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The Sustainability Opportunity Study

The Case of Swedish Cement and Concrete

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Purpose of the paper*:* There seems to be no agreed way of measuring organizational sustainability and sustainable development in common value chains, such as building. Without agreed definitions agreed performance indicators are probably missing. Effective and efficient change starts with a measurable opportunity or problem. Sustainability indicators can be identified by doing a Sustainability Opportunity Study (SOS). The SOS provides a quantitative assessment of the existing improvement potential. The SOS also identifies causes for the existing potential and proposes ways of solving. The purpose in this paper is to do an SOS for Swedish cement and concrete production, to do a review of the SOS practice, and to propose improvements.

Methodology*:* The starting point is the SOS matrix that combines the logic of Understanding-Defining-Measuring with the Opportunity Study steps of Diagnosing-Analysing-Solving. This matrix is applied on the Swedish processes of producing cement and concrete. The information used is based on earlier work which is used for further conceptual development.

***Main Findings**:* Results demonstrate that the SOS can be adapted to Swedish cement and concrete production resulting in proposed sustainability KPIs, identified main causes and proposed ways forwards. The SOS matrix has been revised and additional content has been added resulting in a new proposed complete SOS.

***Practical implications**:* The SOS can be used as starting point for continued research on sustainability and sustainable development in the Swedish building value chain. The SOS should also be useful in other systems to identify sustainability opportunities.

***Originality/value**:* Results provide further development of the SOS theory

***Type of paper**:* Conceptual research paper

***Keywords**:* sustainability, sustainable development, sustainability opportunity study, cement sustainability, concrete sustainability, Sweden.

1. Introduction to understanding sustainability

Sustainable development is today on most organizational agendas. The UN SDGs, which most countries have signed up for, result in requirements on companies and organisations. In addition to formal requirements, customers expect companies to behave sustainably. This means that appearing sustainable could provide a market advantage, which means that there will be greenwashing presenting companies and products as greener than they are. Generally, we could say that most companies subscribe to sustainability. However, there are indications that many companies are not clear on what they mean by sustainability and sustainable development, which possibly is combined with some greenwashing. Isaksson et al. (2022a) study branches such as building, education, health care and tourism noting that there does not seem to be any generally accepted definition of sustainability in the studied fields. The 1987 UN Brundtland Commission definition proposes that: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This is an agreed definition of sustainable development, which needs to be adapted to the area worked with, such as building. We need more specific and actionable definitions for building sustainability and sustainable building development. Isaksson and Rosvall (2020) show in a study of leading Swedish companies in the building value chain that there is no consensus on what building sustainability is. Similar results are found for global companies and leading literature on building sustainability (Isaksson et al. 2022b). Isaksson et al. (2022a) show that based on a focus on the main sustainability impacts in the value chain it is possible to create working definitions for the different areas studied. Proposing the definition has been done applying the Pareto principle which suggests that 20% of all causes are responsible for 80% of the effects. In the words of the late quality guru Joseph Juran, focus on the vital few. The logic is that we should start with the most important challenges and not be struck by analysis paralysis, while trying to figure out all aspects of sustainability. In the residential building value chain, the main People stakeholder is the house dweller having a human right for safe and acceptable shelter. The building value chain is responsible for 40% of the manmade carbon emissions (Architecture, 2030), while climate effects are singled out as one of the main global Planet sustainability concerns (Steffen et al. 2015). These two impacts make it reasonable to point out housing affordability and climate change as the two main sustainability impacts. Sustainable residential building is defined as: "At least affordable and carbon neutral". Creating a working definition with the use of "at least" seems to provide a feasible way forwards in defining sustainability and sustainable development.

In addition to the Brundtland commission definition of Sustainable Development another commonly used expression is the Triple Bottom Line (TBL) which suggests viewing sustainability in the dimensions of economy, environment, and social issues. The TBL was proposed in the 1990s by John Elkington and was introduced in a time when most focus was on the single economic bottom line. The TBL is difficult to use in practice since the three dimensions cannot be added. The Global Reporting Initiative standards divide indicators in the three dimensions but do not provide any support for how to deal with value conflicts. In practical terms this could often mean business as usual with focus on the economic bottom line while showing some concern for environmental and social issues. Another consequence is focus on the footprints while forgetting the value created. A typical example is within flying where we are urged to fly less without any consideration of what value the flying is providing. Countries depending on tourism, such as the Maldives need the tourism money to take actions when the islands eventually are flooded. Some flying might add more value than harm. Another way of viewing sustainability performance is to use Eco Efficiency which defines sustainability in terms of value per harm. Value in the original concept from the World Business Council for Sustainable Development (WBCSD) is defined as sales value. This is also the case in the GRI standards. Dealing with sales value makes measurement easier but with the cost of relying on the assumption that sales value equals user value. This is often not the case. Isaksson et al. (2015) propose a value per harm measurement, where the ratio can be interpreted as stakeholder value divided by stakeholder harm. This contributes to the understanding of sustainability like the value-based quality approach (Garvin, 1984) which compares what we get for what we pay. The stakeholder harm includes price in addition to main environmental and social footprints. Using relative indicators enables the comparison of companies within a branch with similar value creation. E.g., with residential building we could define value as an apartment of a certain size and comfort. A simplification is using a year m^2 of adequate living space and comparing it with the cost and the carbon footprint (Isaksson et al. 2022a, 2022b). What is adequate is contextual and needs to be defined. The definition proposed by Isaksson et al. (2022a) is focused on the footprints and does not clearly include value. This is relatively easy to add and to specify.

When studying the sub-process of cement manufacturing the value produced needs to be discussed. Major cement producers focus on carbon emissions which are related to tonnes of cement produced. This implies that all cement has equal performance, and that cement weight can be used as value. This is a gross simplification and more correct would be to study the cement performance in terms of its binding performance, the compressive strength that it can provide (Isaksson, 2007), (Isaksson and Babatunde, 2019). Cement is the binder, the glue in concrete, which means that the stronger the glue is the better for the concrete producer. A strong cement means that the concrete producer can reduce cement content which reduces costs and the carbon footprint in the concrete. Since cement production in developed countries is a mature market based on de facto monopolies and oligopolies it is understandable that there is little focus on improving cement performance, since this only would lead to reduced sales. This could be an explanation to why value is only presented as tonnes. There seems to be no publicly available data on cement strength performance in Sweden. However, these could be estimated based on the different cement standards used and the performance requirements that the standards have. There is some information on cement carbon emissions. These can also be assessed based on the content of cement clinker which is approximately specified in the different standards. There should be enough information to propose a definition for sustainable Swedish cement and how this relates to sustainable Swedish building. It should be possible to suggest cement sustainability KPIs based on value per harm.

Assessing value produced in the sub-process of concrete manufacture is also a challenge. Concrete forms parts of buildings and infrastructure. The value of it could be assessed defining functional units like a m^2 of wall or a m^3 of concrete of a certain strength. In this there is a problem of defining what is good enough concrete and strength for the purpose. There are indications that amounts of cement used in Swedish concrete have increased over the years (Mistra, 2020). Cement is relatively cheap, and it can be used to dry out the concrete quicker. Mistra (2020) writes that pressed construction times in Sweden lead to the use of higher amounts of cement to dry structures quicker. Isaksson and Buregyeya (2020) use a m^2 of acceptable wall as the functional unit and conclude that the most sustainable block in East Africa is a substandard solid block, which has the lowest cost and the lowest carbon footprint, but which provides the required structure. This indicates that standards cannot always be trusted. Strength requirements can be clearly excessive due to different reasons, which could include cement producer lobbying. This means that when defining the quality of the functional unit we might have to start with basic principles to calculate what a required strength and durability of the functional unit should be. With solid scientific backing standards could then be rectified. In terms of circular economy, the first question is if a product is needed. Cement is needed to make concrete, which is the mostly produced product in the world and currently indispensable. Portland cement could possibly be substituted for another material (Rosvall and Isaksson, 2021) with one alternative being Belite calcium sulfoaluminate (BCSA) cement, which is more expensive, but which has a lower carbon footprint. If Portland cement cannot be substituted the next question is if less could be used? This is an area worth of scrutiny. Logically cement monopolies producing a commodity product would have done what they can to increase the use of cement. This type of strategy could over the years have led to considerable overuse of cement in concrete. Despite lack of data, it should be possible to propose a definition for sustainable concrete and how to measure it based on the value per harm logic.

The UN SDGs and the Global Reporting Initiative (GRI) standards both deal with sustainability and sustainable development as synonyms. This could further complicate the understanding of how to work with sustainable development. Isaksson et al. (2022a) suggest using sustainability as a level of performance as we do with quality. Sustainability will describe the "What", the right thing to focus on. With building sustainability, the two areas in focus are price and carbon footprint of housing. Affordability targets can be defined in function of income levels and the carbon footprint target should be zero. Having targets, enables assessing the current level of sustainability in terms of price and carbon footprint. Sustainable development is by Isaksson et al. (2022a) seen as a change process – sustainability change – to a speed which is compatible with external requirements. For the carbon footprint there are national and global objectives of when to become carbon neutral. Sweden has a commitment to become carbon neutral in 2045. This target enables setting a rate of change for carbon reductions. Managing change to this speed or quicker could be seen as sustainable climate development for buildings.

The GRI standards, like the forthcoming European standard for sustainability reporting, suggest reporting sustainability in the value chain. This is part of understanding company sustainability. The company is not only in charge of its own sustainability impacts but also of those in the entire value chain it decides to be part of. For e.g., clothes retailers and other business to customer companies, this is nothing new. Companies like H&M and IKEA have since times back had to report for both their upstream and downstream performance. H&M is held responsible for working conditions in the supplier companies it deals with and must watch out where used clothes end up in order not to be criticized and thereby lose brand value. IKEA needs to keep track of all carbon footprints occurring, starting with how the timber, which is used for furniture has been produced and ending with end of product life management.

Assessing improvement opportunities and improvement potential requires an agreed Key Performance Indicator (KPI) and a defined target. An example of this is building carbon emissions and the Swedish zero net emissions target in 2045. However, frequently there are no agreed KPIs since a common sustainability definition is missing which indicates that there is not a common understanding in the organization, or the system studied. With agreed KPIs we can use the Opportunity Study (Isaksson, 2015), which has the stages of Diagnosing, Analysing, Solving (DAS). Diagnosing quantifies the improvement potential using the agreed KPIs, the target and the current performance. Analysing the causes for the existing potential identifies the main causes for the existing potential. Solving or finding solutions proposes how change could be carried out. If all parts of the DAS are understood and feasible to work with there is an opportunity for improvement. The Sustainability Opportunity Study (SOS) creates working KPIs by going through the logic of Understanding-Defining-Measuring (Isaksson et al. 2022a). Combining DAS and UDM creates a 3*3 matrix; see Table 1.

Table 1. The conceptual overview when combining the Opportunity Study DAS logic with the three stages Understanding, Defining and Measuring. The state of Measuring describes the Opportunity Study, which can be carried out when there are agreed KPIs. Adapted from Rosvall and Isaksson (2021).

	Understanding	Defining	Measuring
Diagnosing			
Analysing			
Solving			

Previous work has focused on the part of Diagnosing (Isaksson et al. 2022a), (Isaksson et al. 2023) which has had the purpose of assessing the improvement potential as a first step for further work. The precondition for any improvement work is that it is worth the effort. Understanding Diagnosing is based on studying the main sustainability impacts in the value chain with focus on People and Planet impacts. Work with Understanding Analysing and Solving and further Defining and Measuring Analysing and Solving has been only partially done (Rosvall and Isaksson, 2021) and needs to be elaborated.

Logically effective and efficient change starts with understanding the "What" to change and then "How" to do it. In Table 1, Diagnosing and Analysing will provide the "What" and Solving the "How". For the residential building value chain, Isaksson et al. (2022a) provide a good starting point. This value chain can be divided into the stages of raw material production, building, use of buildings and demolishing/reusing. Price of cement and concrete is a relatively small issue when it comes to the effect on building costs in Sweden. Climate effects in rich countries like Sweden are main concerns, which justifies the focus on building climate effects. In Rosvall and Isaksson (2021) Swedish cement sustainability is studied with results showing that production is very carbon intensive, and that carbon reduction is slow and well below a required rate to classify as sustainable development. The proposed industry solution is to build a unit for Carbon Capture and Storage. This is a very costly investment risking of doubling the cement price. Higher cement prices in Sweden and other rich countries are manageable. The result for the final customer is a building price increase of a few percent. However, for most countries in the world, higher cement prices are not acceptable. This indicates that finding other solutions for climate neutral cement are of interest. The main climate emissions generally come from using buildings. Emissions come from the energy used for heating and cooling. However, in Sweden this part is rapidly shrinking due to the use of renewable energy. With a combination of low-energy houses and renewable energy the use of buildings stage can be solved. For the part of raw materials and building the main carbon emissions are generated in cement and concrete production. Most of the building emissions are from traditional cement. There are also some emissions from the steel used as reinforcement in concrete and as material for steel structures.

There seems to be no agreed way of defining and measuring cement and concrete sustainability, which makes it difficult to assess improvement opportunities. This indicates that at least at the explicit level there is no common understanding in Sweden of what sustainable cement and concrete are. This indicates that doing an SOS as described in Table 1 could be a way forwards in proposing definitions for cement and concrete sustainability and cement and concrete sustainable development in Sweden. With working KPIs for cement and concrete sustainability it will be possible to do the Diagnosing of a first indicative improvement potential. This will then enable Analysing causes for the potential and further proposing how Solving could be done.

The purpose of this paper is to carry out a complete SOS for Swedish cement and concrete while simultaneously reviewing and proposing improvements for the SOS practice. More specifically this work will deal with:

1. Reviewing how Swedish cement and concrete sustainability and sustainable development are currently reported
2. Doing a Sustainability Opportunity Study (SOS) for Swedish cement and concrete
3. Critically reviewing the existing SOS theory
4. Presenting areas of further research both for the area studied and for the change theory used

2. Theory background

This work forms part of a project called Supplementary Cementitious Force II, which studies barriers for introducing new cement solutions on the Swedish cement market. The work done in SCM Force I focused on studying the role of standards as possible barriers to innovation and to the introduction of alternative cements.

2.1 Cement and concrete in Sweden

The preliminary conclusion is that standards constitute a considerable barrier for introducing new materials and new cements which are not listed in the existing standard for common cements the EN 197-1. In context of the Opportunity Study - Diagnosing-Analysing-Solving (DAS) (Isaksson, 2015) the standard barrier could be viewed as relating to the M of Method in the 10 M qualitative analysis which is used in Analysing (see Tables 4 and 5). The existing standards are a result of the context, which is a stable business. The cement as a product in Europe has changed very little during the last 20 years. The EN 197-1 from 2000 which introduced 27 common cements has only changed marginally. In Sweden the main change has been going from Type I cement which has more than 90% cement clinker to the use of Type II cements that contain more limestone, fly ash and slag. The clinker component has due to this been reduced to about 80%. Since clinker drives the carbon footprint this has reduced the cement carbon footprint.

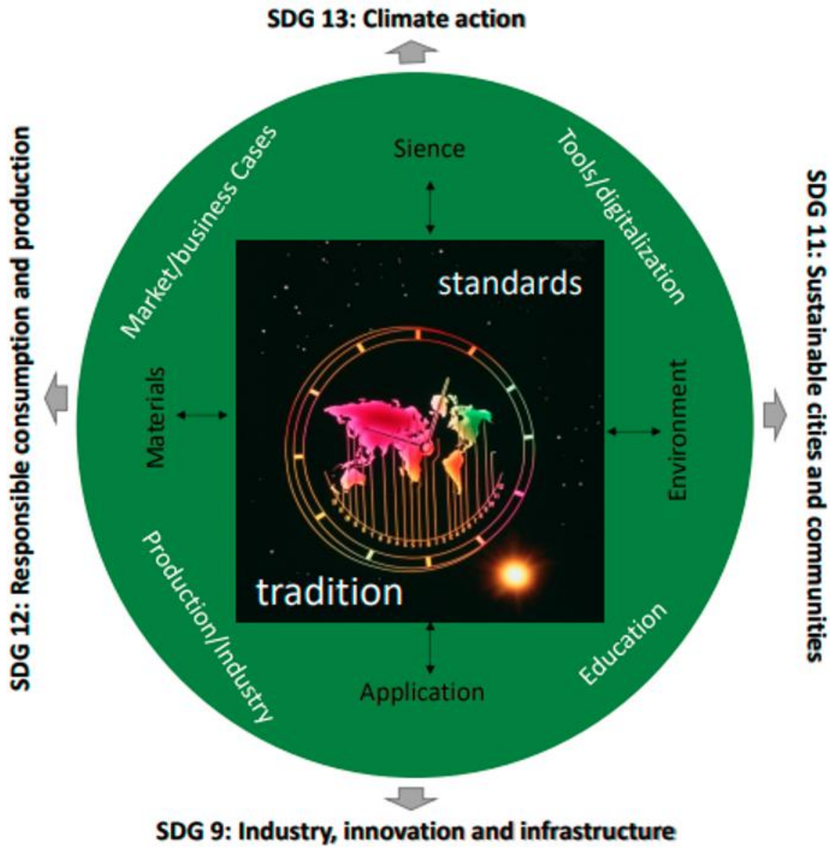
In Europe the average clinker content is lower than in Sweden (Mistra 2020) due to more use of materials such as Granulated Blastfurnace Slag (GBS) and fly ash. Sweden has steel production but historically there has been limited use of slag in cement. Due to increasing climate requirements concrete producers like Skanska, PEAB and NCC have started promoting green concrete based on increased use of Ground Granulated Blastfurnace Slag (GGBS) in concrete. GGBS can be directly added into the concrete mixer, which thereby becomes competition with cement manufacturers. The building company PEAB has invested in Swecem a company founded in 2013 which has a milling unit for grinding slag producing GGBS, which is mixed into concrete directly. In Sweden, the cement manufacturer Cementa, belonging to the global Heidelberg group is the main producer having a market share of about 90%. Concrete manufacturers start feeling the pressure to reduce their climate impact which mainly is caused by cement. In terms of reducing the carbon footprint concrete development seems to have been as slow as with cement. Both cement and concrete production in Sweden have been stable and conservative businesses operating in a stable market.

Cementa has a de facto oligopoly in Sweden and the five largest builders PEAB, Skanska, NCC, Veidekke and JM have 65% of the Swedish market. A stable market with a limited number of large companies creates a climate for oligopolies. Competition would lead to lower margins and would require extraordinary efforts.

2.2 Understanding the context with models

Sustainability challenges are putting pressure on the current business models. In Figure 1 the SCM Force II conceptual background is described highlighting the complex environment of cement and concrete manufacturing. Figure 1 highlights the complexity and the challenge in understanding, defining, and measuring sustainable cement, concrete and building. One way of describing systems is to use the Process Based System Model (Isaksson, 2019). In Figure 2 the PBSM has been used to describe the global process of providing accommodation. The model aspires to include all the relevant elements needed for understanding, defining, and measuring the performance of the current system. The challenge with standards is described as a resource issue under Methods. Tradition or culture forms a central part in Figure 1 and could possibly be seen as part of the Mission and Management resources. The research in SCM Force II will include sensemaking using the PBSM.

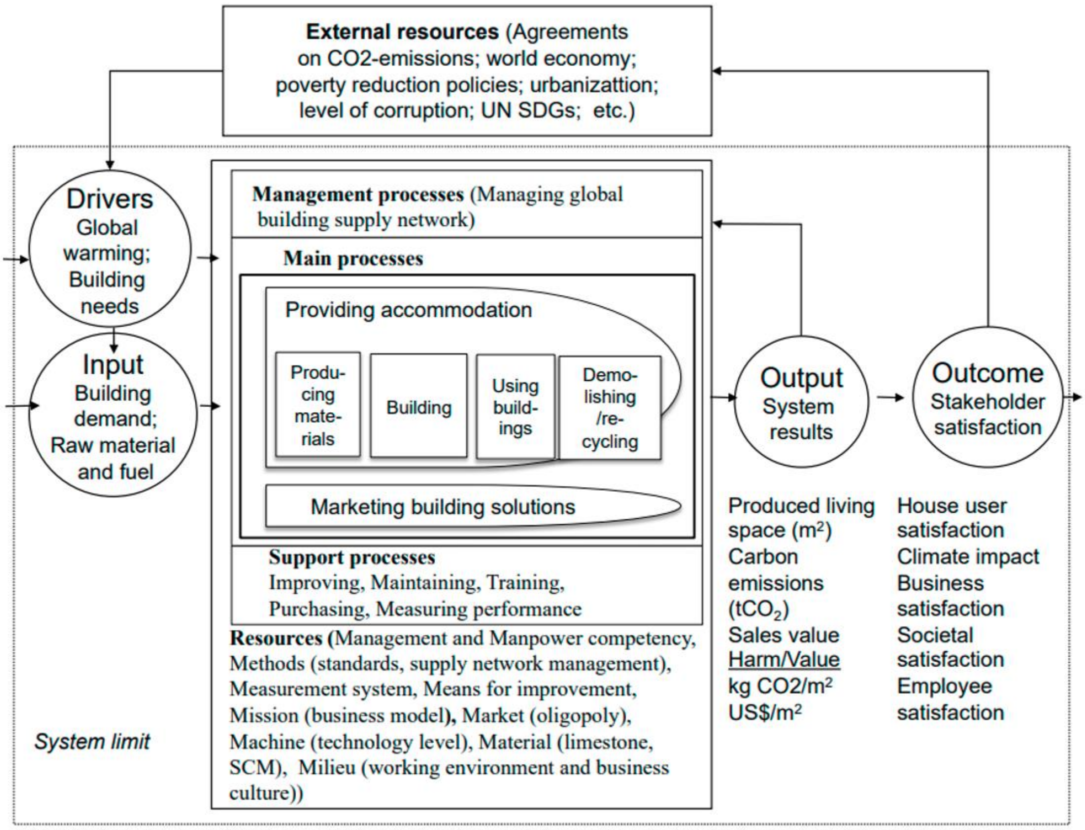
Figure 1. Model from Supplementary Cement Force II application describing the complexities of the studied system.



Focus in this paper is to discuss how the SOS matrix in Table 1 could be visualised for Swedish cement and concrete using the PBSM to describe the systems studied. Cement and concrete manufacturing form parts of the sub-process of producing materials in Figure 2. A detail is that cement manufacturing delivers not only for residential building but also for infrastructure and for other uses of cement like for soil stabilisation. This means that the overall value chain needs some modifications especially when it comes to Key Performance Indicators. For residential building, which is about 50% of global building, the value per harm indicator is living space per price and carbon footprint often expressed as the inverse as price/m^2 and kg CO_2/m2. It is important that the sub-process KPIs has a clear correlation with the overall KPIs.

Producing cement, concrete, buildings, and infrastructure in Sweden is a system which can be mapped using the PBSM. There is a saying that a system does not understand it. We need to step out of the painting to see it. We can as researchers take the role of viewing the entire system of producing cement-based products in Sweden. Once the important actors have been identified as well as their wants and needs and their position, a common understanding of how the system works, what its current performance is and how the sustainability goals look like could be built using the PBSM.

Figure 2. Process Based System Model (PBSM) describing the global system for providing accommodation. Adapted from Isaksson (2019).



The PBSM is based on basic quality and process theory. It describes a system using management, main and support processes. An essential part of the PBSM is defining internal and external resources. For example, in the context of producing concrete in Sweden, external resources define the context where a system works (e.g., the influence international standards and practices), whilst the internal resources define all those that apply for Sweden (e.g., Swedish building regulations). An equivalent approach can be taken, when considering the production of cement. This part can be expanded using the same model to provide more details. The main process follows the four sub-processes described in the European standard EN 15978:2011 on assessing environmental performance of buildings.

3. Methodology

This work relies on previous work with the Opportunity Study (Isaksson, 2015) the Process Based System Model (Isaksson, 2019) and with the Sustainability Opportunity Study (Isaksson et al. 2022a). Also, specific work describing understanding sustainability in cement and concrete production and in building has been used as a starting point (Isaksson 2007, 2016), (Isaksson and Rosvall, 2020), (Isaksson and Buregyeya, 2020), (Rosvall and Isaksson 2021), (Isaksson et al. 2022b), (Isaksson et al. 2023).

The four areas worked with in this study are presented below with comments on methods used.

3.1. Reviewing how Swedish cement and concrete sustainability and sustainable development are currently reported.

The information for this has been collected by analysing six sustainability reports from companies working in Sweden with cement production, concrete manufacturing and building. Since Heidelberg Materials is the sole producer of cement in Sweden only one of the reports cover cement manufacturing. Cementa is a member of Heidelberg Materials with leading market positions in aggregates, cement, and ready-mixed concrete. The five other sustainability reports are from the largest Swedish building companies which are PEAB, Skanska, NCC, Veidekke and JM. Even if the number of sustainability reports is limited they cover most of Swedish cement and concrete production and provide a good understanding of the current sustainability reporting maturity. The sustainability reports have been analysed using the AI tool: "Ask your pdf" (https://askyourpdf.com/) using questions based on the Sustainability Reporting Maturity Grid (SRMG) (Cöster et al. 2020). The SRMG has six areas, three on reporting the right thing and three on the reporting in the right way. The three areas for the right thing consist of the value chain, stakeholder identification and stakeholder needs identification. The three doing the right way consist of performance indicators, targets and reporting clarity. In this work the clarity has not been included. Since the AI tool did not manage to read all pdfs, these were also controlled manually and answers to the questions were obtained by manually using the find function. The resulting assessment of measurement maturity combine AI tool results with manual results.

Previous work with Swedish sustainability reporting (Isaksson and Rosvall, 2020) and international reporting (Isaksson et al. 2022b) have shown that there seem to be no agreed definition of building sustainability. This brief review is to check if there are any updates and if there would be any specific mentions on cement and concrete sustainability.

3.2. Doing an Opportunity Study (Diagnosing-Analysing-Solving - DAS) for Swedish cement and concrete

This work is based on the SOS description in Table 2 which presents a complete 3*3 matrix for a Sustainability Opportunity Study (SOS) from Rosvall and Isaksson (2021) describing parts of the Swedish building value chain. The matrix has been applied both for cement and concrete production clearly indicating the interfaces of the two Swedish building value chain sub-processes. Previous work with SOS has focused on Diagnosing (Isaksson et al. 2022a), (Isaksson et al. 2023), which is the part that proposes definitions and KPIs for sustainability and sustainable development. The main new contributions are found under Analysing and Solving, but additionally Diagnosing has been subjected to a thorough review leading to substantial proposed changes. For Analysing the qualitative 10 M checklist (Isaksson, 2016) is used and adapted for the improvement potential identified in Diagnosing. Further the 10 M logic is used to propose a checklist for the external resources, see Figure 2. For Solving, agency and change management competency are discussed with specific focus on introducing alternative binders and new cements.

3.3. Critically reviewing the existing SOS theory

All the nine parts of the matrix are applied for the processes of producing cement and concrete. Previous work with understanding, defining, and measuring cement quality and sustainability is used (Isaksson, 2007, 2016), (Isaksson and Babatunde 2019). Concrete performance is discussed with starting point in Isaksson and Buregyeya (2020) and Isaksson et al. (2023) where the functional concrete unit is presented as a m^2 of wall. Other suitable units for user value have been proposed based on discussions in the research group.

3.4. Presenting areas of further research both for the area studied and for the change theory used

The work in this study covers several areas superficially serving as an overview for important parts in the SCM Force II research. The identified areas for further research have been identified based on preliminary discussions in the research group that includes both researchers and practitioners from cement manufacturing, concrete production, and building.

Table 2. The SOS Opportunity Study combining DAS and UDM, adapted from Rosvall and Isaksson, 2021).

	Understanding	Defining	Measuring
D	The Process Based System Model (PBSM) for the building value chain can be presented as in Figure 2. The main stakeholder needs identified are similar to those for the entire building value chain, cement affordability and zero or low climate impact. Defining the qualitative improvement potential as the difference between possible and/or required performance and current performance. This should be done for cement strength performance, price and carbon footprint. New cements could have a potential in higher substitution with calcined clays (LC3) and with higher use of different slags.	Based on the Pareto principle define the vital few stakeholders and impacts Focus on People and Planet needs and convert this to a proposed definition that can be operationalised. Cement sustainability is defined as producing affordable user building value (cement strength generating capacity) with zero climate impact. Sustainable cement development is that zero climate impact is achieved latest 2045. Strategy could be CCS and new or alternative cements.	Measure sustainability as a state and sustainable development as change (chosen y-values as average, variation and a trend). Identify value and harm indicators – the KPIs (y-values) that can be used to describe current sustainability and the sustainability performance over time. Cement MPa*tons Carbon emissions per ton of cement Price per ton of cement MPa*tons/carbon emissions MPa*tons/price
A	A qualitative review of main causes by using the 10 M checklist (Isaksson, 2015).	The main Ms identified for cement industry generally are: Mission – 1; Management – 2; Measurement – 3; Machine – 4; Manpower (5); Milieu	A quantitative review could consist of calculating how many MPa*tons that could be substituted by using available slag as raw material and as SCM. Similarly, the potential of calcine clays could be assessed.
S	Product innovation could consist of developing and producing LC3 and slag-based binders.	Defining solutions and strategies for these.	Setting targets for level of sustainability and rate of change that corresponds to sustainable development.

4. Results

Results are presented following the four areas studied.

4.1. Current understanding, definitions and KPIs for Swedish cement and concrete sustainability and sustainable development

In Table 3 the sustainability measurement maturity of the six studied sustainability reports has been assessed sustainability. The results in Table 3 have been obtained by typing the questions in the left column in the AI program used. Results have further been manually verified. The average measurement maturity level ranges from 1 to 2.6 out of 5, which is relatively low and supports the findings in Isaksson and Rosvall (2020) and in Isaksson et al. (2022b). The results are particularly low for defining sustainability and sustainable development, indicating that there is no common understanding of what cement, concrete and building sustainability are.

Table 3. Review of sustainability reporting maturity in Swedish cement and concrete manufacturing.

Questions used for AI	JM	PEAB	Skanska	NCC	Veidekke	Heidelberg Materials	**Average**
Is value chain mentioned in the document?	1	1	2	2	2	4	**2.0**
Which are the main sustainability impacts	4	1	2	2	3	1	**2.2**
How are sustainability and sustainable development defined?	2	1	0	0	1	1	**0.8**
How is sustainability measured?	3	2	2	2	2	2	**2.2**
Sustainability targets?	3	0	2	2	2	3	**2.0**
Average	**2.6**	**1.0**	**1.6**	**1.6**	**2.0**	**2.2**	**1.8**

The results in Table 3 support earlier observations of a low level of sustainability reporting maturity and a need of clarifying how this could be done by establishing working definitions and performance indicators for the building value chain and for the sub-processes of cement and concrete manufacturing.

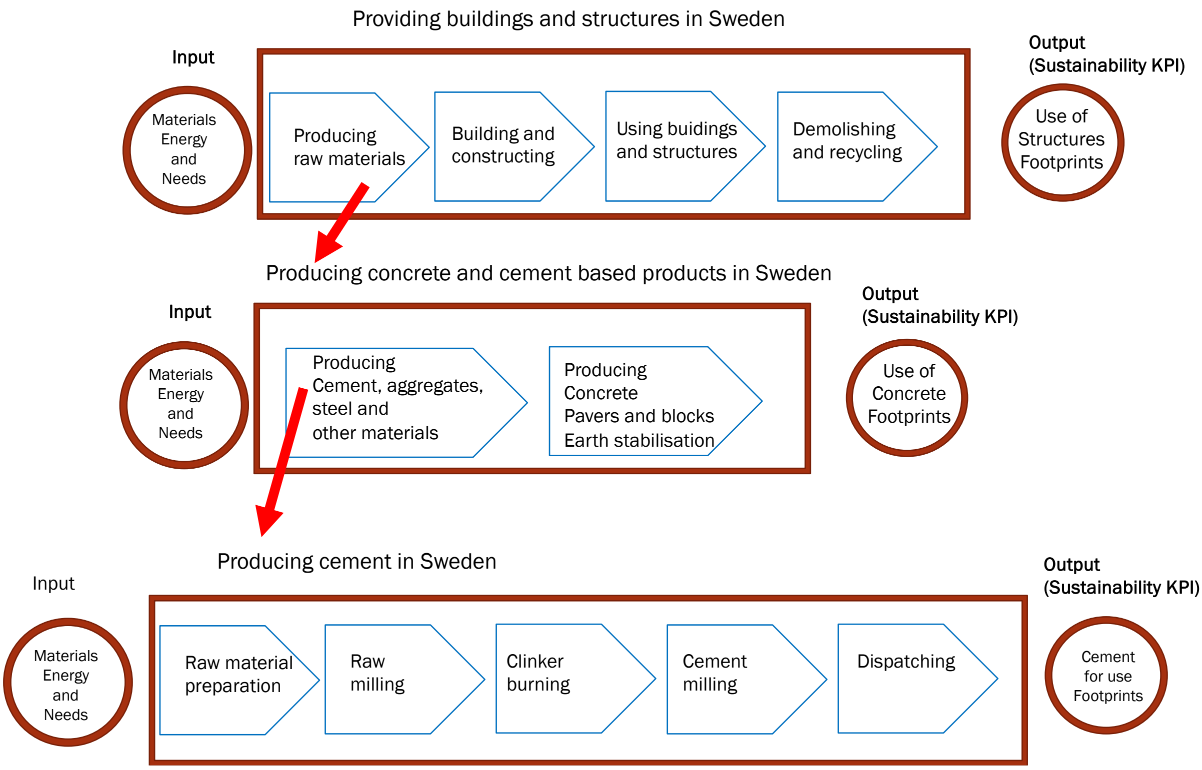
4.2. Opportunity study for Swedish cement and concrete - Diagnosing

The SOS starts with Diagnosing Understanding which also could be seen as Understanding Diagnosing when it comes to creating the logic. When the logic has been created it becomes possible to diagnose the level of understanding. Here, we discuss the logic of the nine spaces in the DAS-UDM matrix in Table 1 and 2. The aim is to review the logic for how the Opportunity Study logic relates to the sequence of Understanding, Defining and Measuring and to propose how this matrix can be adapted to cement and concrete production. The DAS includes Diagnosing of the improvement potential, Analysing of the causes for its existence and Solving by proposing solutions to address identified causes.

4.2.1 Understanding Diagnosing

An important part of understanding is visualising the value chain that the company is part of and being able to place the company in the value chain. In Isaksson et al. (2022a) it is suggested that using the PBSM is introduced in the part of Analysing. Instead of a full PBSM flow charts can be used in Diagnosing to describe the scope of reporting, which forms an important part of understanding. This simplifies the start of the work at a stage when it is not known if there is any improvement potential worth further work. In Figure 3 the Swedish value chain for building is presented together with the sub-processes of concrete manufacturing and cement production. Cement is what binds concrete together. Cement value is created when it becomes part of concrete or some other cement applications like pavers or earth stabilisation. The Global Reporting Initiative (GRI) standards as well as the forthcoming European standard for sustainability reporting propose that reporting should be done for the entire value chain. This means that companies in addition to their direct own footprints need to take collective responsibility for the value chain performance in terms of value and harm. This underlines the importance of understanding the full scope of company responsibilities.

Figure 3. Swedish building value chain and the sub-processes of concrete and cement manufacturing



Results from Table 3 show that there are no clear definitions of building, concrete or cement sustainability. Without clear definitions it becomes impossible to agree upon the main KPIs for sustainability. Understanding the value chain from cradle to grave and the studied sub-processes help in identifying main stakeholders and the main stakeholder needs. Isaksson et al. (2022a) propose a shortlist focusing on the main global challenges identified as climate change, loss of biodiversity and poverty. For the Swedish building value chain, the main impact is on climate. Globally the building value chain could be responsible for as much as 40% of the global carbon emissions (Architecture, 2030). In Sweden the building value chain contribution is about 20%. The main reason for the difference is that in Sweden the sub-process of using the buildings and, especially heating is done using renewable energy. However, the parts of producing raw material and building are presumably at international levels. The concrete carbon footprint originates mainly from cement. The value chain has effects on biodiversity, but this is minor compared to climate. For the Swedish residential building process the level of housing affordability is a critical sustainability impact where there is significant improvement potential.

Costs for cement and concrete play a minor role for housing affordability. The main harm in Swedish concrete and cement production is therefore the emitted carbon dioxide leading to climate change. At this stage only the cement and concrete climate footprint will be studied.

Value in Table 2 is defined as stakeholder needs. For residential buildings this has been identified as m^2 living space (Isaksson et al. 2022a) which in Table 2 has been related to concrete and cement performance. The logic is that stronger cement and concrete enable material reduction which reduces the carbon footprint. This seems like a sound logic and the overall user value that can be applied for all types of buildings and constructions can be broken down to concrete and cement strength as the main material values. There are obviously a whole range of quality indicators for cement and concrete, but the main purpose of cement is to glue concrete together and the stronger it is the more concrete of the same strength can be produced. The main purpose of concrete is to provide structural strength. Durability is an important concrete quality parameter. This and other quality indicators are needed as checks, but the proposed value performances are cement and concrete strength. The building value produced is both in the form of the quantity produced and its compressive strength. Value for cement and concrete could therefore be described as strength times tonnes of cement and strength times m^3 of concrete. Value for cement and concrete is understood as compressive strength times quantity and harm as carbon emissions.

Isaksson et al. (2022a) suggest including the business idea or the business model. The business model relates to the company mission and its commitment to sustainability. Here, it is suggested that the business model should be an explanatory part taken up under Analysing. Again, this will simplify the first Diagnosing and assessing of the improvement potential. The: "Defining the qualitative improvement potential as the difference between possible and/ or required performance and current performance" suggested in Table 2 is excluded and so are the ideas related to solving. The reason is that we do not need to assess improvement potential in the part of understanding. Understanding should focus on agreeing on what sustainability is in the studied process. With this done, Understanding Diagnosing will be done by defining the branch value chain from cradle to grave and further identifying the company part of it. This sets the scope for understanding sustainability. The main sustainability impacts in the value chain are chosen as focus areas. In Figure 3 the scopes are set for the Swedish building value chain and the cement and concrete manufacturing processes. Residential building value is identified as sufficient building area with a sufficient quality. Industrial building is providing the functional value needed. Harms for the building value chain are cost and carbon emissions. Cement and concrete value are identified as quantity times compressive strength and harm as carbon emissions.

4.2.2 Defining Diagnosing

The proposed definition of residential building as at least affordable and climate neutral (Isaksson et al. 2022) lacks a clear description of value. In Sweden there are norms stipulating that people should have a separate bedroom and at least 40 m^2 of space per person. Without going into the details, Swedish sustainable residential housing could be defined as: "Satisfying housing needs based on relevant standards while being at least affordable and carbon neutral". For industrial buildings and other cement-based applications the proposed definition is: "Satisfying building and construction user needs while being at least affordable and carbon neutral". The latter definition could be used for all building.

Based on the logic in Table 2 Swedish cement and concrete sustainability are defined as a state where maximal compressive strength quantities are produced with a minimal climate impact. The goal is to reach carbon neutrality latest by 2045. Sustainable cement and concrete development are change processes, which reach carbon neutrality latest 2045. The strategy, which forms part of Defining Diagnosing in Table 2 is moved to Defining Solving. This clearly focuses Diagnosing on reviewing the current performance only - the effects - not the causes.

4.2.3 Measuring Diagnosing

Cement sustainability using value and harm indicators, which should be both absolute and relative are proposed to be based on Isaksson (2007):

Absolute

- Compressive strength times quantity = building value potential (MPa*tonnes)
- Carbon emissions (tonnes of CO_2)

Relative

- MPa*tonnes/ tonnes of CO_2 (could also be expressed as the inverse of t CO_2/MPa*t)

The difference to the branch standard of reporting emissions per tonne of cement is that there is focus on cement quality as its strength performance. Some of the current proposed branch improvements risk reducing strength, like when limestone filler is used instead of e.g., fly ash. Limestone is an inert material whereas fly ash contributes to strength.

The proposed concrete sustainability indicators are similar to cement with the difference that with concrete it will be easier to define functional units with a clear value for customers.

Absolute

- Compressive strength times volume = concrete building value in (MPa*m^3)
- Area of wall produced in m^2
- Floor area produced in m^2
- Carbon emissions (tonnes of CO_2)

Relative

- MPa*m^3/ tonnes of CO_2 or kg CO_2/MPa*m^3
- kg CO_2/MPa*m^3 of defined functional unit
- m^2 wall/kg CO_2 or kg CO_2/m^2 wall

Functional units enable the comparison of different materials (Isaksson and Buregyeya, 2020). The required wall strength performance could be viewed based on standards or from first principles and basic calculations. It could be that standards and practices because of different reasons result in over engineering, increasing climate impact and costs without providing additional functional value. E.g., concrete MPa*m^3 could be high but if the strength is four times what is needed then performance is not sustainable. This highlights the importance of studying value and science-based targets for value as is done for the harm of carbon emissions (SBT, 2023).

Strength performance can be further developed including variation as is suggested in Isaksson (2007). This is done by using an indictor derived from the cement performance standard 197-1 and which combines average and variation. The performance is described as the Lvalue which defined the level of where 90% of values are higher. This requires having a data set of at least 20 values to calculate the average and the standard deviation. The EN 197-1 presents the formula: L = Average (n) - kA*standard deviation (n). The kA is a function of n and is 2.4 for n=20. The Lvalue can be used as a more precise customer value for both cement and concrete.

4.3. Opportunity study for Swedish cement and concrete - Analysing

4.3.1 Understanding Analysing

Analysing can be qualitative as suggested in Table 2, but also quantitative if data for performance as y and correlating x-values are available. An important part of Analysing is to describe all the important elements in the studied system. The Process Based System Model (PBSM) exemplified in Figure 2 forms a core part of Understanding Analysing. The proposal is to do the PBSM for the studied areas, which in this case are the cement and concrete production systems, which are presented in Figures 4 and 5. The company internal resources and the external national resources have been presented using the 10 M checklist. Details of these resources are found in Tables 4 and 5.

Table 4. 10 M General proposed checklist for company internal resources for cement and concrete production. Based on Isaksson (2016).

M	Criteria for espoused system resources
Mission	Mission that clearly describes the purpose of the studied organisational system and that describes core principles explaining what company sustainability and sustainable development are and the overall strategy for how sustainability will be achieved. Mission which is compatible with sustainability (doing the right thing). References to SDGs 9, 11,12 and 13 (see Figure 1).
Management	Policies, goals, and strategies for managing and improving process sustainability performance. Business model that is compatible with sustainability (doing the right thing). High level of maturity in following core principles.
Method	Management mode that enables effective and efficient management of key processes with focus on main value adding process and sustainability communication process. A high level of organisational process maturity. Clear integrated process-based management systems for managing policies, goals and strategies. A knowledge management structure identifying know how and competencies needed.
Manpower	Competency for the required tasks. Competency could be seen as education, experience and attitude compared to specifications. High level of maturity in following core principles.
Measurement	Sustainability measurement system that has at least identified the vital few sustainability impacts in terms of value and harm and goals for them. The system follows up performance and change is compared with targets. There is as system for tracking stakeholder satisfaction.
Machine	Adequate equipment and premises for the intended use including hardware and software for measurement systems.
Material	Understanding of upstream part of the value chain. Supplier knowledge. Methods for controlling sustainability of incoming material and information with clear specifications of incoming footprints. Established contracts and good relations with suppliers. Agreed definitions of sustainability in the entire value chain and for incoming material.
Milieu	Good level of physical (effects both personnel and equipment) and social working environment. Organisational culture that supports sustainable performance.

Market	Understanding of downstream part of the value chain. Customer knowledge. Agreed definitions of sustainability in the entire value chain and for delivered products.
Means	Availability of funds for sustainability improvements

The 10Ms in Table 4 cover the internal resources In Table 5 external resources based on the 10Ms have been proposed. In the previous versions of the PBSM (Isaksson, 2019) the external resources have not been classified using the 10 Ms.

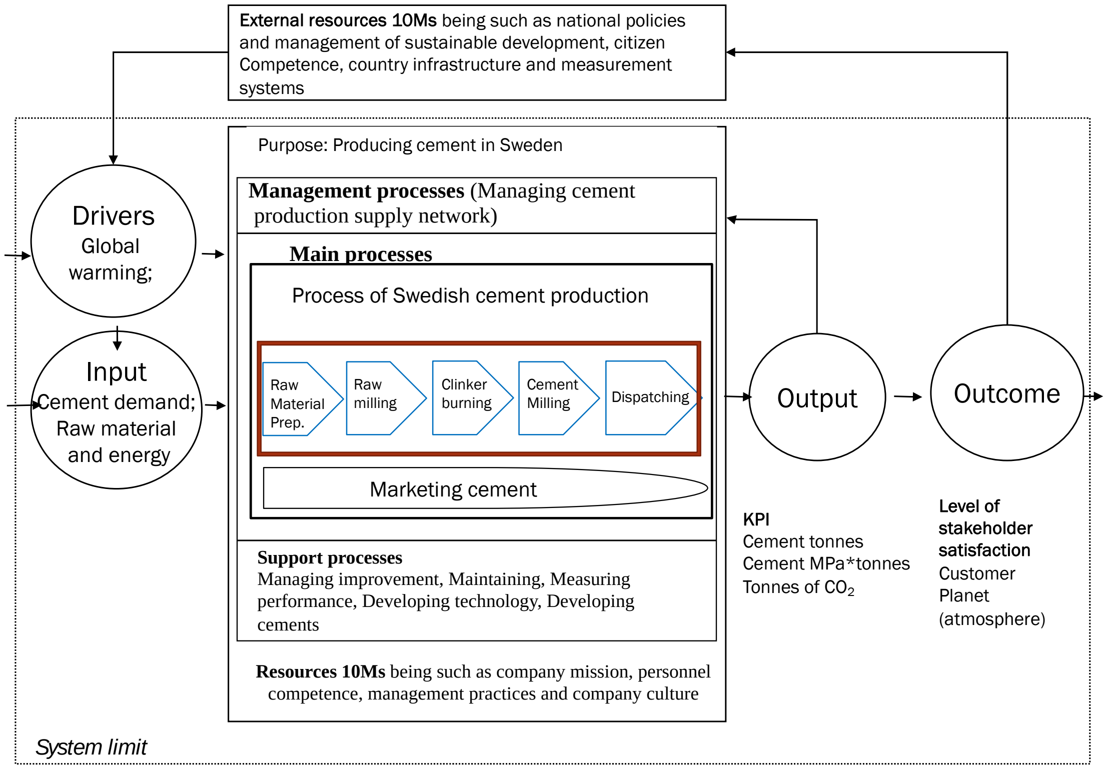
Table 5. Proposed 10 M checklist for external resources with inspiration from Table 4.

M	Criteria for espoused system resources
Mission	National mission on sustainable development. Level of commitment to UN SDGs and UN declarations. Commitment to climate, biodiversity, and poverty reduction. Commitment to development aid. Commitment of national companies, public organisations, universities and NGOs to sustainable development.
Management	Policies, goals, and strategies for managing and improving national sustainability performance (Government and public sector, private sector, universities and NGOs). Business and organisational models, which are compatible with sustainability (doing the thing right). High level of maturity in following core principles (enacting espoused policies). Democratic, effective and efficient national management.
Method	Government management mode, which enables effective and efficient management of key processes with focus on main value adding process and sustainability communication process. Legal structure support for agile organisations and companies including universities. Good business climate. No corruption. High level of process maturity for processes providing housing, food, transport, health care, education, energy, etc. High process flexibility. Balance between democratic bureaucracy and change ability. A knowledge management structure identifying know how and competencies needed.
Manpower	Competent citizens able to do the jobs needed. Competency could be seen as education, experience, and attitude (committed to democracy and improvement) compared to national requirements. High level of maturity in following core principles.
Measurement	Sustainability measurement system that has identified main sustainability impacts in terms of value and harm and goals for them. GNP, Gt of CO_2eq., GNP/capita, GNP per CO_2eq. Development aid. Systems for recording key data for performance and causes. Data for performance change are available.
Machine	National infrastructure with roads, railways, and airlines. IT infrastructure enabling continuous internet access for everybody.
Material	Understanding of upstream part of the value chain. Supplier knowledge. Methods for controlling sustainability of incoming material and information with clear specifications of incoming footprints. Established contracts and good relations with suppliers. Agreed definitions of sustainability in the entire value chain and for incoming material.
Milieu	Good level of physical (effects both personnel and equipment) and social working environment. Organisational culture that supports sustainable performance. High level of trust in society.
Market	Level of competence and free market conditions. Understanding of downstream part of the value chain. Customer knowledge. Agreed definitions of sustainability in the entire value chain and for delivered products.
Means	Budget for sustainable development (reducing carbon footprint, improving biodiversity, supporting poverty reduction)

Tables 4 and 5 and especially Table 5 should be seen as a work in progress. Table 5 is a first version of important general resources, which should be considered when working with a company or a branch for improved sustainability. The different Ms need to be reviewed more in detail and linked to literature.

An important feature of the PBSM is that it presents a snapshot of a situation at a certain time. It distinguishes between what is being done in the network of activities and the resources that support these activities. Resources can in the shorter time perspective, including several process cycles, be seen as constant.

Figure 4. PBSM for Swedish cement manufacturing system

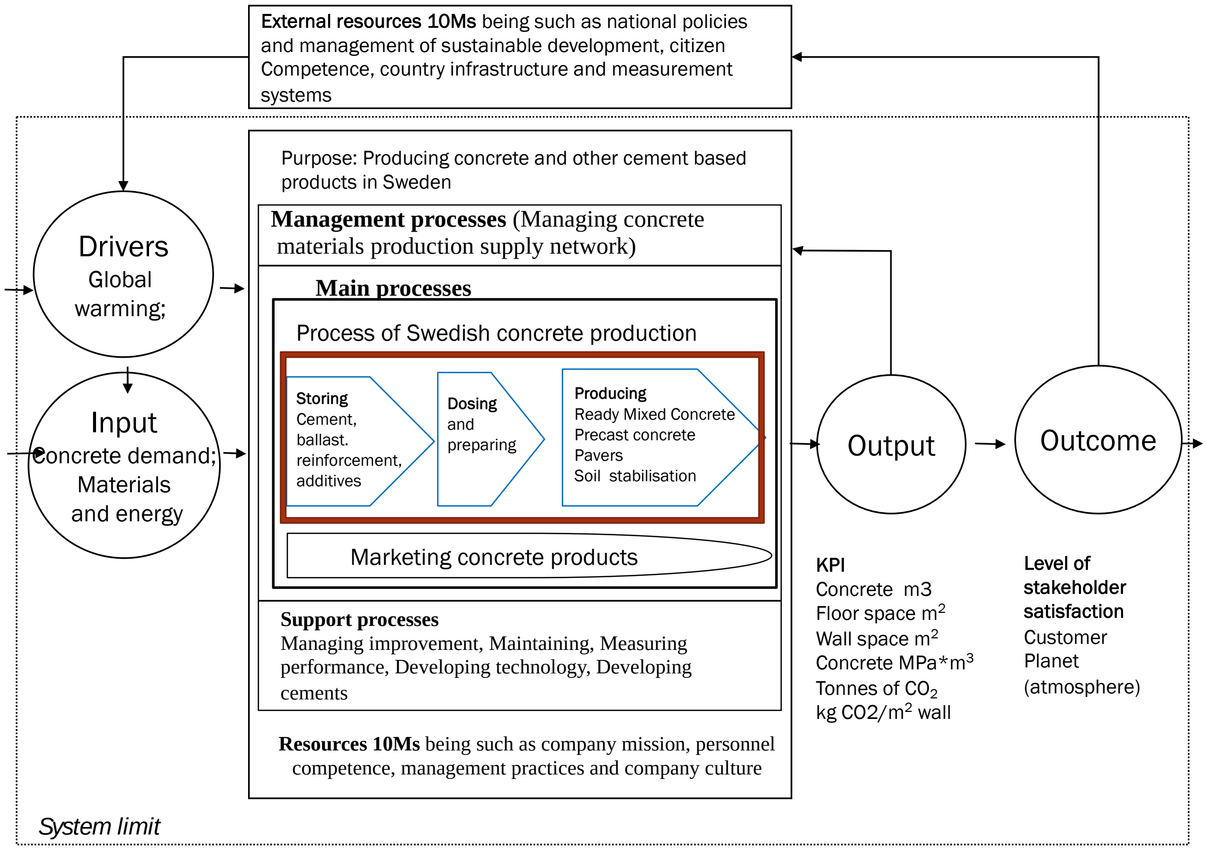


Conclusions from Diagnosing have been included in Figures 4 and 5. The KPIs only focus on user value and the climate footprint. In this simplification cost of production and price of cement and concrete have not been included. The underlying assumption is that customers will have to pay what it costs to make cement and concrete sustainable. This assumption is also the based for the current cement industry strategy of going for Carbon Capture and Storage which could double the cement prices.

The qualitative analysis can be done using the 10M checklist (Isaksson, 2016), which describes common causes for improvement potential In Table 4 changes have been introduced based on reviewing Table 2. The business model mentioned in Isaksson et al. (2022a) and the overall sustainability strategy are included in Mission. Strategies for change are introduced as part of Management. In addition, changes have been made in such a way that the 10Ms only provide criteria for understanding causes for a detected improvement potential in Diagnosing. Issues related to assessing the level of performance are not included here. For each of the Ms and for the branch studied it should be possible to propose systems for rating the resource maturity. As an example, the M of Measurement could be rated for how well sustainability is being reported and based on an assessment like the one done with Sustainability Reporting Maturity Grid (SRMG) (Cöster et al. 2020). The 10 M in Table 4 can be seen as a generic 10M model for company internal resources. It has not been adapted for the building system. This work is left for further research.

Understanding Analysing has focused on describing the studied subsystems using the PBSM. The processes of producing cement and concrete described in Figure 3 as part of the process: "Providing buildings and structures in Sweden" have been presented in Figures 4 and 5. The PBSM has been used to describe the main values and harms identified as important for measuring sustainability. Generally, qualitative analysing could be done first. This part is described using the 10M checklist, which is proposed for identifying both internal resources (Table 4) and externals resources (Table 5).

Figure 5. PBSM for concrete products manufacturing system.



4.3.2 Defining Analysing

In Table 2 the suggestion is to identify the main Ms that could explain an important improvement potential. From a technical perspective cement clinker production is the process that generates the carbon emissions which are the main system harm for both cement and concrete production. Cement clinker emissions are to about 60% generated from the main raw material in Portland cement, which is limestone. About 30% is generated from the fuel used, which often is coal. This would point at the M of Material and how this is managed. Table 2 suggests Mission, Management and Measurement as the three most important causes. Mission relates to the business model. For cement this could be one of the most important causes for continuing to produce limestone-based cement instead of finding other binders with lower or no use of limestone. The enacted business model is maximising sales of a commodity. This means maximising tonnes since this is what is paid for. Producing a commodity in large and capital intensive factories provides the conditions for an oligopoly which is hard to break into. With focus on maintaining profitable and sheltered markets, good profits can be made without much cement or concrete innovation. Improving cement performance by making it stronger would lead to reduced sales and reduced profits. Concrete manufacturers have an incentive to reduce cement use. However, in a sheltered market there are few reliable options for any major changes in the form of new binders. Management is part of the existing Mission and culture and has limited freedom of action. Lack of a Measurement system for sustainability performance could be a major reason for the limited drivers for change. Focus is on reducing carbon emissions per tonne of cement. User value is not included in any of the presented performance indicators. Neither cement nor concrete strength seem to have been in focus. The explanation could be that cement has been relatively cheap and as such it has been used for other purposes than strength. One example is using more cement to speed up drying times for concrete. Method, which includes standards and practices could be another explanation for using more cement than is needed. It is in the interest of the cement industry to maximise cement use in concrete. This makes it interesting for the cement industry to lobby for standards which increase the use of cement. Standards can also be used as a barrier for introducing new cements. The more complicated the requirements and standards are the more likely status quo can be retained. Preliminary results from the SCMForceI project indicate that introducing new materials and new cements into the Swedish market is extremely complicated.

At this stages the 10M analysis only provides indicative answers to the main causes being barriers to change towards more sustainable cement and concrete production. Ms requiring further studies are Mission, Measurement, Material and Methods. The results are mainly based on a review of cement manufacturing.

4.3.3 Measuring Analysing

Table 2 suggests calculating how much more cement building value in MPa*tonnes could be produced using available alternative raw materials. This requires having information about the total building value production, which then can be compared with how much additional building performance that alternative binders could provide and to which carbon footprint. This information mainly contributes to Diagnosing of the improvement potential. In Measuring Analysing the question is how to assess the main reasons are for this not happening. Based on 4.3.2 this would be putting some weights on Mission, Measurement, Material and Methods as barriers. How to do this is part of future research.

4.4. Opportunity study for Swedish cement and concrete - Solving

Solving has not been studied in any detail previously. Table 2 provides limited input for how to understand, define and measure Solving.

4.4.1 Understanding Solving

Product innovation is mentioned in Table 2. An important question is where in the 10M innovation could be residing or if it is missing? One interpretation could be that all resources should be subjected to continuous improvement whether incremental or major. Innovation should therefore be present in all the Ms. When viewing the Ms identified in 4.3.3 the question is if there are feasible solutions? What would be needed to change the cement manufacturing business model? In Table 2 the use of LC3 is mentioned as a solution to reduce carbon emissions. This would not require a change of the mission and the solution is being promoted within the cement industry. The LC3 would be an improvement and a step towards sustainability but not a solution for sustainable cement. The cement industry solution is Carbon Capture and Storage (CCS), which will enable continuing with the same business model with continued focus on the carbon emissions and without a need to discuss produced building value. With this in view, there might be limited interest in introducing new binders. Understanding Solving could be defined as understanding if there is an acceptable solution that can be worked with and which within a reasonable time could lead to realising at least parts of the existing opportunities.

Table 6. Understanding Solving based on Ms identified in section 4.3.3

M	Description	Solution	Solvability with 1 being very difficult and 5 being very easy
Mission	Business model maximising tonnes of cement as a commodity	Changed business model paying for performance in terms of building value in concrete compared to carbon emissions	1
Measurement	Building value is not measured Drivers for change are not explicit and they have not been assessed.	Introducing cement and concrete value performance in reporting. Introducing assessments, maturity levels for main Ms in the studied system.	3
Material	Limestone based clinker with a high carbon footprint is used. Current strategy is to reduce clinker component which also risks reducing strength.	Using more slag to reduce clinker content Introducing new cements like Limesone Calcinated Clay Cement LC3 which reduce clinker to 50%. Other new cements	2
Methods (linked to new cements in Material)	Current standards and rules are very difficult to change	The solution is both proving the business case for new cements and materials to create interest and then to navigate the standards jungle. The current business model reduces interest in standard work.	1

The best option forwards based on Table 6 is to work with Measurement. This could be seen as a prerequisite for good communication which would be needed to create interest for change. Presenting facts on the improvement potential based on Diagnosing of cement and concrete performance in Sweden and then the suggested causes for having this potential could be the first step in creating interest for change. Even focus on R&D for sustainability performance measurements as suggested, requires an agreement of this being important. A leading coalition is needed, which then can suggest a strategy for change. Understanding Solving requires more work that should include an assessment of the agency for change in the studied system.

4.4.2 Defining Solving

Table 2 suggests: "Defining solutions and strategies for these". Defining Solving needs to be seen in the context which in this case with existing agency points at work with the Measurement system. Improvements are needed for better describing sustainability performance and then collecting data to study the Swedish cement and concrete sustainability performance over time. Best performance targets need to be identified to enable an assessment of the existing improvement potential in terms of building value per carbon footprint. With performance data it becomes possible to better identify both direct technical causes and indirect causes in the form of maturity of system resources. Business excellence models assess performance both in terms of results and enablers. The 10Ms form a description of the enablers. It could be discussed if understanding solving includes finding solutions to identified gaps in resources. The magnitude of the gaps should be presented under Measuring Analysing, see 4.3.3.

4.4.3 Measuring Solving

In Table 2 the suggestion is: "Setting targets for level of sustainability and rate of change that corresponds to sustainable development". This is an important result from an Opportunity Study and should form input for the process of Improving. However, Measuring Solving could also be seen as following up time and resources consumed work with the defined solutions. An improvement opportunity needs to produce more value than it consumes. A rule of thumb that can be used is that a good solution should realise half of the existing potential in one year and that the payback for the improvement investment should be less than two years. However, this rule would not be applicable for the example of improving measurement. Better measurements would not directly lead to any emission reductions costs, but they should provide the means for realising improvement potential.

4.5. Summary of the proposed UDM-DAS matrix

In Table 7 the results from the review are summarised to describe the content of a Sustainability Opportunity Study for Swedish cement and concrete. The LMPa used in Table 7 is the strength performance including variation (Isaksson 2007).

Table 7. Proposed UDM-DAS matrix for Swedish cement and concrete

	Understanding	Defining	Measuring
Diagnosing	The value chain of building starts with raw materials going over the processes of, cement and concrete production, building and use of buildings and demolition/reuse to building value and harm created (See Figure 3) Swedish sustainable building has the main sustainability impacts of user value, carbon emissions and affordability. Main stakeholder value for cement and concrete are produced quantities times strength and volume. Main harm for cement and concrete production is carbon emissions.	Sustainable Swedish building is: "Satisfying building and construction user needs while being at least affordable and carbon neutral". Swedish cement and concrete sustainability are defined as: "A state where maximal compressive strength quantities are produced with a minimal climate impact". The goal is to reach carbon neutrality latest by 2045.	**Absolute cement indicators** Compressive strength times quantity = building value potential (L MPa*tonnes) Carbon emissions (t CO2) **LMPa-target** needs to be studied but could initially be set at 60 MPa **Tonnes needed** depend on concrete need and the different functional strength needs **Relative** LMPa*tonnes/ t of CO2 (could also be expressed as the inverse of t CO2/LMPa*t) **Absolute concrete indicators** Compressive strength times volume = concrete building value in (LMPa*m3) Area of wall produced in m2 Floor area produced in m2 Carbon emissions (tonnes of CO2) **Relative** LMPa*m3/ tonnes of CO2 or kg CO2/LMPa*m3 kg CO2/LMPa*m3 of defined functional unit m2 wall/kg CO2 or kg CO2/m2 wall

Analysing	Description of the studied cement and concrete manufacturing systems using the PBSM (See Figures 4 and 5) Qualitative Analysing based on the 10M for internal and external resources (See Tables 4 and 5).	The main Ms identified for cement and concrete industry are: Mission - Business model Measurement - How to measure sustainability and sustainable development Material - Cement development using other materials than limestone (alternative binders) Methods - Standards and practices	Future research includes operationalising Business Model Maturity Adapting and developing the SRMG (Cöster et al 2022) for assessing cement and concrete measurement sustainability maturity Assessing sustainability performance of different alternative binder solutions Assessing limiting effects of standards
Solving	**Focus on Measurement**. Measuring cement and concrete building value compared to needs. Introducing cement and concrete value performance in reporting.	**Cement and concrete sustainability measurements** are defined in terms of values and harms produced, where value is expressed as strength times amount produced compared to the assessed structural user need. Harm is defined as the carbon footprint embedded in the stucture .	Time plan and budget for establishing current cement and concrete performance based on building value and climate impact. Best performance targets are defined. This will enable finalising the diagnosing of the improvement and analyse the contribution of main causes such as type of cement used and standard limitations. The following SOS review will then lead identifying solutions such as change of standards and introduction of new cements.

5. Discussions and conclusions

The study has several limitations and should be seen as a conceptual contribution for planning of ongoing research. The presented results will be further discussed in the research group and modified. When there is a common understanding in the research group different stakeholders will be involved in further development.

The planned work includes presenting historic Swedish cement and concrete sustainability performance data using the proposed performance indicators. This will enable calculating an improvement potential in terms of the difference in carbon footprint when creating the current functional value with minimised use of cement compared to the actual.

5.1 Discussions

The purpose of this paper was to carry out a complete Sustainability Opportunity Study (SOS) for Swedish cement and concrete while simultaneously reviewing and proposing improvements for the SOS practice. It proved to be a challenge to stay at a chosen system level. For the sake of clarity, the Swedish building value chain has been reviewed as the main system of which concrete and cement manufacturing constitute sub-systems, see Figure 3. Having examples from cement and concrete manufacturing helped in redoing the SOS matrix. Since this was a mainly conceptual exercise the proposed matrix in Table 7 should be seen as a step in the ongoing research. The UDM-DAS matrix has been reviewed using the logic of Understanding the different parts of the DAS improvement logic, followed by how to Define and Measure it. When final criteria have been set the matrix could be used both as guidelines and for the purpose of assessing the maturity of conceptual understanding in a studied system. Such a work could answer the questions of how well Diagnosing, Analysing and Solving of a studied system have been done.

The performance indicators proposed in Table 7 need to be checked with data to see if they are usable. The L-value in its original form requires 20 values to be calculated, but the logic can be used with smaller groups of data.

The main novelty in this work is including customer user value in addition to footprints. Current building reporting and reporting from cement and concrete production has a focus on reporting mainly footprints.

The 10 M lists will be used in the research to organise and test the assumptions of the main causes to the detected improvement potential. They will be further developed to check correspondence with how main causes are interpreted by different stakeholders. The main Ms could be developed to become maturity assessments as has been done with the Sustainability Reporting Maturity Grid (SRMG) that measures how well sustainability reporting is done (Cöster et al. 2020).

5.2 Conclusions

The overall conclusion is that the SOS theory seems to provide a structure for a critical analysis of system opportunities.

5.2.1 Swedish cement and concrete sustainability reporting

The results in Table 3 support earlier observations (Isaksson et Rosvall, 2020) of a low level of sustainability reporting maturity in Sweden. This justifies the current effort of clarifying how cement and concrete sustainability could be understood, defined, and measured. In Table 3 the part of defining sustainability and sustainable development has the lowest score with 0.8/5 which indicates that there is reason for starting the work from creating a common understanding.

5.2.2 Doing a Sustainability Opportunity Study (SOS) for Swedish cement and concrete while critically reviewing the existing theory

The result of the work presented in Table 7 constitutes a total remake of the previous Table as presented in Rosvall and Isaksson (2021). Still, this is only a proposal which will be discussed in the research group. The proposed definition for Swedish building sustainability has been modified from earlier to clearly include both value and harm. A 10 M analysis for external resources has been proposed and the 10 M for internal resources has been modified. Both are generic checklists needing a further adaptation for building. There are no data yet to enable Diagnosing of the improvement potential for reduced carbon emissions. However, the assumption is that there is a considerable potential. Analysing of causes points out Mission, Measurement, Material and Methods. At the level of Solving the suggested way forwards is to establish a measurement system that will enable communicating the existing potential and the identified main causes for it.

5.2.3 Further research

Further research is needed both for the theoretical structure of the SOS. The proposed practice needs to be tested, while discussing if the structure supports understanding sustainability opportunities or not. The testing of the structure is done in the context of Swedish cement and concrete manufacturing as an example. However, the expectation is that the SOS theory is general.

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