Urban Insight
By Sweco

Circular materials in infrastructure

The road towards a decarbonised future

Lund-Arlöv 4-track project, Sweden. Around 92% of the existing macadam was sorted near the site and reused instead of quarrying new material.

More than 100,000 billion kilograms of natural resources are consumed globally.

Europe's annual use of aggregates - the size of 33 sections of Matterhorn peaks

By pursuing possible coordination with other projects nearby, there could be considerable benefits for all involved

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Introduction

By managing the huge amounts of natural resources we use for building our infrastructure, we can take a significant leap towards a circular society. If we were to go from today's circularity rate for aggregates of 7 per cent to 20 per cent, we would save around EUR 6 billion and 546 million tonnes of annually produced aggregates in Europe, which would make resources last longer and reduce the need to open new quarries, as well as the need to landfill buildable materials.

More than 100 gigatons, or 100,000 billion kilograms, of natural resources were consumed globally in 2019, half of which were minerals and ores. Everything that does not grow and comes from the ground is mined in the form of minerals and ore. All finite, non-renewable resources. The largest share of these resources, close to 40 per cent, is used for construction and infrastructure.

The world economy is still largely linear, and the extraction of natural resources plays a significant role. In fact, global circularity has decreased from 9.1 per cent in 2018 to 8.6 per cent today, according to the latest Circularity Gap Report[1].

Materials on infrastructure projects, such as soil, stone and gravel, are used universally. But despite the large quantities of materials handled and the significant environmental, economic and social effects they have, the average citizen often has limited knowledge of how these resources are handled. With this report, we want to contribute to capturing the huge untapped potential of a more circular management of aggregates in infrastructure while meeting societal needs and the UN's sustainability goals.

5 reasons
for a more circular aggregates sector

- Reduce costs and climate impact
- Save natural habitats, fewer quarries and landfills frees up more land
- Make scarce resources last longer
- Fewer lorries transporting materials resulting in less congestion and wear on existing roads
- Less pollution

Aggregates are granular materials used in construction. They include sand, gravel, crushed rock, recycled and manufactured aggregates and excavated materials.

The circular economy focuses on creating more sustainable value creation, through optimisation of the use of resources.

More sustainable production means preventing existing goods from becoming waste after only one use, through reduced use of primary raw materials and increased use of secondary raw materials.

The EU goal is for 70 per cent of non-contaminated construction and demolition waste to be recycled.

Additionally, this report aims to raise awareness of the huge impact of infrastructure, in terms of aggregates used and its environmental and financial costs. The report investigates how we can progress towards circular infrastructure through a more efficient management of aggregates. What can be done to minimise the amount used? How can we manage aggregates in a more circular manner within the value chain? And what are the key actions and roles? We look at current practice, barriers that exist and the best solutions to manage uncontaminated and buildable materials. It is vital that we close the knowledge gap that lies between society today and a more circular future. Infrastructure will be vital in the transition to a low carbon future.

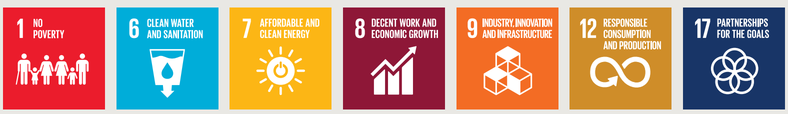
The management of infrastructure aggregates can be complex as it generally involves a multitude of stakeholders and tasks across the value chain. Aggregates are a resource and emerging circular approaches can lead to improvements in sustainability compared to current practices. Even marginal savings can lead to major benefits, such are the quantities that are managed. Improvements early in a project, for example, in how we classify, report and track these materials, can enable larger savings later on when access to improved data opens up more opportunities.

20% circularity of aggregates could save up to EUR 6 billion and half a billion of tonnes of annually produced aggregates in Europe.

Study by Sweco

UN Sustainability Goals
Through the United Nations, the global community has agreed on seventeen sustainable development goals (SDG). Minerals play an important role in fulfilling these goals because several of them involve an increase in the usage of resources. SDG1 (No Poverty), as well as SDG6 (Clean Water and Sanitation) and SDG7 (Affordable and Clean Energy) all require an increase in resources. Also, circularity is linked to SDG8 (Decent Work and Economic Growth) and SDG9 (Industry, Innovation and Infrastructure).

SDG12 (Responsible Consumption and Production) and SDG17 (Partnerships for the Goals) link, on the other hand, to the need to manage resources more responsibly.



An under-appreciated issue?

Infrastructure materials are not widely understood by society, despite infrastructure being a critical part of our lives, just like energy, water and waste management. There is a much greater engagement, for example, in waste and recycling across society because we are actively involved in their management. As the climate crisis unfolds, there is an increased awareness of the importance of renewable energy and water stress. By contrast, there is less engagement in how infrastructure materials are used, even though we use infrastructure every day. Our relationship with it is much more passive.

And, while European decision makers in general have taken the circularity issue on board, they may have yet to fully grasp that in a sector where weight defines your market, decisions which work at the local level are what matters in the end.

It's easy at the top level in the EU to make a political decision but, when it comes to the aggregates business, this decision must be implemented locally to meet individual Member State requirements.

Brian James, European Aggregates Association UEPG.

We can´t only concentrate on the rapidly developing visible parts of the future possibilities of circularity, we also need to look down under the ground to the vast but unassuming quantities which we shuffle around in our infrastructure projects.

Karin Larsson, Team Manager Waste and Resource Management, Sweco

More than 100 gigatons, or 100,000 billion kilograms, of natural resources are consumed globally each year.

The annual use of aggregates in Europe is 4.2 billion tonnes – only 7 per cent is part of the circular economy

Europe's use of aggregates in 2019 was 4.2 billion tonnes.[10] This is equivalent to 33.3 times the amount of the top 300m of the Matterhorn, about as high as the Eiffel tower. With close to this quantity of aggregate, we could cover the whole of Denmark to a depth of 33 cm, or Belgium to a depth of 47 cm, each year.

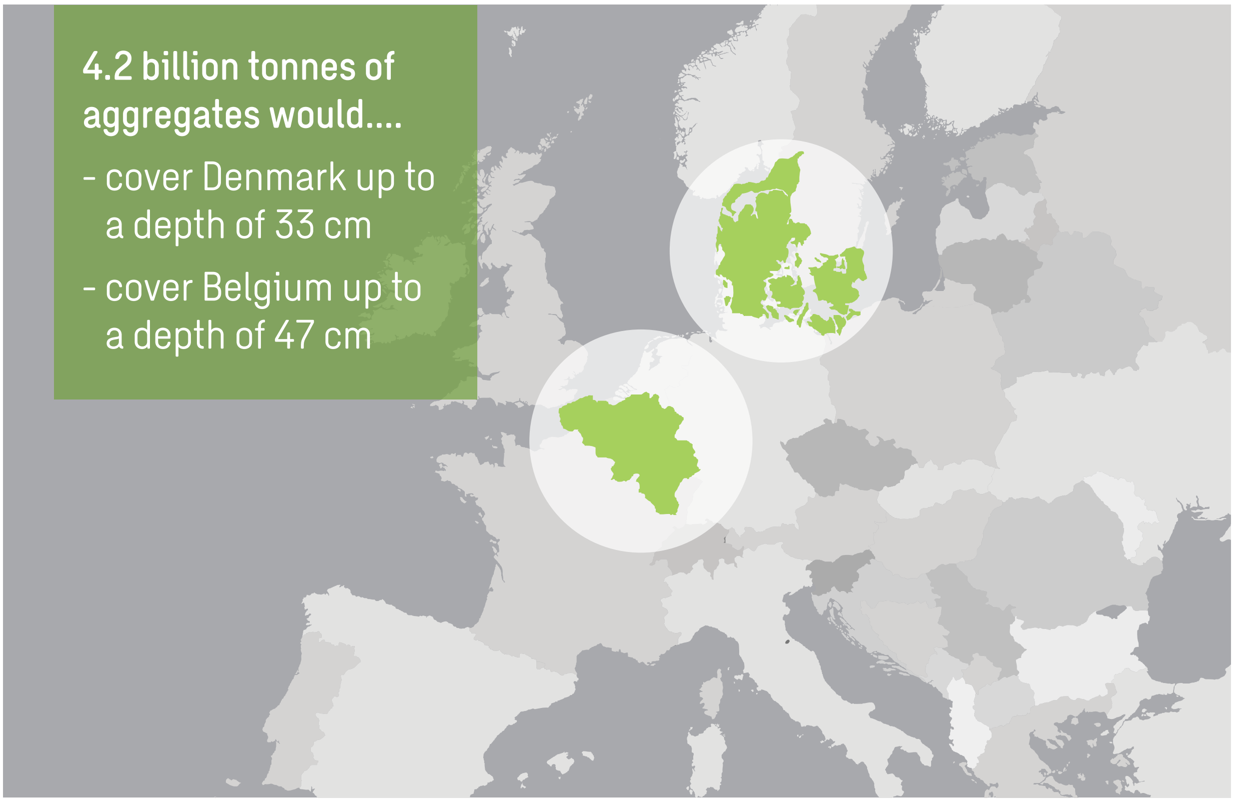
And yet only about 7 per cent of these vast 4.2 billion tonnes are part of the circular economy. The processes by which aggregate materials are managed are complex and include geotechnics testing and classification, tender specifications, procurement, regulation, planning and permitting, skills, data, culture, networks, collaboration, business models, supply chain and logistics.

Overall, the current picture is mixed with regards to circular practices. Successes are often thanks to local or project factors rather than institutionalised and universal circular systems. The European Aggregates Association states that up to 20% of the current total demand of aggregates could be recycled in the long run.[10]

Potential savings of EUR 6 billion per year

What would happen if we increased circularity from 7 to 20 per cent? Which untapped possibilities and savings would there be? New analysis by Sweco shows that we could save around EUR 6 billion each year in aggregate costs and just over half a billion of annually produced aggregates in Europe, the same amount of material that Germany produces in one year.

The EUR 6 billion per year could be achieved by saving the cost of virgin material, based upon prevailing market prices, by increasing reuse and preventing the extraction of raw materials from quarrying. There would, of course, be costs associated with the circular use of aggregates, including crushing and transport, but there would nevertheless be a reduced dependency on virgin material. There could also be associated benefits in terms of the reduction of transport, traffic-related pollution and environmental degradation. It is inevitable to ask oneself which other untapped possibilities and savings there would be. And, how could we manage such a shift?




Europe's annual use of aggregates – the size of 33 Matterhorn peaks
4.2 billion tonnes is equivalent to 33 times the top 300m...
....of the Matterhorn mountain, the same height as the Eiffel Tower.

The effect of aggregates on the climate

In the UK, construction, operation and maintenance of infrastructure assets result in approximately 16% of total carbon emissions[4]. On many projects, quantities of surplus materials can be in the hundreds of thousands of cubic metres and, on large scale projects, the quantities are in the millions of cubic metres. In Sweden, the National Transport Agency[5] estimates that to transport 10,000 tonnes of excavated rock 10 km for disposal, a lorry must make 300 round trips, releasing 12 tonnes of CO_2e, costing around EUR 20,000. According to the Swedish Transport Agency, the shadow cost of carbon (the cost of carbon emissions to society) is 7 kr/kgCO_2e. If we apply that figure to the 10,000 tonnes of excavated rock, it would correspond to a cost of about EUR 8400. So, on top of the paid costs, the hidden costs of the carbon are an additional 40 per cent. There are also impacts associated with the management, transport and use of circular aggregates but, through good planning, these should be smaller.

Current circularity goals

The circular economy is a key factor in reaching the aims of climate neutrality by 2050. At the EU level, this is highlighted in the new Circular Economy Action Plan launched in 2020 as part of the EU Green Deal.[6] The EU goal is for 70% of non-contaminated construction and demolition waste to be recycled by 2020. This includes excavated materials.

The challenge is to maximise circularity of materials through optimal use and minimisation of associated activities such as transport. To this end, a great deal is yet to be achieved.

Availability and abundance

In some societies, such as in the Nordic countries, raw materials like rocks and sand are regarded as cheap and abundant. In other societies, such as the Netherlands, there is less access to raw materials which increases the need for more circular methods.

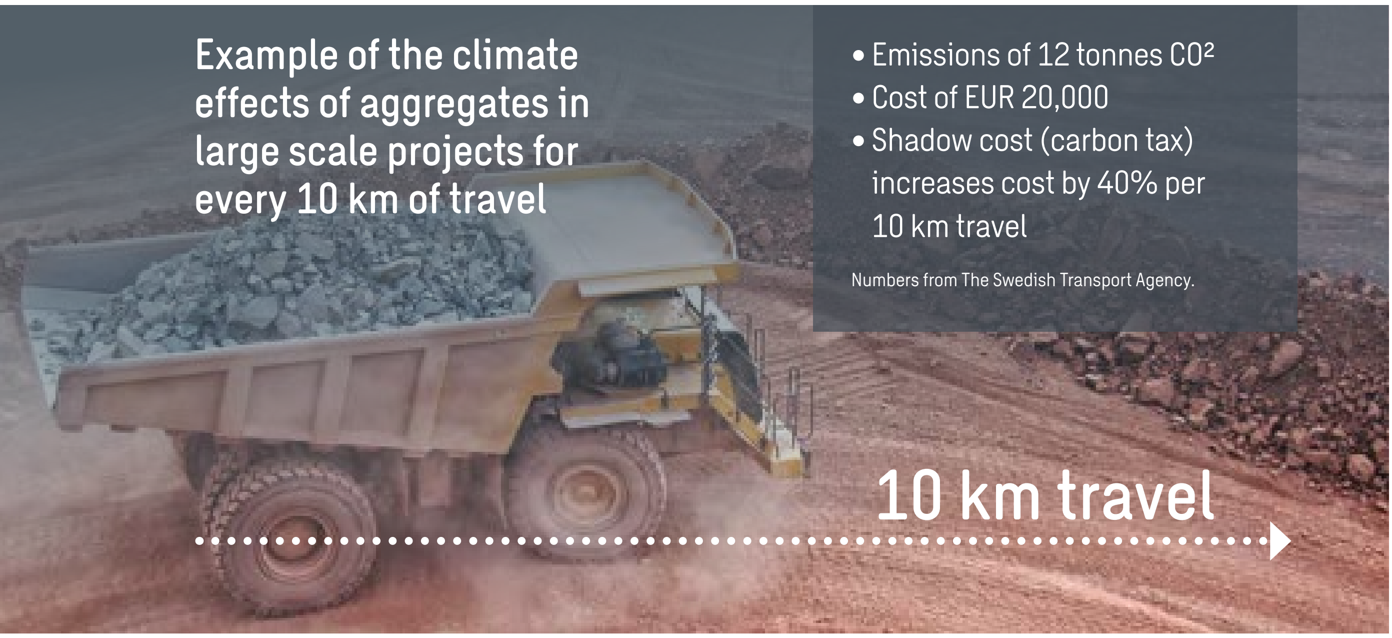
Data reporting

There are shortcomings in the statistics where, for example, materials that are used as construction construction materials that are used to cover landfills are usually included in the statistics as recycling.

There are divided opinions in the industry as to whether this should actually be classified as recycling. If you see aggregates as a resource, landfill cover should not be seen as anything other than downcycling, as the material 'disappears' from the cycle.

Karin Larsson, Team Manager Waste and Resource Management, Sweco

There is also a lack of data on the quantities that are excavated. Without seeing the full picture, we cannot understand the scale of the challenges or benchmark the benefits of potential solutions. The lack of statistics indicates that these materials are not yet fully regarded as a resource.



Future trends

There are several large-scale, long-term trends that will affect the aggregates market and are therefore important to consider.

- Growth in population.
- Increased urbanisation, two-thirds of the world's population will be living in cities by 2050.[7]
- Demographic differences and the needs of citizens.
- Pressure on maintaining ecosystems and reducing biodiversity losses.[8]
- Energy transition, renewable energy and requirements for new infrastructure.
- Challenge to maintain an aging infrastructure.
- Increased expectations and regulations for sustainable solutions.

The citizen's perspective

Water companies are criticised for leakage rates of 20 per cent when their commodity is lost due to leaky pipes. Although infrastructure materials are complex in that they can't just be reused anywhere due to their properties, type etc, there should also be much greater awareness of the need to manage this resource system more effectively. The goal should be to make their usage much more visible to the society, as well-informed public attitudes can influence decision-makers.

Infrastructure materials are not just soil and rocks. They are resources with commercial, environmental and social value, which require intensive management. They are also finite.

Citizens can be affected by vehicle movements importing and exporting materials on projects. Noise, dust and vibration, as well as increased congestion, are amongst the most complained-about impacts.

A well-managed system with a higher degree of circularity, especially in urban areas and with areas set aside for materials management, can help reduce vehicle movements and therefore nuisance. Space taken up by quarries and landfills could also be put to other uses.

Aggregates handling is often on a very large scale, involving large sums of money, mainly public money. Since the use of these materials is currently not very circular, societies are losing out on large sums of money and, at the same time, impacting our own environment. There is strong public interest in closing loops.

Alastair Carruth, Consultant, Waste and Resource Management, Sweco

Major challenges, local solutions

The need for the transport of heavy material makes circularity, as in the production of aggregates and transport of materials between projects, mainly a local issue. The need to coordinate materials between different projects and players in the industry makes circularity more relevant in urban areas. In or around cities, it is often challenging to find suitable areas in which to manage materials and there can be problems relating to regulatory conflict. One reason the aggregate sector is not yet fully circular is the weight of the product. Rocks used for aggregates are normally 2-3 times as heavy as water. This normally means that if you transport a lorry of aggregates any further than 30 km, the transport can cost more than the value of the load. This again means that the environmental footprint of the material decreases and the financial value increases the closer the quarry is to the project the material will be used.

On top of this, the transportation of aggregates is a source of climate emissions and congestion. Consequently, you are generally limited to relatively local use of the material, be it virgin or circular. Available space for intermediate storage is also limited in urban areas. And, if you cannot find any use for the material locally, 'surplus materials can be disposed of for relatively little extra cost.'

The circular use of aggregates in Europe has great potential. Local resource management in infrastructure is the key. It needs to be supported by systems on a larger scale, e.g., coordination of materials between different projects and players.

Elisabeth Gammelsæter, Senior Industry Advisor, Sweco

Meeting supply with demand

Based on the future needs of investment in transport infrastructure, the Geological Survey of Sweden predicts that the demand for aggregates will continue.[9] Society's demand for aggregates can partially be met with recycled material from construction; however, it is expected that the extraction of aggregates will still be needed to fulfil society's needs. The European Aggregates Association states that "In practice, the available number of recycled aggregates of the appropriate quality would not allow for the complete substitution of natural aggregates. Even with the total recycling of all construction and demolition waste, it would only cover some 12-20% of the current total demand of aggregates."[10]

Material classification has a significant impact on their further use. Materials are subject to testing, risk assessment, classification and evaluation. Contaminated materials are problematic. Materials are tested for the presence of contaminants that determine whether they can be reused or if they should be disposed of. Depending on the situation, sorting and remediation is possible but it adds to the steps that need to be factored in. This report discusses only those materials that are non-hazardous and suitable for use.

The type and characteristics of materials are a major factor in how or if they can be reused or recycled. Materials to be managed on projects can include soil and stone, crushed rock, gravel, sand, ballast material, peat, silt and more. Each type of material has several sub-categories. Added to that there is the question of whether the materials are contaminated and, if so, to what degree, where the materials are located in relation to where they might potentially be reused, and the timing of their extraction and filling. Furthermore, there are logistical challenges such as transport and storage, the need to obtain land to manage and store materials on projects and regulatory requirements that need to be fulfilled. The picture can become quite complex. Digital tools are invaluable in identifying the factors that affect a project, weighing up the interplay between them and identifying optimal solutions.

Lund – Arlöv, 4-track project
Reuse of infrastructure materials in focus
This is a major rail infrastructure project where the 11 km stretch between Lund and Arlöv in southwest Sweden, is going to be upgraded from a double-track to a 4-track in order to increase capacity. In addition to the widening of the track area, four stations are being rebuilt or newly-built and new bridges and tunnels are being constructed across roads and rivers. To stimulate sustainability innovation, the project features environmental bonuses in the main contract. One aim is to reuse 40% of existing materials in the new tracks and 80% of existing materials on a temporary track that is to be used while works are ongoing. Also, excavation materials are to be reused as much as possible. Other sustainability aspects driven by the bonus system include the use of fossil-free fuels, reduced climate impact from the use of steel and concrete, biodiversity, technical innovation and the use of electric vehicles.

In 2020, around 92% of the existing macadam (ballast) was sorted near the site and reused instead of quarrying new material. Also in 2020, 325,000 m3 of surplus earth had to be managed, of which 25% was used in the construction of noise barriers, 30% went to local redevelopment projects and the rest was sent to Malmö for redevelopment projects in the city's harbour area. In 2021, around 350,000 m3 of soil was managed, of which 200,000 m3 was surplus. 10% of this was used for the construction of noise barriers and 20% was used for a project in the harbour in Malmö. 200,000 m3 will be needed in the future for remediation and restoration works, so earth for this has been set aside. Around 82% of old macadam has been re-used.

Challenges in sustainable material management
Planning of excavation works is essential for sustainable construction. There needs to be cooperation between projects that need materials and projects that have a surplus, as well as cooperation with the authorities. A systemic assessment of the environmental/sustainability aspects is also essential to determine the best usage of the materials. These aspects include e.g., transportation distances, contamination, usage of public funds and potential purposes. Excavation materials are often considered contaminated and not a natural resource, which restricts their potential usage. Additionally, it is also essential that the receiving party has their permissions ready in time.

The project won the Sweden Green Building Award in the sustainable infrastructure category.

Klostergården station, Sweden. Image by Lund Municipality and Sweco.

Hjärup station, Sweden. Image by the Swedish Transport Agency (Trafikverket) and Sweco

Client: Swedish Transport Agency
Designer/Architect: OHLA/NCC
Location: Lund to Arlöv, southwest Sweden
Role of Sweco: Construction control , Lund-Flackarp section

The 'NIMBY' challenge

'NIMBY' (Not in My Back Yard) is defined as 'facilities which offer useful services to the general public and are often considered necessary by society, but almost everybody agrees that they should be placed outside their neighborhood'. This reaction makes industries and infrastructure hard to place, as they often generate opposition from affected stakeholders. The management of materials and minerals can cause increases in traffic, noise, dust and cause problems around the use of land, which can make them unpopular with neighbours. This is relevant for circular materials as well as for virgin aggregates, mines and many necessary but unpopular installations and constructions.[11]

Environmental impacts

There are significant environmental impacts associated with aggregates and infrastructure. Transportation and excavation of materials produces CO_2, CO, CH4, NOx, volatile organic compounds (VOC) and particulate matter, which impact human health and the natural environment, especially in the vicinity of projects. Other environmental risks include dust, vibration, spills in the natural environment and road accidents. Traffic, noise and dust are amongst the most common causes of objections to construction projects. There is also increasing focus on the cost of reducing natural habitats by building infrastructure. In June 2022, the Norwegian Ministry of Infrastructure asked the transport directorates to present their new national transport plan one year earlier than agreed, in order to reduce costs as well as the impact on nature and the climate by increasing the focus on maintenance. The focus on operation and maintenance and on prioritising the projects which have already been started has been confirmed in the Norwegian Government's state budget for 2023, which was presented in October 2022.

The local perspective

The Nordic Countries have higher aggregate production per person compared with other European countries. Access to large sources of virgin materials is relatively high and weather and population densities are also a factor. Rain, storms and frost call for a higher yearly consumption of aggregates. Infrastructure must be sturdy, to withstand the weather. Norway has a particularly high production per person due to exports. The countries which have the highest percentage of recycled aggregates have an aggregates levy which is exempted for recycled aggregates (UK) or have a shortage of available natural rocks (the Netherlands). In the Netherlands, however, due to a shortage of natural rock that can be used for road foundations, crushed concrete and masonry granulate is used. Whilst this is circular and can be reused over and over again, it is also downcycling and can prevent this material from being used in new concrete constructions or products.

The 'NIMBY' challenge could be described like this: we want smart phones and smart watches, more electrical vehicles but no mines. We want to cook warm food and get our electricity from renewable energy but do not want to live close to wind farms or have them within our sight. We need the end product but don't want it to be produced next to us or where we live.

Elisabeth Gammelsæter, Senior Industry Advisor, Sweco

A success factor for countries that have achieved a high share of recycled aggregates is that there is a greater emphasis on trying to integrate recycled material. There is also a better understanding and confidence in what the material can and cannot do.

Brian James from the UK's Minerals Products Association and the European Aggregates Association (UEPG)

Economics and time are big traditional drivers

Given that infrastructure projects often generate millions of cubic metres of surplus materials, the management of these materials is a significant project cost and local disposal to landfill can be financially more viable than reuse slightly further afield. The sector is transitioning from a model where low cost has traditionally been the driver with all components of the market configured towards linearity rather than sustainability. However, the sector is gradually developing, as the discussions about sustainability and climate evolve. There's also a risk of depending on local construction projects for reusing surplus materials since timing is a factor. When aggregates appear, it doesn't mean that local projects for reuse of those materials are available, which means there is a matching problem. In that case, storage space is needed. The lack of areas for sorting, crushing and handling (sustainable management of these materials) is also a limitation.

Better collaboration may succeed in identifying a greater range of options for storage. This could open up the market to more businesses and not just those who already have storage facilities.

Procurement and policy geared towards linearity

Procurement of public infrastructure contracts have traditionally focused on low cost. Risk-averse attitudes have also led to 'gold-plating' specifications in procurement where very high requirements are stipulated which are often better than what is really necessary. This makes it harder for recovered materials to be used, even where they could have been used.

Regulating the circular economy using linear-era legislation

Current legislation on the classification of materials excavated from projects can create barriers to reuse. This includes the classification of materials as waste, which requires additional measures to handle it despite it being no different in character to other materials that are not classified as wastes.

The regulation of surplus aggregates still often treats materials as if they are waste that should be safely disposed of, even when they are a clean and suitable resource. Without compromising the safe disposal of contaminated waste, circular practices should be embraced thanks to, rather than in spite of, regulatory frameworks.

Attitudes and carbon costs

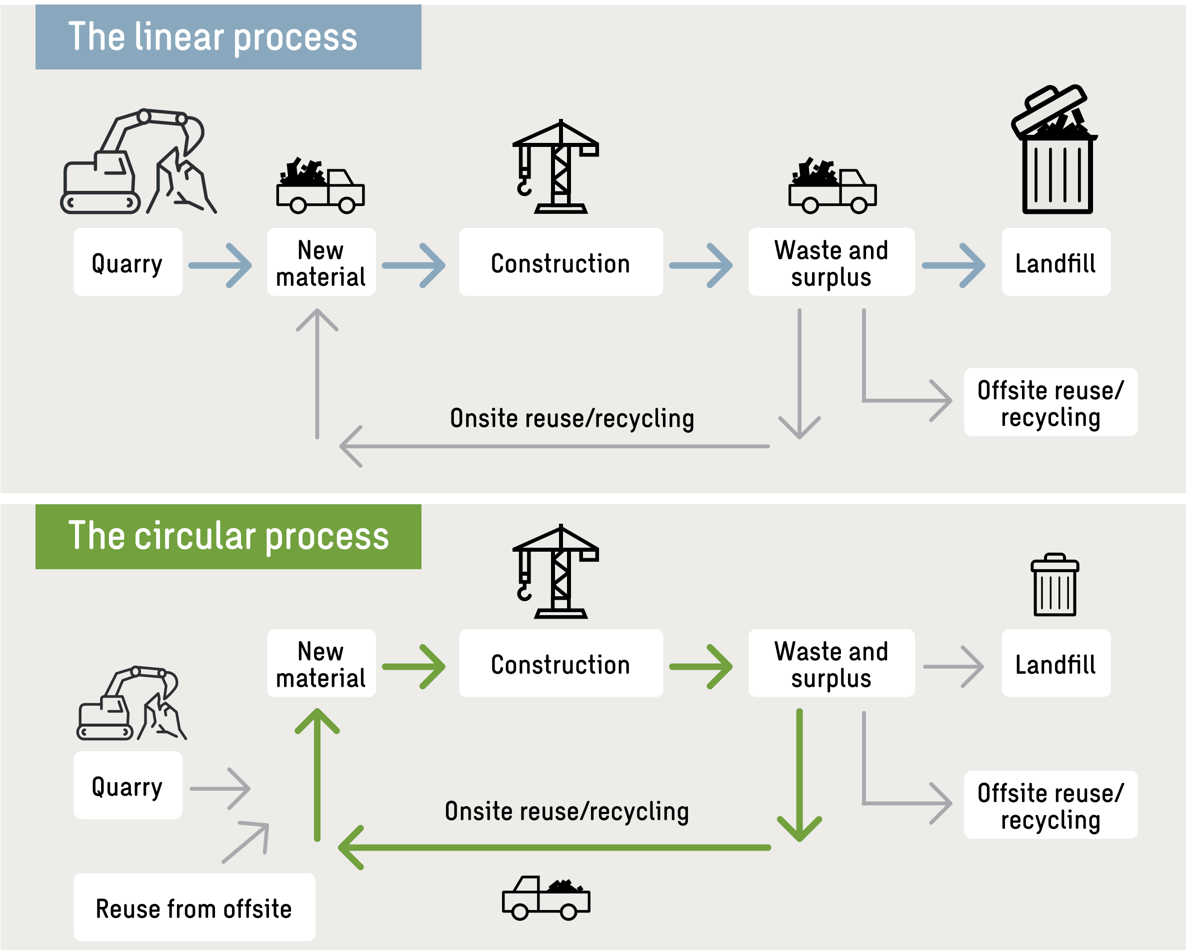
Legal frameworks, attitudes and behaviours often still regard such materials as wastes rather than resources where the burden is on safe disposal. As a consequence, skills and supply chains develop around these objectives. Without strong leadership, carbon reduction is, at best, a passive environmental aspect that has no bearing on a design. With strong leadership, proactive carbon cost management occurs at every design decision point.[4]

The Swedish EPA (Naturvårdsverket) suggests the following changes:[2]

- Introduce legislative amendments that allow non-hazardous waste to be stored for longer than three years before it is recycled.
- Investigate whether the regulation behind tax on waste needs to change for today's policy instruments to function optimally.
- The introduction of environmental test regulations for the storage, sorting and mechanical processing of materials that are not waste.
- Increase knowledge about the contents of materials to improve matching between supply and demand.
- Relevant authorities to look into possible tools for increasing the recovery of materials and including moving non-polluted soil from waste regulations to environmental regulations to enable more efficient handling of resources.

The road towards circular aggregates

In the previous chapters we have learned about many of the challenges faced in terms of the financial and environmental impact of infrastructure materials and the transition to more circular solutions. This chapter looks at turning those challenges into solutions.



Design and process optimisation

- Minimising of material excavation
- Quality and reuse
- External collaboration
- Digital material banks
- Circular procurement
- Project incentives
- Financial incentives

Onsite reuse/recycling areas and equipment

- Coordination with external networks to plan and enable reuse

Regional coordination between stakeholders

- New business models
- Better data and tracking of materials
- Clearer regulation and guidance on material classification

Significant investments are made in European infrastructure

The management of aggregates is subject to many overlapping factors and complexities. This report has, however, identified key areas that can contribute to the circularisation of this sector.

Large sums of money are continuously invested in infrastructure projects. In 2017, across the EU there were over 217,000 km of railways, 77,000 km of motorways, 42,000 km of inland waterways, 329 key seaports and 325 airports.[17]

When it comes to infrastructure investments, the German Federal Transport Infrastructure Plan 2030 identifies the need for EUR 141 billion expenditure on road, rail and waterways by 2030, with EUR 98 billion of this earmarked for expansion and new construction projects.[18] The French Government announced EUR 100 billion of investment in infrastructure to help boost the economy after the Covid pandemic. In the summer of 2022, the new Elizabeth Line was opened on the London Underground, the culmination of a 12-year construction project costing GBP 18.8 billion and involving the excavation of 8 million tonnes of material.[19] In France, another underground rail project, the Grand Paris Express will extend the Paris Metro by 200 km, costing around EUR 35 billion. Across Europe, transport infrastructure ranging from rail to roads to waterways, projects ranging from small-scale local works to those of national strategic importance will cost hundreds of billions of Euros, with large associated environmental financial and social impacts. The World Bank estimates that around 1 trillion dollars is spent globally each year on infrastructure.[20]

Leave no stone unturned - seek solutions to circularity in many ways

There is no single solution to increased circularity. It can be achieved through a wide range of measures, such as better legal frameworks and guidance, use of financial instruments, better reporting, increased planning, greater collaboration between projects, better procurement and specification, use of mass balance analyses and digital tools that can identify optimal solutions.

New requirements for circular infrastructure

The circular economy is becoming increasingly enshrined in policy and legislation at different layers of governance. 'Construction and Buildings' is listed as one of the six key value chains identified by the EU's Circular Economy Plan[6] (the others being electronics and ICT, batteries and vehicles, packaging, plastics and textiles). Within 'Construction and Buildings', there are five key actions identified of which the sustainable and circular use of excavated soils is one.

There is also an increased focus on the circularity of mineral resources on a national level. For example, in its political platform Hurdalsplattformen from 2021,[12] the Norwegian Government states that they will facilitate the circulation of mineral resources and reduce the waste from mines through stricter requirements for resource utilisation and backfilling.[14] In June 2022, the Norwegian Ministry of Industry made it clear that the circularity of surplus minerals and materials will be part of the Norwegian mineral strategy which will be presented in the autumn of 2022. In the UK, the government requires Whole Life -Cycle Carbon assessments for all public works projects to understand and minimise greenhouse gas emissions. Also in the UK, an aggregates tax is levied which is only applied to primary aggregates, the objective being to make secondary and recycled aggregates more competitive.

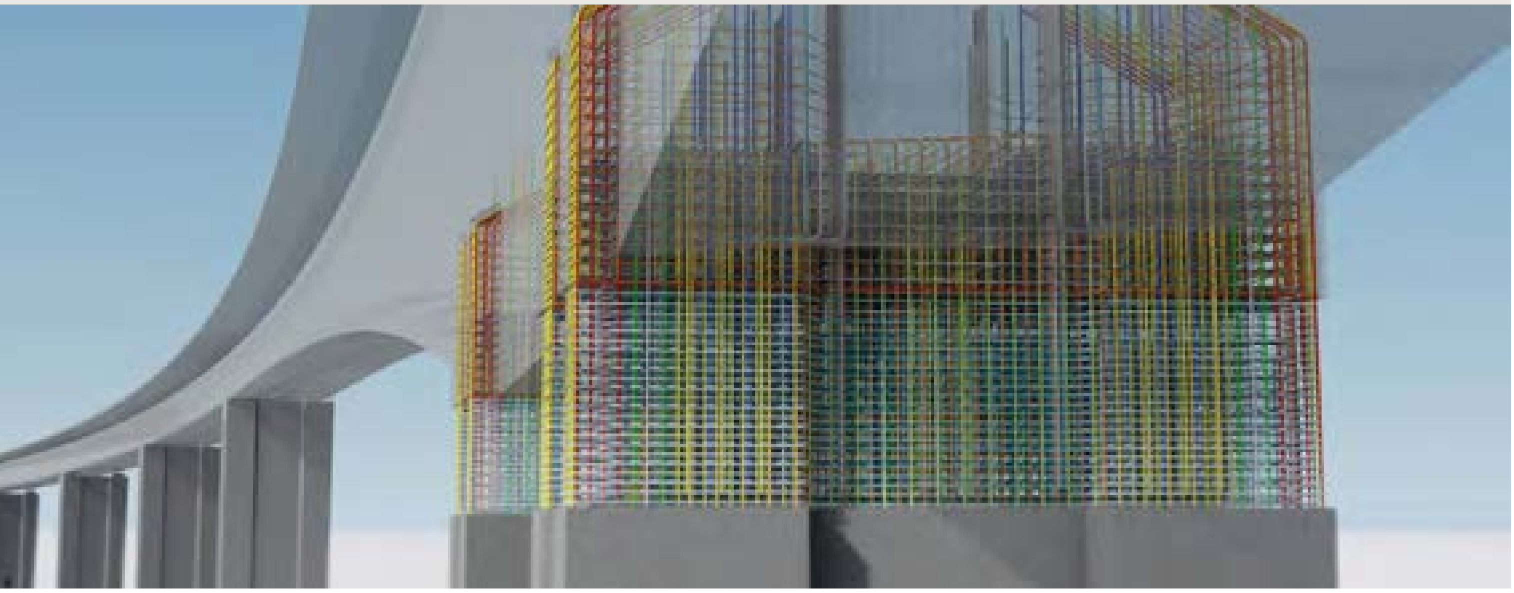
However, aggregates producers state that the aggregates tax in general increases the cost of construction and that suppliers of recycled material have increased their prices accordingly. There are also some, but not many, other examples of taxation on the use of raw materials.

InfraLCA – a tool for lifecycle assessment, CO_2 emissions and environmental impact in infrastructure projects.

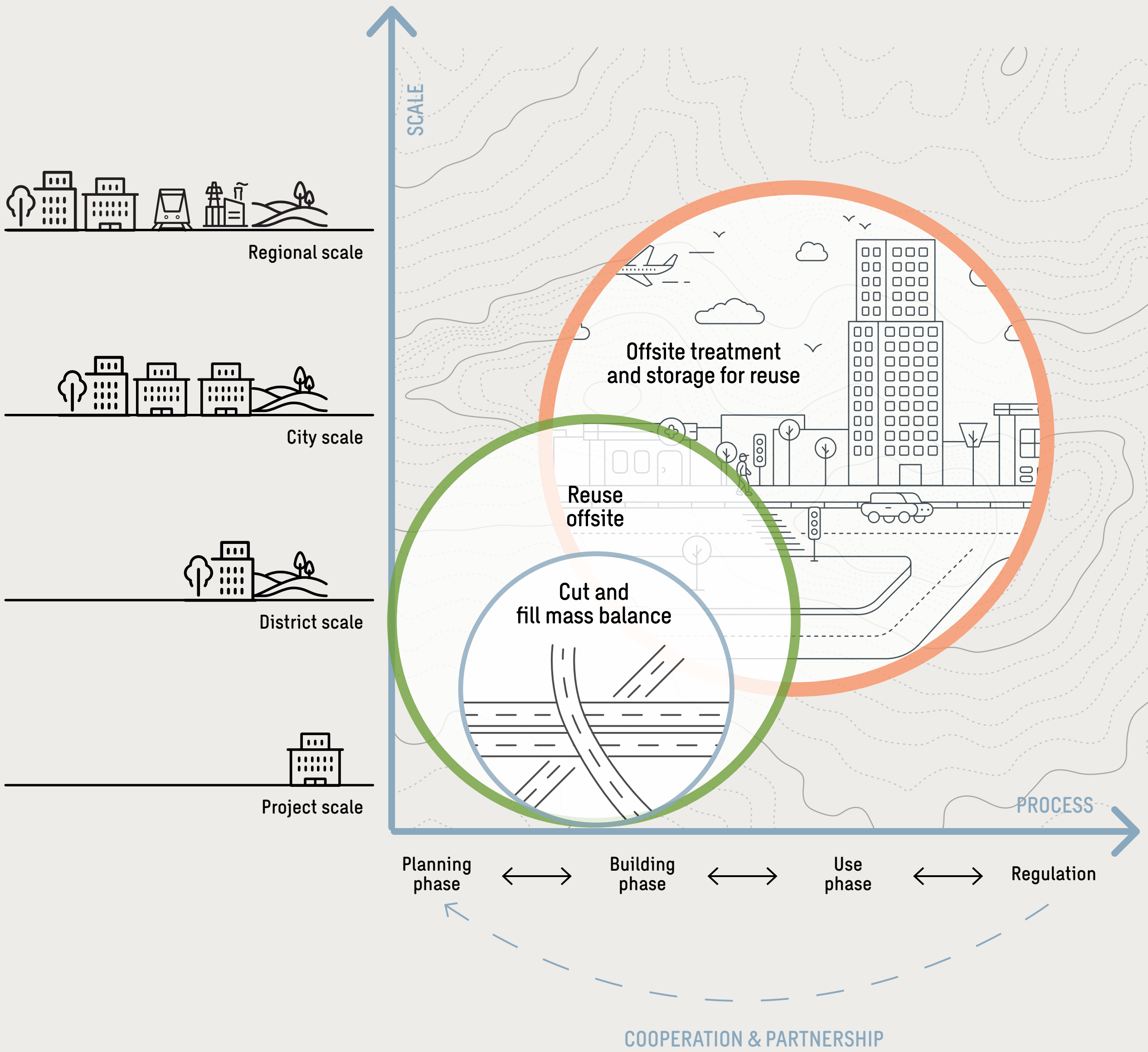
InfraLCA, which is Banedanmark's (the Danish rail agency and the Danish Road Directorate) tool for life-cycle assessments, CO_2 emissions and environmental impact in infrastructure projects, will be expanded to cover a larger part of the infrastructure industry and Sweco is playing a key role. "The tool will be crucial for the industry's ability to be able to calculate, document and reduce CO_2 emissions in relation to infrastructure projects for the next several years," says Heidi K. Stranddorf, team leader and specialist for the LCA track on the project at Sweco.

Sweco will develop the platform on which the InfraLCA tool is based, so that the latest standards can be used. In addition, Sweco will enrich the tool with new data and develop sub-components, so that the tool can be used on all types of infrastructure projects in all life-cycle phases. To undertake the task, Sweco is providing a combination of environmental experts, LCA specialists and software developers.

Client: The Danish Road Directorate
Location: Denmark
Role of Sweco: LCA programme developer



Circularity on different scales



Circularity occurs on different scales. The larger the "loop" the more variables there can be to consider. The most circular solutions are often those with the most direct measures focusing first on prevention and minimisation, and then on the most localised form of reuse, avoiding processing and transport wherever possible.

Clear guidance is needed on the use of materials

Legal frameworks and associated guidance connected to the management of aggregates are still, to a large degree, emerging from the linear era. To help pave the way for more circular use of materials, clear guidance and reviews of legislation are needed to help those involved navigate towards the most optimal outcomes. Examples include the need to clarify when a material is a waste or a product. When materials are classified as waste, existing requirements can be obstacles to their reuse, both in terms of handling and administration. Guidance is also needed on the criteria to be used to allow waste to be treated and, therefore, no longer classified as waste but instead classified as a product, on testing protocols and thresholds of environmental quality standards and on the use of materials that contain lower levels of contamination, but which could conceivably be put to certain uses if treated accordingly.

Some materials are contaminated and cannot be reused, but with updated legislation and clear guidance that helps keep suitable materials in circulation, existing barriers to circularity, such as uncertainty and risk, can be addressed.

Circular procurement

Requirements to use recycled materials in public procurement have increased, which drives demand. All public works in Zurich, for example, must use a minimum of 50% recycled concrete or 25% recycled mixed demolition aggregate.[13] In Switzerland, the builders are responsible for the materials extracted from a project, according to Annina Margreth, researcher at the Norwegian Geological Survey, who used to work at the 57 km long Gotthard Basis Tunnel and who thinks that the contracts of projects should be drafted so that the materials MUST be used for as beneficial a purpose as possible.

In the early phases of a project, procurement can be informed by studies which examine different options and identify sustainable solutions. This information can be taken forward into project design and procurement and raise the bar on circularity.

Furthermore, contracts can incentivise circular practices to a greater degree.

Large amounts of materials are used as if they are lower quality than they actually are, in other words: downcycling. Transportation is often excessive and specifications on quality vary between builders. Identifying suitable material quality standards for the application quality would ensure increased sustainability. Too many procurers over-specify leading to over-reliance on virgin materials. Different specifications are used for materials from quarries compared to materials recovered from construction sites.

Procurement can be documented via environmental product declarations, which is normal for concrete, but not yet for aggregates.

Consultants should think outside the box. Builders should ask more clearly for sustainable and climate-friendly solutions. It's also important to measure the value of the resources by evaluating solutions according to the waste hierarchy.

Ida Nilsson, Norsk Gjenvinning M3

Environmental cost indicator – sustainability in design and tendering.
Sweco was commissioned by the Rivierenland Water Board to examine sustainability aspects in the design and tendering process for dyke improvement on the Tiel - Waardenburg section. The general sustainability ambitions from the policy of the Rivierenland Water Board have been translated into project-specific measures that have been included in the project. The ambitions led to two feasibility studies on the themes of energy generation and circular construction. In a practice called 'making work with work', soil transport optimisation was achieved during the design phase.

A reference environmental cost indicator (ECI) calculation was made to find the components with the highest environmental impact/CO_2 footprint. This led to the use of an ambitious procurement strategy, including minimum requirements that the ECI calculation and specific equipment were to be deployed. In addition, award criteria for reducing emissions (NOx and CO2) and circular material use were applied.

The result was a high percentage of high-quality reuse. This includes second-hand sheet piles and the use of emission-free and low-emission equipment. A 70% reduction in CO_2e was achieved, as well as a 40% reduction in the use of primary materials. The Rivierenland Water Board has awarded the Tiel-Waardenburg dyke improvement to the contractor combination Mekante Diek, a collaboration between Ploegam, Van Oord and Dura Vermeer.

Client: Rivierenland Water Board
Location: Tiel – Waardenburg, Netherlands
Role of Sweco: Sustainability assessment

Photo by Sweco

Photo by Perth and Kinross Council / Sweco.

Cross Tay Link Road — carbon management in design and procurement

The Cross Tay Link Road (CTLR) will link the A9 over the River Tay from Perth to the A93 and A94 north of Scone in central Scotland. Carbon management has been at the heart of this project from the outset.

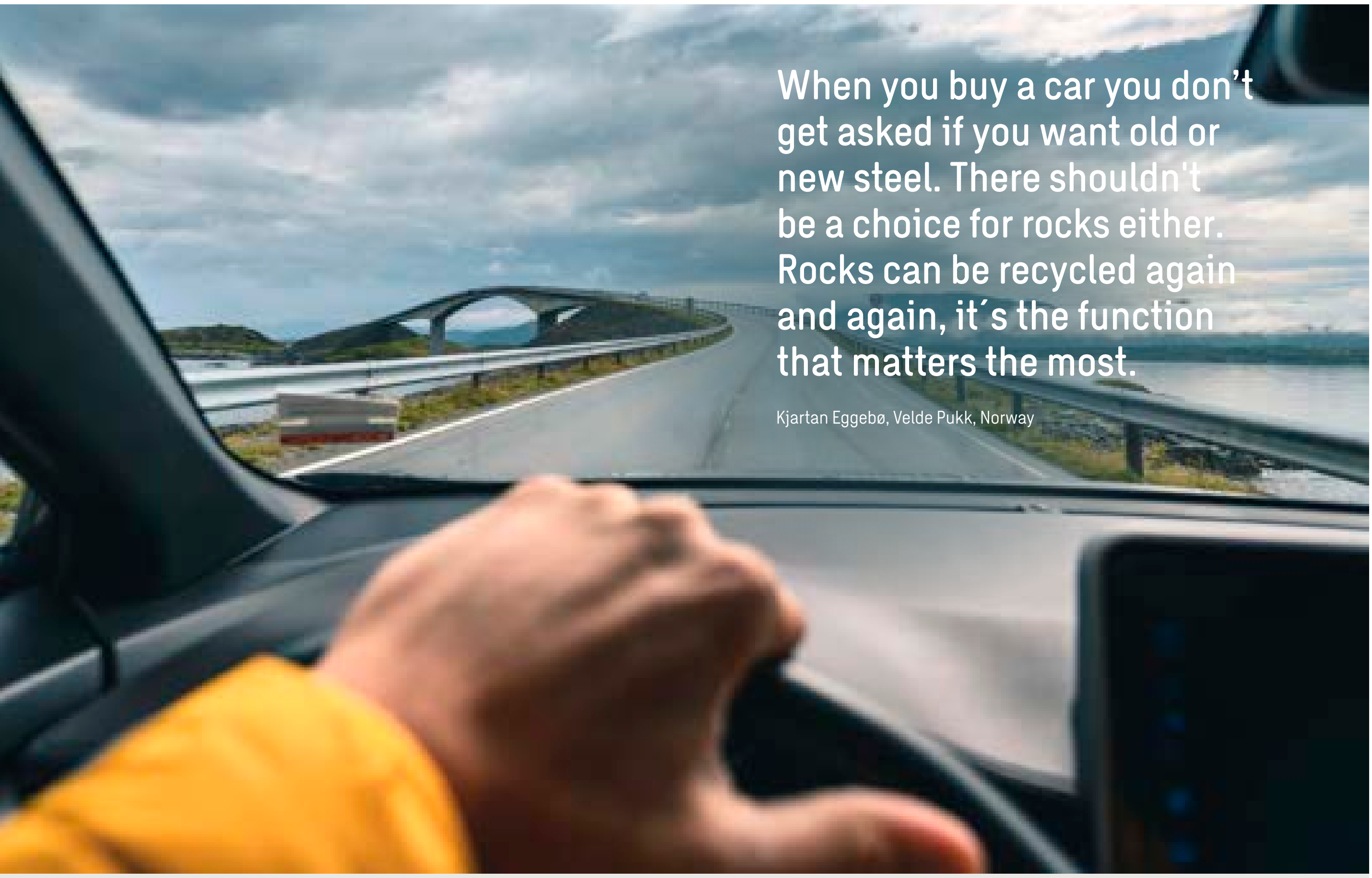
The Carbon Management in Infrastructure standard (PAS 2080) was integrated into design choices and decision-making, then further still into the procurement and delivery stages.

An initial carbon baseline was developed to identify carbon hotspots. Over the course of the design process, engineering modifications were introduced by Sweco, which resulted in associated carbon savings from earthworks, structures and pavements amounting to some 13,000 tCO_2e.

Sweco worked with Perth and Kinross Council to integrate carbon management into the procurement of the works contract. Tenderers were challenged to propose further value engineering changes that would result in a minimum saving of 14,100 tCO_2e of CO_2e compared with the baseline. This element of the tender was weighted at 15% of the quality evaluation criteria, with the maximum reduction being awarded the highest score.

A commitment was established within the tender requirements to deliver its proposed carbon savings during construction. The successful supplier submitted a proposal in excess of the 14,100 tCO_2e target. The project is currently in the design phase and the design and procurement process together are expected to result in a minimum carbon saving of 26,300 tCO_2e compared to the baseline design.

Client: Perth and Kinross Council
Location: Scotland
Role of Sweco: Engineering modifications and carbon savings



> When you buy a car you don't get asked if you want old or new steel. There shouldn't be a choice for rocks either. Rocks can be recycled again and again, it´s the function that matters the most.
>
> Kjartan Eggebø, Velde Pukk, Norway

Velde Pukk material recycling: the importance of specifying quality standards

Velde Pukk, an aggregates and asphalt producer located in Sandnes close to Stavanger, Rogaland, has plants from Bergen down to Kristiansand plus two in Østlandet. Since 2013/2014, Velde has been using recycled asphalt in several of their plants.

This means a reduction of 30% CO_2 if you use 40% recycled asphalt, or a 40% reduction in CO_2 if you use 50% recycled asphalt. Oil products (bitumen) and rocks can be reused, and virgin materials can be saved for other usage. The documented properties of recycled materials are similar to virgin materials. The climate footprint of using these materials is documented in an environmental product declaration (EPD).

Municipalities are generally conservative and can ask for whichever quality they wish. Nye Veier, the new Norwegian state-owned builder of roads, is less conservative than the Public Roads Authorities (Vegvesenet). Vegvesenet has a rule that they use a maximum of 40% recycled asphalt.

Recycling earthworks reduces climate impact by 90% according to Kjartan Eggebø, Velde Pukk. Recycled materials are slightly cheaper but not by enough if the customer is worried that the quality is not good enough. Quality specifications are available, these materials work for all types of 'unbound' specifications (where loose materials are required, such as crushed rock, and which do not use adhesive mixtures). The solution is to avoid being conservative and to stop asking for 'what you know works' just because this is a comfortable choice. The document properties that are stipulated in the procurement documents should be ones that recovered materials can fulfill.

Resource and climate effects should be a larger part of the tender process than they are today. The function of the road should be more important than absolute requirements of quality.

Company: Velde Pukk
Location: Rogaland, Vestland, Agder counties, Norway

Material banks, data, digitalisation and traceability

Data has a huge role to play. Better and earlier data on the materials that need to be managed greatly improves the ability of a project to manage them in an optimal way.

The building industry is embarking on a new circular path whereby buildings are increasingly regarded as a digitalised asset and material banks, enabling forward planning for the reuse of materials. Collaboration between stakeholders has enabled the emergence of shared material banks and resources, driven by access to good data. Infrastructure materials could follow the same path to close the current gap on data and statics. Flanders in Belgium operates a national excavated soils database.[15] Sweco Belgium has carried out projects using Buildings Information Modeling (BIM) and track and trace to optimise material management during projects.

BREEAM Infrastructure is a certification system to document the scope of sustainability work related to project implementation and choices of sustainable solutions for different types of infrastructure and civil engineering projects.

Obsurv – the material passport
Obsurv is a material passport for infrastructure and civil engineering materials as assets. It is an integrated, web-based management system with the simplicity of Google Maps, the flexibility of Excel and the design of Apple.

It is the first truly integrated management system for public space, which includes planning and budgeting in one process. It is accessible on PC, laptop, tablet and smartphone.

In asset management, it is essential to get a grip on crucial management questions such as what is managed, quality and costs. Obsurv maps out the answers to the above questions and thus helps to shape integrated asset management. The application is flexible and where material information parameters are depicted on maps as well as in databases.

Information can be shared between the client, contractors and other players in good time to allow for forward planning. It is currently used on a range of projects including in Maastricht, Rotterdam, Zwolle, Twente, Voorburg, Sittard-Gelleen.

Client: Various municipalities in the Netherlands
Location: Netherlands
Role of Sweco: Material passport creator and manager and support

Taking into account the use of circular solutions for the handling of materials will be viewed as a positive thing when deciding on individual projects. The same thing applies to achieving a good mass balance.

Sweco has BREEAM Infrastructure assessors that carry out evaluations of projects and has been involved in the assessment of several road projects, both in the early planning phase as well as for design and construction. Modern IT-tools for earthworks modeling, such as MAGNET Project, may support the supervision and management of infrastructure and construction projects. These projects are growing in complexity and size. MAGNET Project gathers the relevant parameters and data into a single model. The model provides new ways of visualising the earthworks and automated estimates of the material usage and transportation options. This in turn can be used to identify alternative solutions, such as designs, alignments or supply chains, thus providing support in making decisions throughout the project in order to improve the earthworks.

BIM can help optimise material management during the project by visualising types and quantities and enabling optimal solutions to be identified. As databases of materials develop, there will be increased opportunities for interrogating a much wider field of materials than was previously possible. Material passports such as Sweco's Obsurv provide essential material data on an accessible, web-based portal.

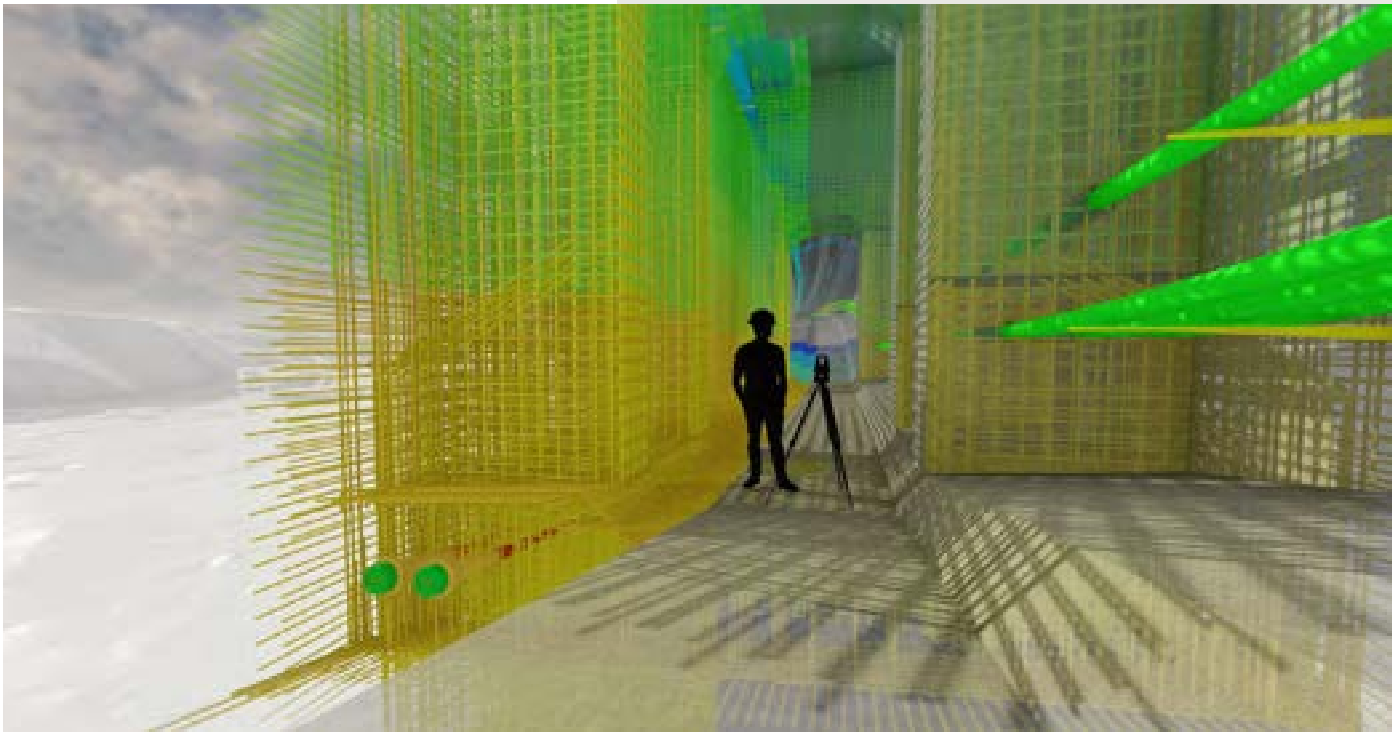
BIM Track and trace - Optimization of Soil Works Oosterweil Link, Belgium

Buildings Information Modeling and a track and trace system provide the control mechanism for ongoing soil works, i.e., where and what is being excavated or backfilled, transported or deposited.

It is being used for the first time on 'The project of the century' on the Oosterweel Link in Belgium. The work enables optimisation on a >10 year long infrastructure project where over 15 million m^3 of soil will be excavated and 8 million m^3 has to be filled.

The objective of using BIM is to have the best possible control over soil extraction and use and to optimise reuse, transportation, etc. It also facilitates the better reporting and administration required by the legislation governing the use of soils. By investing time in effective modelling and tracking, greater project efficiencies can be made. Optimisation of soil works reduces ecological and financial impacts. Automation and digitalisation reduces error, thereby optimising engineering and risk reduction.

Client: Several, including Port of Antwerp & Ghent, Highways in Ghent
Location: Antwerp, Ghent, Brussels
Role of Sweco: BIM and track and trace



Collaboration and partnership is crucial

A running dialogue between actors is crucial to achieving greater circularity. There are moves towards this, such as the Pådriv Arena in Oslo which enables organisations to store and exchange materials. Collaboration between partners was essential in achieving this. The Swedish Transport Agency has also established a research project to investigate how the circular management of materials can be developed, using projects in Stockholm, Södermanland and Östergötland as a testbed for collaboration, new business models and exploring the roles of different actors in a circular system.

Infrastructure management is a multidisciplinary issue, which therefore requires multidisciplinary responses. Project teams looking at the circular reuse of materials should draw upon the necessary skills from day one. This includes data modellers, geotechnical specialists, planning and permitting specialists, sustainability specialists and external parties such as local authorities and regions. There is a growing recognition that materials management is dependent upon coordination and that lead regional coordinators, such as regional administrations, will emerge. Although it is vital that coordination takes place, it is of even greater importance that the coordination effort includes the right people.

Effective collaboration can also avoid problems. The need for temporary set-down and storage areas on projects is vital. If such areas are insufficient, it can restrict the available options for material management. For example, sufficient space and time for treating excavated materials so that they can be used on site. It is critical, therefore, that the need for this is identified as early as possible as planning and getting the required permissions can take time. The best circular intentions can be hampered by issues such as space and time.

Cooperation opens up different possibilities for resource management.

Maria Harbo Dahle, Pådriv Arena, Oslo

Pådriv Arena – Oslo material bank for excavated material
Pådriv is a partnership for sustainable urban development in Oslo. It includes an area for shared circular material management in Hovinbyen in Oslo. It is a collaborative space for the reduction of the climate footprint from construction activity in Oslo, by increasing circularity and encouraging reuse of materials within Oslo and in order to reduce transportation distances in and out of the city.

The lessons that can be learnt from this initiative are that circular materials management is complex and cannot be solved by one actor alone. The area actively facilitates ongoing dialogue as well as cooperation between a number of actors who normally don't cooperate like this. Both public agencies as well as industry associations and advisors as well as entrepreneurs have been active in the arena. For a city like Oslo, it is important that there exists recycling facilities for mineral masses in or close to the city in order to reduce transport emissions. Mineral materials can be recycled and used again. One challenge that has been identified is the lack of space being allocated for the handling of materials.

The project shows the need for areas to be set aside by the municipality and highlights the need for private actors to be allowed to establish recycling facilities. As Oslo is looking at a situation where there will be a lack of local resources of aggregates before 2050, using recycled materials can prolong the life of existing high quality resources.

Client: Klimaetaten i Oslo kommune plus numerous partners:, PBE, EBY, VAV, BYM, Oslobygg, Entreprenørforeningen Bygg og Anlegg Oslo og Akershus, Ecoloop, NGI , Sweco among others.
Location: Oslo, Norway
Role of Sweco: Partner, member of working groups

Function in focus

Resource and climate effects should be part of the tender process to a greater extent than today. The function of the road should be more important than absolute requirements of quality. The innovative use of materials and techniques can unlock huge benefits that prolong the lifetime of infrastructure and reduce the demand for new materials. An example of this is the use of circular business models in infrastructure and the use of new materials such as mycobase in the Netherlands, where Sweco supported a pilot project that tested the use of a bio-based raising material for roads in soft soils. By using innovative local materials, the downcycling of other materials into road sub-bases can be avoided, thereby freeing up that material for reuse and recycling elsewhere.

Innovative material selection to support roads against peat subsidence

Soft soils cause headaches for governments and road builders due to the subsidence they can cause on roads and other infrastructure. That is why producer Mycelco, together with Sweco, came up with a bio-based raising material for such soils in Woerden, the Netherlands. Cattail, reeds and fungus are used as a 'bio-based styrofoam' to protect against subsidence, and the municipality of Woerden piloted the solution.

A large part of the municipality of Woerden consists of peat soil. Wherever you have peat, you have to deal with settlement of the subsoil. The result is that roads sink lower and lower, roads get damaged more quickly, water problems occur more frequently and eventually the road foundations collapse. Sewerage systems also become damaged. To prevent roads from subsiding in the future, lightweight materials like petroleum based styrofoam can be used to reconstruct infrastructure and return it to its original height.

Sweco was commissioned by Platform Slappe Bodem to investigate, and it was calculated that the management and maintenance costs of infrastructure on a peat soil are twice as high as the same infrastructure on a sandy soil. When you consider that normally about 10% of a municipality's budget goes to the management and maintenance of public space, this is a significant cost.

To make the bio-based styrofoam, the stems are finely ground and a fungus is then added to the mixture in a mould. Within a few days, the fungus makes a 'mushroom flake' of the biological material. When the mushroom flake is fully grown, growth is halted by killing the fungus. What remains is a block of solid, light biological material called mycobase.

As a pilot, a number of blocks of this product were installed in the ground in Woerden at the end of 2020. It creates less CO_2 emissions and is a circular product which allows municipalities to maintain the height of the ground in public spaces.

With this bio-based product, you can increase the lifespan of the infrastructure whilst growing the raw materials locally.

Client: Woerden Municipality
Location: Woerden, Netherlands
Role of Sweco: Support to feasibility investigation

Temporary landfills and geoscans
The geotechnical properties of the cut materials and, where relevant, pollution levels are often unable to meet the requirements of all the fill materials. There are, however, examples of contractors that are establishing temporary landfills where they clean lightly contaminated materials and market and sell these to the next project. We are also seeing increased use of tunnelling materials to create new areas, for example, by reclaiming new land along the coast. Norway has successfully used such materials from projects to improve agricultural land.

In many projects, increased environmental surveys could reduce such uncertainty. Geoscan by helicopter can be combined with regular geotechnical surveys and machine learning to provide increased information and sometimes full geomodels with information on depths, weaknesses and layering.

Infrastructure as a service

Commercial models are also an area in which greater circularity can be achieved. 'Infra-as-a-service' is a programme in the Netherlands that is looking to develop this business model and new way of cooperation between clients and contractors on infrastructure. Seven pilots are running in order to test the business model in practice.

Sweco wrote a guide that described best practice and valuable lessons learned from the pilots, focusing on the effects on internal organisation, the new way of cooperating, how to tender an 'as-a-service' contract and some important specifics/characteristics of a long-term 'as-a-service'.

In this model, the contractor is the economic owner or operator of an infrastructure item for an agreed time (for example, a road section, bridge or lighting). As owner/manager, the contractor has a direct interest in using sustainable, high quality and low maintenance materials. This reduces maintenance costs and the contractor is encouraged to sell or reuse materials for the maximum prices at the end of their serviceable life. Consequently, the total lifecycle costs are reduced, work can be offered more competitively and returns are increased. 'As-a-service' is, therefore, a win-win-win model for the contractor, the client and, above all, society as a whole.

Some other questions that are being researched within the pilots are:

- Which infrastructure assets are suitable for 'as-a-service', and which are not?
- What can and must be done differently in contracts, organisation and co-operation?
- How do we create the right circular incentives?
- How do we determine the residual value of the assets at the end of the contract?

The programme is more about developing a new circular business model within the infra sector rather than focusing on technical innovations. The rationale behind the new model is that life-cycle thinking will be stimulated.

The reuse of materials and resources on infrastructure projects in the Netherlands is already quite standard. The challenge now is to explore the next step and think about how the underlying business models of the sector can become more circular.

Sweco is one of the 11 partners contributing to this research programme. The other partners are the Dutch government (municipalities and provinces), Dura Vermeer as contractor, two banks and the Technical University Delft as research partner.

The pilot projects are:

- A road in the city centre of Utrecht
- Sustainable road maintenance on a provincial road in Overijssel
- Guardrails in the province of North Holland
- A temporary road near the Johan Cruyff Arena in Amsterdam
- A road and two bridges in the city of Amersfoort
- Light-as-a-service in the province Noord-Brabant

Client: Partner programme The Circular Road
Location: Various in the Netherlands
Role of Sweco: Programme partner

Photo by The Circular Road.

Gävle railway – Looking beyond the project to solve challenging earthworks

The alignment of the 4 km railway project, from Gävle central station to Gävle west station, is severely constrained by slope limitations and nearby buildings and infrastructure. With these constraints the project is expected to generate roughly 1,000,000 cubic meters of various cut materials and require roughly 640,000 cubic meters of various fill materials. At a first glance, this suggests a theoretical recycling rate of generated cut materials of around 64%, which still would mean that 360,000 cubic meters of excess soil, equivalent to approximately 36,000 truck loads, are unaccounted for. Worse yet, the actual recycling rate is reduced to 24% when accounting for the roughly 400,000 cubic meters of rock aggregates needed in the project which cannot be met by any of the cut materials in the project.

The possibilities of increasing the recycling rates through modifications of the individual project are limited. However, by pursuing possible coordination with other projects in the nearby area, there could be considerable benefits for all involved.

For instance, a transit-oriented, urban development project near downtown Gävle has estimated a need for about 1 million cubic meters of fill materials to ensure long-term resilience to potential flooding and sea level-rise due to climate change. Those fill needs could be substantially met by excess materials from Gävle railway project. This would significantly increase the recycling rates and reduce the mass hauling distances for both projects. Other nearby infrastructure projects are expected to generate rock materials which, if they are generated in excess, could provide the Gävle central railway and the Gävle west railway project with rock aggregates.

Client: Swedish Transport Agency
Location: Gävle, Sweden.
Role of Sweco: Planning and preliminary design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What if?

Large sums of money and material are invested into infrastructure projects. The impacts are large, but so are the rewards if circular methods become normalised. And yet, as a system it still has a high leakage rate in terms of materials and value.

Sweco has looked at two current European railway construction projects of different scales and considered the impact of an issue that is one of the most visible of all: transport of materials.

One is a major national project, the other is the Gävle railway project in Sweden. Options for the management of non-contaminated, reusable materials have been assessed and, using the Magnet Project tool, Sweco has identified solutions that minimise haulage requirements in terms of kilometres travelled, carbon emissions and costs.

The large project is faced with significant challenges of scale, time, geography and complexity. Nevertheless, the example shows that, given the scale of the activity, even a 3% reduction in the transport of materials can yield large benefits.

The Gävle project demonstrates the benefit of good collaboration with local parties who can benefit from using material in projects such as embankments and noise barriers. Transport optimisation analyses reflect the effects of a range of circular measures. If the whole project embraces circular approaches from the outset, the field of options are widened considerably, and it is highly likely that the savings will be more significant.

Even measures that implement savings of 1% can yield significant results. The challenge lies with everyone involved in the management of these materials, at all stages of projects and at all links in the material value chain.

Marginal gains, major benefits

Consider that a new analysis by Sweco has revealed that an additional 1% saving on the large railway project would reduce haulage further by 347,000 km, saving EUR 3.2 million and 1,500 tonnes CO_2e. If, through a combination of measures, we were able to reduce haulage by 10% that would save EUR 31 million and 15,000 tonnes of CO_2e. And remember, transport is just one factor in infrastructure construction.

The Gävle project, being a local project, has smaller overall savings even though percentage-wise they are larger. But there are hundreds of similar-sized projects in Europe each year. If there were a hundred projects in Europe of a similar size and with similar potential to reduce their impact from haulage, annual savings would be around EUR 270 million and 70,000 tonnes of CO_2e.

Governments across the world continue to invest considerable sums in infrastructure. Given the scale of such works, even modest increases in circularity can have significant benefits.

The challenge for greater circularity is that there is no simple solution that solves everything. Greater circularity can be achieved through a wide range of measures such as better legal frameworks and guidance, use of financial instruments, better reporting, better planning, greater collaboration between projects, better procurement and specification, use of mass balance analyses and digital tools that can identify optimal solutions.

As a result, there are potentially many 1%s to be achieved. Add to that, more substantial savings of dozens of percentage points thanks to circular solutions, and replicated across many projects, the benefits are potentially enormous.

Summary of savings	Base case	Optimised	Saving	% saving	Further 1% saving?
Large railway project					
km – Total haulage	35,815,793	34,677,035	1,138 757	3.2%	346,770
Cost (EUR)	330,438,995	319,531,183	10,907,812	3.3%	3,195,312
tCO_2e	154,884	150,699	4,185	2.7%	1,507
Shadow cost of carbon (EUR)	102,997,860	100,214,835	2,783,025	2.7%	1,002,148
Gävle					
km – Total haulage	694,546	500,726	193,820	28%	5,007
Cost (EUR)	9,897,280	7,135,342	2,761,939	28%	71,353
tCO_2e	2,781	2,005	776	28%	20
Shadow cost of carbon (EUR)	1,849,365	1,333,325	516,040	28%	13,333

The calculations (costs, CO_2e emissions and the shadow cost of carbon) are based on a value estimated by the Swedish Transport Agency at 7kr/kgCO_2e to be the cost to society overall of carbon emissions in Sweden.

Savings of 1% on the transport of materials alone on one large railway project would be approx EUR 3 million, which is enough to run seven public libraries for a year or pay the annual food bills for 600 European households.

Analysis by Sweco

Summary and actions

This report has shown that much can be done to exploit the enormous potential there is by making the management of infrastructure materials more circular.

Materials are a resource and, therefore, should be managed as such, not something to be mitigated. To make this important shift faster, and to acknowledge the multi-disciplinary nature of it, we have produced an action list for all the stakeholders involved.

The planning and management of circular infrastructure materials is dependent upon a wide range of tasks, roles and responsibilities. It is also an area with significant complexities and challenges. However, by making gains in all possible areas, from regulation and guidance, to procurement and specification, from collaboration, data use and digital tools to financial instruments, incentives and planning, individual marginal gains can be translated into substantial benefits. The measures identified will steer management of these resources towards more circular and sustainable practices, whilst making them more economical. Let us make the aggregates sector become more circular together.

The challenges are global, the rules and regulations are national, the consequences are local.

Elisabeth Gammelsæter, Senior Industry Advisor, Sweco

The following are recommendations to increase levels of circularity in the management of aggregates. They require input from a range of stakeholders, from government to municipalities to business and, crucially, consultants and advisors who often have the tools and remit to optimise outcomes.

Regulation, legislation and finance

- European decision makers should develop and maintain contacts on a national level in order to make decisions that are able to be implemented locally
- Improve guidance on what is waste and what is product
- Minimise landfilling of recyclable minerals in order to save the good resources for where they are really needed
- Consider revision of tax systems on aggregates/waste
- Clarify regulations and guidance to support storage and reuse of materials - flexible yet consistently applied
- Include sustainability as a key project parameter

Regional and local coordination

- Establish local and regional storage areas
- Promote - and require - collaborative business models where clients, contractors and supply chains are coordinated
- Regional material plans supplying overviews of available resources and strategies on how to optimise use and management of these across municipal borders
- Coordinate regional efforts to stimulate circulation of materials through all means

Procurement

- Raise the level of procurements - e.g. less 'goldplating' of specifications, greater role of sustainability, material selection, technology used, incentivisation
- Builders should require environmental considerations in the procurement of projects, not only climate considerations but also the efficient use of resources
- Be proactive in planning and supply materials
- Specify the avoidance of measures that inhibit effective resource use e.g., soil sealing that locks in soil
- Advisors and consultants should be much more clear when giving advice, stop giving copy and paste advice out of convenience and, to a larger extent, suggest materials as resources and explore the possibilities of circularity

Digital solutions

- Develop specific materials databases (volumes, types, characteristics, etc) - increase traceability, transparency and proactive planning
- Use digital tools as trading platforms
- Create public-access material databases - e.g., excavated soil databases

Collaboration and business models

- Start early in the process and use colloborative design involving multiple stakeholders - integrated rather than fragmented approach
- Industry associations and local authorities should stimulate and coordinate networking, especially in urban areas
- Work with strategic partnering where client, entrepreneur and advisor all work towards the same goals
- Suppliers of aggregates should be frank about limitations and explore possibilities of circulated materials
- Designers should seek circular solutions, avoid 'business as usual' mentality
- To be most effective, carbon cost management must be integrated into the design process

Logistics

- Create storage facilities to bridge time gaps between the supply and demand of materials
- Place quarries to minimise transport to projects/natural markets
- Enable storage of inert waste for longer periods before recycling

Society

- Increase society's knowledge and engagement in recycling materials and the potential for reaching UN Sustainable Development goals, saving natural resources and reducing public expenditure

Importance of mass balance

- Apply mass balance in all projects
- Project quarries to be placed as close as possible to the project
- Aggregates producers should encourage customers to accept not so easily sold fractions and 'good enough' qualities
- Policies to include landscaping/ 'framing in'/usages of material that can be positive for the local community (such as noise walls etc)
- Consider how to avoid or minimise quarrying and excavation of material in the first place

About the Authors

Feel free to contact us with your questions and thoughts.
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Karin Larsson holds a Master's degree in Science in Business and Economics and has worked at Sweden's leading recycling company for almost a decade. Among other things, she has worked as operations manager at a larger recycling plant where her primary focus has been on the sustainable and circular management of construction and demolition waste from the industrial as well as domestic sector. She has also worked strategically with waste issues and has several years of experience from the optimisation of waste collection and logistics. In Sweco, Karin works as an environmental consultant and Group Manager and helps customers with challenges related to waste and resource management in the new context of circularity. Her driving force lies in combining practical experience from the recycling industry with the vast amount of technical knowledge that Sweco provides to find the best solutions for a greener future.

Elisabeth Gammelsæter is a national economist with engagement and knowledge about the social aspects of projects. She is a former secretary general of the Norwegian Mineral Industry association. She has also worked in the Norwegian Ministry of Industry for close to 10 years. She was a member of the Norwegian government's expert committee on dangerous waste in 2019, including giving advice on the choice of location for deposition plants.
She has worked with challenging industries all her career, which has led to her publishing a non-fiction book called *Ikke i mitt nabolag* (Not in My Neighbourhood) published in April 2022. It is a review of Norwegian examples of unpopular but necessary development projects. She has followed the aggregates industry on a Norwegian and European level since 1998 and has taken part in its discussions on how to steer towards a more sustainable and circular society. In Sweco, she works with finding sustainable solutions in early phase mining projects as well as other green industries.

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Urban Insight
By Sweco

Urban Insight by Sweco is a long-term initiative that provides insights into sustainable urban development as, seen from a citizen's perspective. The initiative is built on a series of reports, based on facts and research and written by Sweco's experts. The initiative provides society and decision-makers with the facts needed to understand and meet both current and future challenges.

This report is part of a series of reports on the topic 'Action Towards Circularity', in which our experts highlight specific data, facts and science that are needed to plan and build safe and resilient future urban environments.

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