providing a differentiated overview of the types and quantities of aggregates supplied and utilised in the selected applications and the share of such applications in public and private infrastructure. The data and information on the physical flows were obtained primarily from the interview respondents and complemented with secondary sources such as sectoral reports, for example, the Swedish Geological Survey (2019), and scientific literature, for example, Törnblom (2011) and Jepsen and Nyberg (2017). The objective of mapping the market activity was to provide a quantitative basis for establishing the market rationale.

The market rationale was established in terms of the users' motives for the utilisation of primary and secondary aggregates, created at the main market processes and the underlying market structures. Regarding market structures, special emphasis was laid upon different institutions, whereas other important aspects such as actor differentiation and competition levels (von Stackelberg, 2011) were addressed as necessary. That is because institutions are the playing rules that govern actor behaviour (Giddens, 1984) and, therefore, are key in explaining the market processes. Regarding institutions, the main focus was put on formal institutions such as policies, legislations, regulations, and agreements because they hold actors legally responsible and accountable for their actions (North, 1990), whereas informal institutions such as norms and habits that shape the practice of doing things (ibid.) were addressed as necessary. Given that institutional structures guide but do not necessarily decide market processes and recurring changed processes could re-shape these structures (Kjellberg and Helgesson, 2007), special emphasis was given to how the user motives are facilitated by

Table 1

Scope of the interviews. The targeted actor perspectives, selected actors and interview respondents, and interview focuses.

Targeted actor		Interview respondent	Responsibility	General structure of the interviews	Specific focus on the current situation
User	Infrastructure constructor	No. 1-3	Purchasing: Regional manager	<ul style="list-style-type: none"> Current practice regarding aggregate utilisation Challenges of continuing the current practice Future developments regarding secondary aggregate utilisation 	<ul style="list-style-type: none"> Physical flows of aggregates Organisation of project procurement Organisation of aggregates sourcing
	Asphalt producer	No. 4	Production: Regional manager		
	Concrete producer	No. 5	Production: Regional manager		
Customer		No. 6	Project manager: Regional		<ul style="list-style-type: none"> Organisation of project procurement
Supplier		No. 7	Recycling manager: Regional		<ul style="list-style-type: none"> Secondary aggregates utilisation Secondary aggregates supply

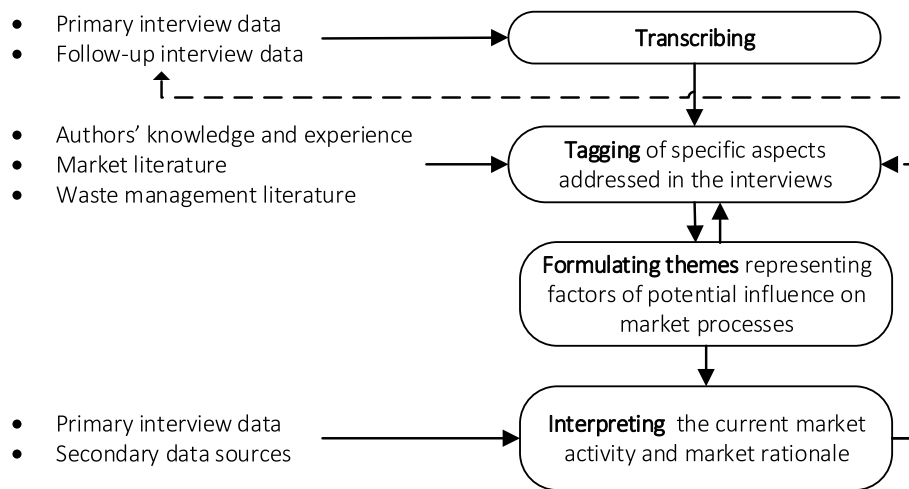


Fig. 2. The process of the data analysis.

different institutions occurring at the organisational, sectoral, and governmental levels. The analysis was performed chiefly based on the interview data such as specific statements by respondents, which are complemented by secondary data retrieved from sources such as consultant reports, scientific literature, actors' corporate reports, procurement procedures, purchasing contracts, market standards, and EU and national waste legislation.

2.4. Discussion

Based on the findings of the data analysis, the challenges of, and possible measures for, initiating increased utilisation of secondary construction aggregates were discussed. The challenges were primarily elicited in terms of the lack of institutional structures for driving and enabling users to select secondary aggregates in their construction projects. The discussion was then performed in relation to addressing

these institutional gaps by mimicking the primary aggregates while maintaining the existing institutions underlying the current secondary aggregates utilisation and having necessary additions to further increase the utilisation of secondary aggregates. The discussion was performed both in terms of the increased utilisation of internal C&D residues generated within the individual construction corporations and within the construction sector and external residues from other industry sectors. The discussion was facilitated by referring to literature concerning sustainable markets in general and aggregates markets in particular, as well as literature pertaining to waste management in general and residue-derived construction aggregates in particular. The findings on the physical flows of aggregates within the construction sector were used to provide mass flow perspectives to the discussion.

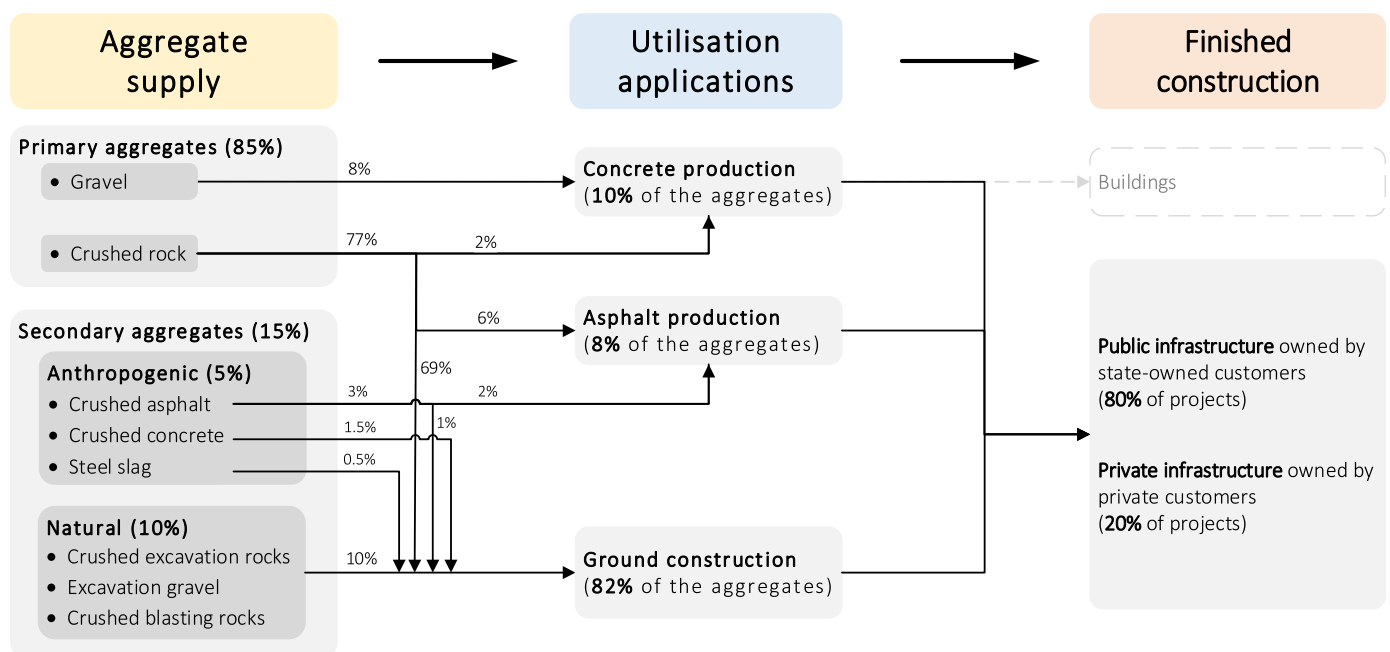


Fig. 3. Activity of the Swedish construction aggregates market. Approximately 100 million tonnes of different types of primary and secondary aggregates are supplied and utilised in different types of infrastructure construction applications, indicated in mass percentages. The finished infrastructures are owned by both state-owned and private customers. Percentage ownership is indicated based on project budgets based on one of the involved infrastructure constructors (Interviewee 1).

3. Findings

3.1. Activity of the Swedish construction aggregates market

The current aggregates supply in Sweden amounts to approximately 100 million tonnes annually (Swedish Geological Survey, 2019) and consists of different types of primary and secondary aggregates that are supplied in various proportions (Fig. 3). These aggregates are utilised in three main types of applications: approximately 10% in concrete (Löfsjögård, 2020), 8% in asphalt (Asfaltskolan, 2020), and 82% in ground constructions. A vast majority of these applications is part of the construction of infrastructures, which are chiefly owned by state-owned customers (national, regional, and municipal organisations), whereas the ownership of private customers (companies, societal organisations, and individuals) is relatively less prominent.

The different types of primary and secondary aggregates are supplied in varied proportions due to different reasons. Approximately 85% (85 million tonnes) of the aggregates supply consists of primary aggregates (Swedish Geological Survey, 2019), chiefly explained by their abundance and affordable production costs (Bertils and Elvingson, 2019). The majority of the primary aggregates supply is crushed rocks (including small amounts of moraine), which are utilised in all the three types of applications. The gravel supply (including small amounts of sand) has drastically decreased over time because of groundwater quality concerns of its extraction and the associated taxes but nevertheless is still being used in concrete production given favourable functional properties of the material (Interviewee 5 and Swedish Geological Survey (2019)).

Given the supply dominance of primaries, secondary aggregates only account for approximately 15% (15 million tonnes) of the total aggregates utilisation. Approximately two-thirds (10 million tonnes) of secondary aggregates is derived from natural residues (Swedish Geological Survey, 2019) that are generated from the excavation and blasting works, which are unintended yet unavoidable. Material-property-wise, they are the same as primary aggregates but still legally classified as wastes in Sweden (Riksdag, 2020). Approximately one-third, (5 million tonnes) of secondary aggregates, is also derived from different anthropogenic residues: crushed (demolition) asphalt 60%, crushed (demolition) concrete 30%, and steel slag 10% (Jernkontoret, 2021; Törnblom, 2011). Crushed asphalt is commonly recycled in asphalt production (Interviewee 4), typically in the ratio of 3:1 crushed rocks to crushed asphalt (Jepsson and Nyberg, 2017). Crushed concrete is almost always down-cycled into foundation layers in ground construction (Interviewee 5), chiefly due to adverse technical properties in recycling into concrete (Jepsson and Nyberg, 2017). There could be regional variations in the different primary and secondary aggregates flows, mainly due to different geological and geographical reasons. Geological reasons, such as the quality of minerals in the Earth, concern primary aggregates, while geographical reasons, such as the occurrence of minerals, distances to utilisation sites, and urbanisation levels, concern all types of aggregates.

3.2. Rationale of the Swedish construction aggregates market

The overall rationale of the Swedish construction aggregates market can be established in terms of two main market processes and different

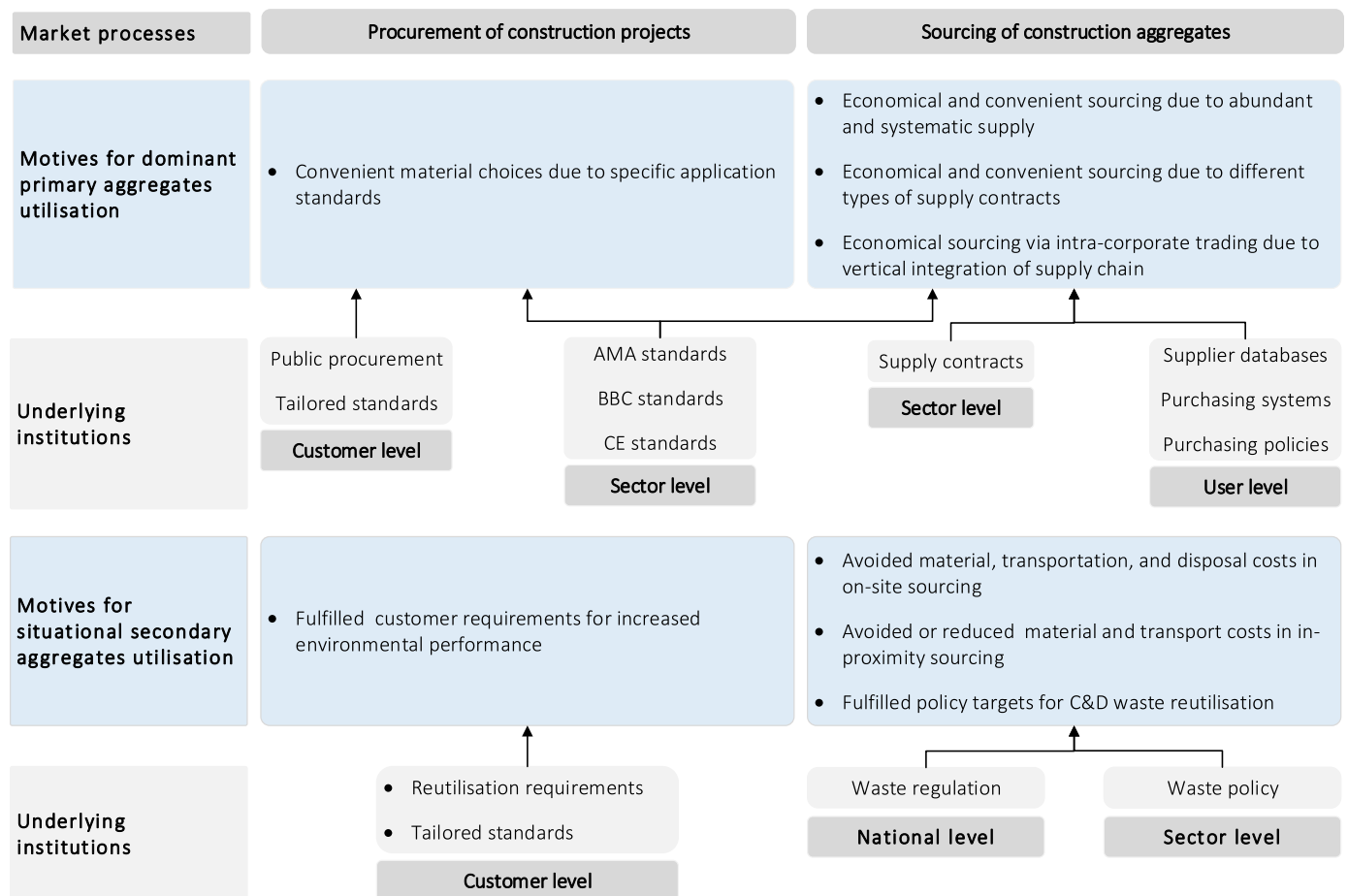


Fig. 4. Rationale of the Swedish construction aggregates market. Different user motives created at the main market processes sustain the dominant primary aggregates utilisation and situational secondary aggregates utilisation. Such motives are facilitated by various institutions occurring at the customer, user, sector, and national levels.

institutions that create motives for the utilisation of primary and secondary aggregates at these processes (Fig. 4). The market processes are started by customers by awarding a construction project to the user, that is, the procurement of construction projects. The user then turns to suppliers to source aggregates for different utilisation applications (Interviewees 1–3). The user motives for the utilisation of primary and secondary aggregates at these two processes are facilitated by various institutions occurring at the customer, user, sector, and national levels. Currently, these market processes and the underlying institutional structures have led to a dominant primary aggregates utilisation and a situational secondary aggregates utilisation.

3.2.1. Dominant primary aggregates utilisation

The users turn to primary aggregates such as crushed rock and gravel by default due to several reasons. One such reason is that the project and purchasing managers could make convenient material choices due to the availability of specific application standards in the construction sector. Customers typically refer to the AMA infrastructure standards (Byggtjänst, 2020), which specify the required physical and mechanical properties of aggregates for different types of ground constructions and asphalt production, and BBC (NORDCERT, 2021) for concrete production. State-owned customers, who own public infrastructure that stands for a large share (approx. 80%) of the users' construction projects, particularly, could exert a significant influence on users' material choice. For instance, in their public procurement, the Swedish Transport Administration (STA) have implemented criteria that clearly require the users to meet the aforementioned sectoral standards. The STA has even tailored such standards, for example, specifications on unbound layers (Hermelin, 2017) and Bitumen-bound layers (Lind, 2020), to meet their own specific criteria. Given that these standards chiefly incorporate primary aggregates, it is natural for the users to turn to such materials, which they could select at their discretion. According to Interviewee 1, "as long as we meet the specifications, they (customers) usually don't have an issue with it".

The utilisation of primary aggregates also provides users with an opportunity for economical and convenient sourcing of the materials, especially in the southern (Göteborg) and middle (Svealand) regions of Sweden, where more than 85% of the country's population lives (SCB Statistics Sweden, 2019) and all the major cities are located. Most of the construction takes place in these regions, where a large number of quarries are located (Swedish Geological Survey, 2019). This situation indicates high supplier competition and low prices, which make the sourcing of primary aggregates economical. According to one of the interviewed purchasing managers, they "usually find three or four suppliers to create competition and influence the price". What is more, the information the user needs to identify suppliers, such as available types of aggregates, CE product quality certificates (European Commission, 2021), and quarry locations, are systematically available (in databases) at the disposal of all the involved users (Interviewees 1–5), which makes the sourcing of aggregates convenient.

The high completion among suppliers also gives users the upper hand in aggregates trading. Consequently, different types of supply contracts, which specify terms such as quantities, prices, and delivery, are entered into at the user discretion to suit different projects. Framework contracts involve large-scale quantities (e.g. > 10,000 thousand tonnes) and are often used for long-term purchasing of regularly used aggregates for lower prices. Project-based contracts are used when it is more beneficial to purchase specific and often medium-scale quantities (e.g. 100–1000 tonnes) for certain projects. Framework and project-based contracts could cater to both large and medium-scale constructions that typically involve state-owned, municipal, and private customers. Contingent contracts are used for the purchasing of small-scale quantities (e.g. < 10 tonnes) that typically involve private customers such as individual enterprises. In framework contracts, the user is bound to purchase only from the involved supplier, and adjustments to the terms are difficult to make. The two latter contracts, given their smaller budgets, allow the

users more degree of freedom to operate in terms of suppliers and prices.

The dominant utilisation of primary aggregates could be further explained by the economic benefits for the construction corporations of intra-corporate trading. For instance, the involved users are subsidiaries of large construction corporations that have vertically integrated the aggregate supply chain. Thus, they source a significant share of their primary aggregates: 70–80 percent in ground constructions (Interviewee 1–3), 70 percent in asphalt production (Interviewee 4), and 90 percent in concrete production (Interviewee 5), via internal suppliers (subsidiaries of the same corporation). Internal purchasing policies, even though not formal, are clearly evident, understandably, due to the opportunity to retain the money within the corporation, whereas convenient negotiation of terms of trade and preparation of documentation could be added advantages. According to one of the interviewed purchasing managers, they would opt for external sources only when either "special types of aggregates, for example, railway Macadam are required, or when it's less costly transportation wise". When it comes to aggregates transportation (between quarries, construction sites, and landfills), it usually costs more than the material itself and hence is prioritised over the internal purchasing policy (Interviewees 1–3).

3.2.2. Situational secondary aggregates utilisation

In contrast to the primary aggregates, users opt for secondary aggregates non-systematically in isolated situations initiated by different actors owing to different reasons. Customers could sometimes require secondary aggregates in their projects. For instance, the STA has developed technical specifications to facilitate the utilisation of the three types of anthropogenic secondary aggregates, that is, crushed asphalt, crushed concrete, and steel slag (Dittlau, 2014) in ground constructions. However, according to the authors of these standards, such initiatives have been chiefly governed by the economic benefits of avoided transportation costs of primaries rather than the potential environmental savings. According to the interviewed STA project manager (Interviewee 6), "unfortunately, between environment and economy, it is the economy that governs". Furthermore, the STA's initiatives for secondary raw materials only seem to target climate performance, whereas resource conservation ambitions as such are absent in their sustainability policies (Swedish Transport Administration, 2019). Such climate impact focus has thus channelled the attention mainly towards CO₂ emissions, which are directly related to and intense regarding materials such as steel and cement (Johansson, 2018). In contrast, the impact of aggregates is indirectly related via transportation (Interviewee 6) and much less intense. Consequently, concepts such as Green Public Procurement that could drive systematic utilisation of secondary aggregates are yet to be practiced. On the other hand, the aforementioned STA standards only target ground construction applications with simple material specifications. Developing tailored standards by customers for asphalt and concrete production, which involve relatively advanced material properties such as viscosity in asphalt (Interviewee 4) and swelling in concrete (Interviewee 5), would not be as straightforward a thing to do.

Given that there is no significant demand from the major customers, users do not actively source secondary aggregates since the utilisation of such materials does not provide them with similar motives of utilising primary aggregates. Even though certain users would claim, for instance, "we have a sustainability policy that we should use more recycled materials" (Interviewee 3), none of the involved construction corporations have explicitly recognised resource conservation in their sustainability policies but an overall focus on the climate performance (NCC, 2019; PEAB, 2019; SKANSKA, 2019), similar to the major customers. The users instead opt for secondary aggregates opportunistically. One such opportunity is the possibility to avoid transportation and material costs of primary aggregates via the reutilisation of secondary aggregates that are sourced on the construction site. That way, the users also avoid the disposal costs of such residues. The improved climate performance of the project due to avoided transportation is usually seen

as an additional benefit but not the main opportunity. Such on-site secondary aggregates are chiefly derived from natural residues (Interviewees 1–3), whereas occasionally, they can also be derived from anthropogenic residues, specifically demolition concrete, and are mainly utilised in ground construction applications. There is not much use of such aggregates in asphalt or concrete production because of the aforementioned lack of specific standards and given that such applications do not always occur on the construction site. Certain processing (crushing and sieving) costs might be involved in deriving secondary aggregates from these on-site residues, but they are often much smaller than the avoided material, transportation (Interviewees 1 and 3), and disposal costs.

Another opportunity for the users in utilising secondary aggregates is the avoided or reduced material and transport costs of primary aggregates by sourcing the former based on residues that are generated in close proximity. Similar to on-site secondary aggregates, the in-proximity aggregates are also mainly derived from natural residues and demolition concrete. In-proximity residues could be sourced from other users with excess residues from their own construction sites, companies that undertake demolition work for users, or other industries that generate aggregate-compatible residues, for example, steel slag. According to the interviewed supplier's recycling manager, "secondary aggregates suppliers are ones in possession of wastes and facing a disposal problem". As a result of the lack of landfill space and high disposal costs, generally, the users are offered in-proximity secondary aggregates by the aforementioned informal suppliers (Interviewees 1 and 3). In urban areas, users too could be actively looking for such materials (interviewee 2), particularly due to the lack of natural aggregates and the abundance of C&D residues. Irrespective of whether the initiative comes from the supplier or the user, the user virtually always capitalises on the supplier's disposal problem and sources secondary aggregates for free, and the supplier often stands for the transportation costs (Interviewees 1–4) and the environmental assessments, which are required by law (Riksdag, 2020) prior to secondary aggregates utilisation (Interviewee 7). The supplier (or the residue owner), in return, gets to avoid the large disposal costs, a win-win situation for the two parties. The sourcing of secondary aggregates is informal and contractual agreements of any sort are currently not used.

Asphalt recycling is a special case. Because of the high added value in bitumen recovery, asphalt producers actively source both on-site and in-proximity demolition asphalt and recycle in asphalt production using both mobile and stationary plants (Interviewee 4). Currently, two-thirds of the demolition asphalt is recycled in asphalt production, whereas only one third is utilised in ground constructions and even that is on the decrease. According to the interviewed asphalt production manager, they have been rebuilding the production facilities to accommodate increased levels of asphalt recycling. Unlike other secondary aggregates, demolition asphalt is also classified as a product in Sweden (Jepsson and Nyberg, 2017). Therefore, the suppliers also have a say in its trading, unlike the other residues, and consequently, the material and transportation costs are open for negotiations with users. Yet in most cases, the material is acquired for free although the transportation and processing (crushing and sieving) costs could be sometimes borne by the users (Interviewee 4).

Generally, secondary aggregates utilisation would also enable the users to fulfil the EU and national policy target for 70 percent reutilisation of construction and demolition waste (European Commission, 2008), a factor which all the interviewed purchasing managers acknowledged. This also explains the fact that project managers focus to source even in-proximity secondary aggregates internally within the construction corporations (Interviewee 2). Additionally, resolving any administration issues and organising logistics would be relatively easier when internally done. However, the means by which the aforementioned policy target is enforced upon the individual users, and consequently, their aggregates choice, are currently unclear. What is particularly noteworthy regarding the utilisation of secondary

aggregates to fulfil policy targets is that such utilisation only takes place when a given situation allows for the economic benefits of doing so.

4. Discussion

The current Swedish construction aggregates market is chiefly characterised by primary aggregates utilisation that resembles a mature marketplace in line with the cohesion phase described by [Aspers \(2009\)](#). Dominant and systematic primary aggregates utilisation is sustained at the main market processes supported by thoroughly evolved specific institutions at the customer, user, sector, and national levels. On the contrary, secondary aggregates utilisation is opted for situationally and unsystematically and governed by scattered and non-specific institutions at the different levels: a situation resembling the orientation phase of market development (*ibid.*). Nevertheless, all the interview respondents (Interviewees 1–7) agree that the actors' value orientations are increasingly leaning towards environmental sustainability chiefly due to national policy reforms. On the one hand, primary aggregates production is becoming increasingly challenging (Interviewee 2) owing to environmental concerns such as noise, dust, and groundwater pollution ([Swedish Geological Survey, 2019](#)). On the other hand, national policies such as the circular economy strategy ([Swedish Government Offices, 2020](#)) are progressively demanding improved resource efficiency in the construction sector. This context signifies that the dominant primary aggregates utilisation is an unlikely option in the long term.

The analysis of the market activity shows that it is impossible to replace substantial amounts of primary aggregates only via the sector-internal C&D residues. Currently, more than 70% of the country's C&D residues are being reutilised ([Jepsson and Nyberg, 2017](#)), which is barely 15% of its annual aggregates demand of 100 million tonnes. Thus, it is insinuated that even a complete reutilisation of C&D residues could replace less than 21% of the total aggregates demand. Hence, a great potential exists for sourcing secondary aggregates based on external industrial residues (EIRs). In this developing context, the actors would want to secure their future in a marketplace for secondary aggregates. According to the involved recycling manager, they "want to be part of and remain competitive in the big secondary construction raw materials market in ten years". However, in order to realise such a transition, the market conditions for secondary aggregates need to be comparable to that of primary aggregates, which is apparently inadequate in Sweden. Based on the findings of this study, the challenges of increased secondary aggregates utilisation are elicited in the following in relation to the lack of institutions in making secondary aggregates a prioritised issue and facilitating the utilisation of such materials. Possible measures of addressing the challenges are discussed in relation to addressing these institutional gaps by mimicking the institutions of primary aggregates.

4.1. Making secondary aggregates a prioritised issue

The greatest challenge in making secondary aggregates a prioritised issue for the construction sector is the lack of customer demand. The lack of specific customer requirements for increased secondary aggregates utilisation, on the one hand, takes away one of the main user motives for utilising such materials. On the other hand, it poses an investment risk for the potential suppliers of such materials since customer demand is key in enabling pricing mechanisms to evolve, and having secondary aggregates formally traded, which are necessary to justify investment for the systematic and commercial-scale production of such materials. Governmental interventions could play an important role in this regard. For instance, policy targets mandating a specific share of secondary aggregates, which is a widely proposed generic measure for realising increased recycling levels in the circular economy context ([Cradlenet, 2021](#)), could be introduced. Thereby, supply chain actors could be made to internalise and materialise the significance of resource conservation in their sustainable policies. Additionally, policy-induced demand by

large-scale state-owned customers like the STA could be used. These measures should target not only the increased utilisation of existing CDR-derived aggregates but also potential EIR-derived aggregates, given that there is a large potential for the utilisation of the latter in reaching circular economy objectives of the country. Examples are the utilisation of municipal bottom ash-derived aggregates by national transportation authorities of countries such as Denmark and the Netherlands (Johansson, 2018), which are socio-economically comparable to Sweden. However, factors such as land space and scarce primary aggregates that have driven such initiatives in those countries are not yet priority issues in Sweden.

Another necessary means of facilitating secondary aggregates in the prevailing supply chain would be improved actor collaborations. Certain actors have already taken initiatives in this regard. According to the involved supplier's recycling manager (Interviewee 7), they have formulated a goal of 50% recycled aggregates and are initiating nationwide collaboration forums involving multiple industrial, governmental, and societal actors to realise it. However, such initiatives are apparently only supplier-driven and unidirectional (Bertils and Elvingsson, 2019). This is specifically because they are the ones who own a residue and are responsible for managing it, whereas customer and user involvements are below parity. Consequently, specific reutilisation targets are absent at the strategic and operational levels at both customers and users, and hence, the project managers are unable to systematically utilise secondary aggregates in their construction projects. Dedicated meeting platforms facilitated via interested third parties such as government organisations or industry associations could be used to create a common dialogue on more inclusive and consistent sustainability policies and practices across the supply chain. Collaborative forums could also enable the identification of new investment opportunities, actors' requirements and challenges, and potential synergies (Cradlenet, 2021). Thereby, users would be able to identify opportunities to create customer value and secure future contracts in reutilising such materials. Once resource efficiency becomes a determinant factor in winning construction contracts, specific resource conservation policies would be more apparent among users.

4.2. Facilitating secondary aggregates utilisation

The Swedish construction aggregates market is identifiable in association with the notion of a self-governed market (Aspers, 2009), where specific institutions at the different levels of the supply chain stipulate the main playing rules. There, one of the most central challenges of the systematic utilisation of secondary aggregates, in general, is the lack of sectoral standards, which enable customers to refer to and users to choose such materials already at the project procurement process. Currently, these sectoral standards target only primary aggregates, whereas secondary aggregates have to be more or less facilitated within this framework, a situation that resembles the outside view perspective described by Garud and Ahlstrom (1997). When it comes to natural secondaries, the AMA infrastructure and BBC standards for primary aggregates are informally referred to. Regarding anthropogenic secondaries, sectoral standards of any sort are currently absent, whereas the only available well-known standards are the ones developed by the STA. Therefore, either the formal consolidation of standards into the existing AMA infrastructure and BBC standards or the development of new sectoral standards for natural and anthropogenic secondary aggregates are necessary. Initiatives by major actors, such as the STA, could potentially lead to such reforms in the sectoral standards, for instance, via demonstration projects. A problem in this regard, especially concerning EIR-derived aggregates, would be that such standards would then have to be developed for each aggregate type, which is time-consuming and resource-intensive. In addition to the sectoral application standards, quality standards, similar to the CE product certification for primary aggregates, are essential to make secondary aggregates competitive in the construction sector (Alsabti, 2019).

Another main challenge of the increased utilisation of secondary aggregates could be seen as the lack of vertical integration of the supply chain by the construction corporations. Consequently, they are unable to create stable conditions and exercise better control of the market (Utterback and Suarez, 1990), hence the users are deprived of economical intra-corporate trading unlike regarding primary aggregates. A particular problem in such vertical integration could be the lack of strategically located terminals and storage places for aggregate provision, which decreases competitive advantage. In that regard, the already-integrated primary aggregate suppliers could be used to streamline the integration of CDR-derived aggregate supply, given that they already do extensive demolition works and have established distribution logistics. An example is found in the case of PEAB (one of the studied corporations). The existing primary aggregates supplier Swerock (a subsidiary of PEAB) has inaugurated its own subsidiary, Swerock Recycling AB, to formally produce secondary aggregates, particularly from demolition residues.

A particular problem with pushing the idea of vertical integration is that it could act as an entry barrier when it comes to EIR-derived aggregates. External industries, which are potential suppliers of EIR-derived aggregates, would not necessarily have the same access to aggregates users as the corporate-internal suppliers do. On the other hand, it could also be viewed as an opportunity for the EIR-derived residues to find their way into the market via the established corporate-internal suppliers. An example is PEAB producing aggregates using slag from the steel industry for infrastructure construction via its subsidiary Swerock Recycling AB. What is more, more formalised secondary aggregates production by existing construction corporations via dedicated subsidiaries would drive the integration of such suppliers into the existing supplier databases and purchasing systems, which is necessary to enable the systematic utilisation of secondary aggregates. The Swedish construction sector, however, is generally recognised as quite conservative (Vogel, 2020). Thus, having all construction corporations investing in the integration of secondary aggregates suppliers would require a significant and predictable customer demand.

5. Conclusions

The analysis of the Swedish construction aggregates market in this study shows that the market is largely characterised by the utilisation of primary aggregates. However, the regional and national policy developments suggest that the need for secondary construction aggregates in Sweden is expected to increase substantially in the near future. To cater to such a large need, the market needs to be prepared to quickly adopt secondary aggregates. Yet, currently, the underlying institutional structures of the main market processes allow users economic benefits and convenience in utilising primary aggregates, which has led to the systematic and dominant utilisation of such materials. Secondary aggregates are almost only opted for unsystematically, depending on situational opportunities for different actors of doing so.

The realisation of increased secondary aggregates utilisation needs changes to the institutional structure underlying the main market processes. On the one hand secondary aggregates should be made a priority issue for the supply chain actors. Concerning project procurement, customers should have specific secondary raw material utilisation targets, which users could follow. Measures such as policy mandates for increased secondary aggregate utilisation levels complemented by policy-induced demand are necessary to enable the internalisation of secondary aggregates into the supply chain. On the other hand, the utilisation of such materials needs to be better facilitated. Concerning aggregates sourcing, secondary aggregates should have specific sectoral standards so that the utilisation of such materials could also become convenient and systematic similar to the utilisation of primary aggregates. Given the way major construction corporations are structured and function, vertical integration of the secondary aggregates supply by the existing primary aggregate suppliers is equally important so that the

users could enjoy similar economic benefits in secondary aggregates utilisation to those of the primary counterpart.

This study presents an in-depth analysis of the Swedish construction aggregates market in terms of the market processes and the underlying institutional structures, chiefly from the user perspective. This type of knowledge on the current aggregates market is universally necessary to facilitate changed practices towards increased utilisation of secondary aggregates. The created knowledge itself is specific to the applicable geographical region (Sweden in this case) and enables the identification of region-specific challenges and possible measures for addressing them. When it comes to facilitating the implementation of systematic, regular, and large-scale utilisation of secondary aggregates, further research creating in-depth knowledge on business development involving the different actors (supplier, users, and customer) is also necessary.

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Tharaka Gunaratne: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Joakim Krook:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing. **Hans Andersson:** Resources, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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