MOTT MACDONALD

Circular economy - think piece for the construction industry

4 January 2018

Mott MacDonald
10 Fleet Place
London EC4M 7RB
United Kingdom

T +44 (0)20 7651 0300
F +44 (0)20 7248 2698
mottmac.com

Circular economy - think piece for the construction industry

Davide Stronati, Global Sustainability Leader
Angus Berry, Group Sustainability Graduate

4 January 2018

Mott MacDonald Limited. Registered in England and Wales no. 1243967.
Registered office: Mott MacDonald House, 8-10 Sydenham Road, Croydon CR0 2EE, United Kingdom

Information class: Standard

This document is issued for the party which commissioned it and for specific purposes connected with the above-captioned project only. It should not be relied upon by any other party or used for any other purpose.

We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties.

This document contains confidential information and proprietary intellectual property. It should not be shown to other parties without consent from us and from the party which commissioned it.

Contents

1 Background

The circular economy is a concept that has long been talked about by governments, by businesses, and by charities as a way of working to create a more sustainable future. The definitions of a what a circular economy looks like vary, but what is clear is that at the very heart of the concept is a shift from a linear model of production and consumption to a more circular system. Industries providing goods to the market have been at the forefront of reaping the benefits of circular thinking by designing products made of modules that can be reused or recycled, or by transforming their business models and letting products or offering outputs from their products instead of selling them directly. Service industries have been slower, but new and existing technologies are enabling them to make circular ideas applicable to their businesses.

The political discourse behind the circular economy is growing, and both the EU and the UK have promoted initiatives, and in some cases binding targets, for the implementation of circular business models, moving beyond recycling into an innovative business environment. Nevertheless, what is clear in the construction industry is that the circular economy is very much grounded in the language and principles of waste management and are often focused on the recycling industry only. What is seriously needed is a redefined understanding of how we can holistically apply the principles of the circular economy to the construction industry, and this is what this paper aims to do, to provoke a fresh view on how and why the infrastructure sector can embrace principles of the circular economy and how this can become a blueprint for society more generally.

2 The current status and the opportunity

The EU estimates that using resources more efficiently will also bring new growth and job opportunities. Better eco-design, waste prevention and reuse can bring net savings for EU businesses of up to EUR 600 billion, while also reducing total annual greenhouse gas emissions. Additional measures to increase resource productivity by 30% by 2030 could boost GDP by nearly 1%, while creating 2 million additional jobs (European Parliament press release, June 2015).

Both the EU and the UK have outlined significant reasons for embracing the concept around waste management. If the scope of the concept was to be broadened, what kind of opportunities could be opened for the infrastructure sector? How can we shift from waste management 2.0 to a truly circular economy realised for this industry?

The key to understanding how infrastructure can capitalise on the circular economy is by understanding what a future sustainable society will, and must, look like.

There seems to be an obsession among the circular economy narrative around the make-take-dispose linear model of production. Whilst this sets out well the current issues around waste management it fails to recognise the intricacies and nuances that are impacting the ways in which society are challenging the status quo. When you think about a city or urban space now and what it will look like in the future, it not only conjures images of a waste free space but it is one where car ownership is obsolete, buildings generate their own power, offices, homes, and social spaces are blurred and all underpinned by a truly sustainable infrastructure.

The thinking around the circular economy needs to be about how we can imagine, articulate, and deliver the infrastructure needed to support the transition to a truly circular economy and a truly circular civic space. As such we believe that there needs to be a circular economy that is defined not just for the whole life of assets but that we split this across the infrastructure lifecycle, thus creating distinct yet complimentary circular *economies*. So, what does this mean and what does this look when we consider the whole infrastructure asset lifecycle and the subsequent lifecycles?

3 Circularity in the asset lifecycle

We will now investigate the opportunities of integrating circular principles into the different stages of an infrastructure asset, from the purpose and planning stages right throughout the end of life. It will become clear that the industry can influence the circularity of assets at different stages of the lifecycle. Thus, it is important to stress that the asset owner must embrace alliancing and partnerships to drive the principles of the circular economy throughout the sector.

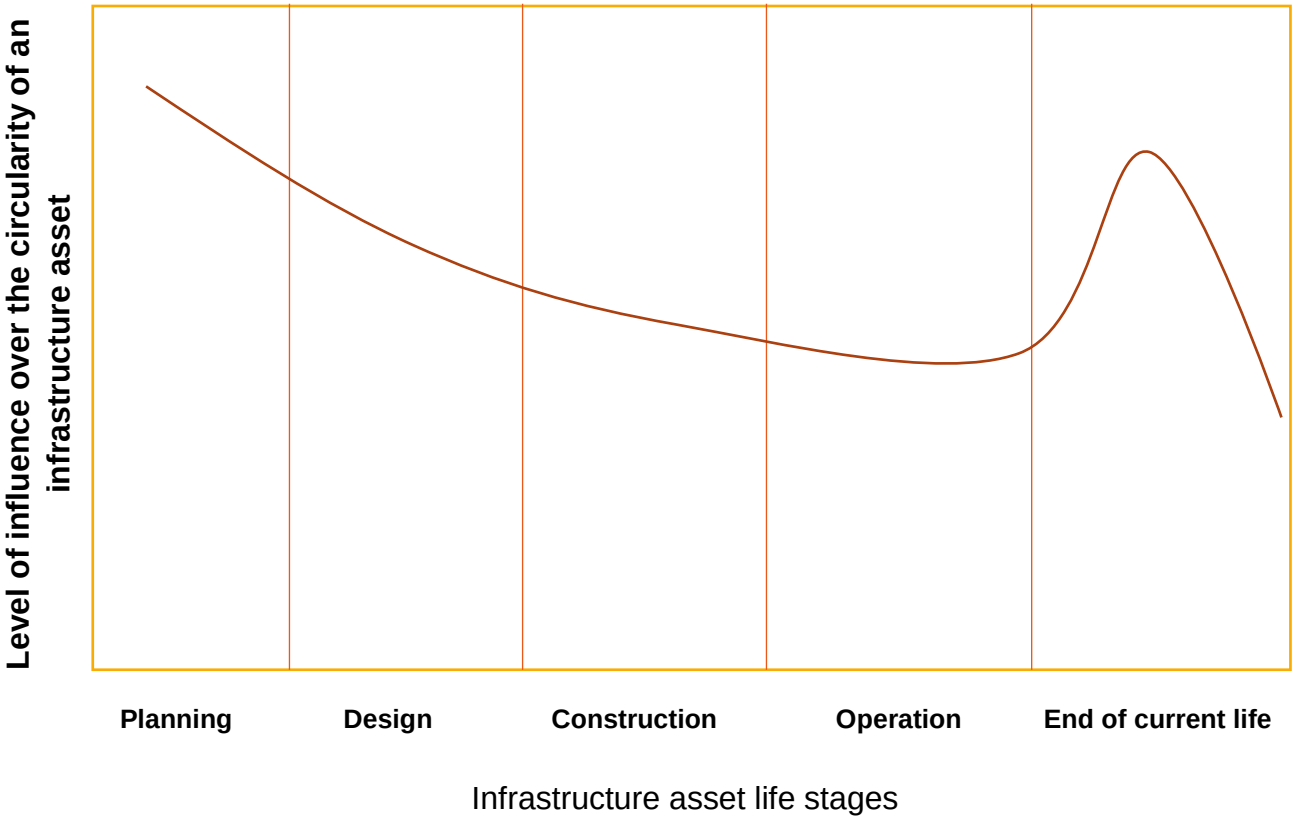


Figure 1 – Level of circularity within asset life cycle

Figure 1 shows how the intensity of circularity fluctuates across the asset lifecycle. Each stage will be looked at in turn, with case studies and analysis into how circular principles can and are being implemented across the value chain.

It is important to note that the figure represents a single life of an infrastructure asset. By correct planning and design, assets and entire infrastructure will develop into further lives. This is shown in figure 2 with the levels of circularity represented by the size of the circles. Both figures 1 and 2 demonstrate the level of circularity that is present within a given asset during its various infrastructure delivery phases and subsequent lives as those assets are reused in new infrastructure. It is important to note that the same rings true not just for assets but components and parts of assets. Following the very same graphs in figures 1 and 2 gives a deeper understanding of the circular economy in the infrastructure sector. The challenge, and therefore opportunity, for the infrastructure sector is being able to understand that both complete assets and components of assets have value in subsequent infrastructure lifecycles.

Broadly speaking, we can identify three levels of asset and components circularity:

- repurpose an existing asset with no major transformations and in the same location
- reuse an existing asset for the same purpose, but in a different location
- reuse components of an existing assets, in the same and different locations

In understanding this, the sector can capitalise on the inherent value contained within infrastructure assets and components and can shift the narrative within the infrastructure sector towards a more circular economy.

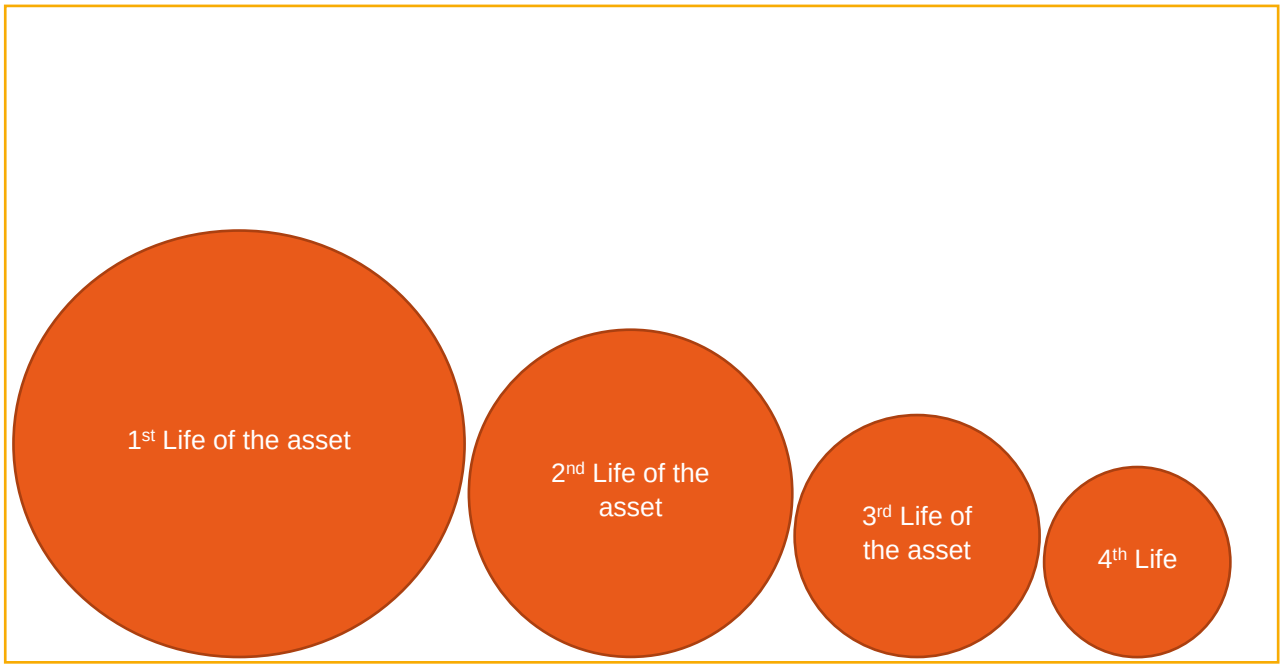


Figure 2 – Level of circularity in different lives of an infrastructure asset

3.1 Planning stage and teleocircularity

During the lifecycle of a project the easiest and most effective way to influence the outcome is to define the asset purpose. As we move towards a more sustainable future, one driven by a service economy and underpinned by clean energy, the purpose of the infrastructure being constructed will need to be redefined from what we understand today. We accept, for example, that electric autonomous vehicles are the future of urban transit. With what appears to be a rapid change in the way in which the urban space is being imagined, there is need for a concerted effort among all stakeholders to alliance to find practical and radical solutions.

Through a thorough understanding of the purpose of infrastructure assets, circularity of the design can be teased out. Without the collaborative understanding and evidence based approach to modern infrastructure, we stand the risk of missing the opportunities that moving towards a more circular economy presents. By being involved in the initial conversations around purpose and the future of infrastructure, we can define the scope of future projects and embed the circular principles into the actual design work and influence our supply chains.

To achieve a level of circularity that can be carried throughout the asset lifecycle there must be a purpose in the planning stage of the project that incorporates a multitude of circular elements. We

define this as teleocircularity as it is at this stage of the asset life that we can define, embed, and capitalise on the opportunities of the circular economy in that project. By planning an asset for repurposing, recycling or reassembly we ensure that the asset will be carried throughout its lifecycle with circularity at its core.

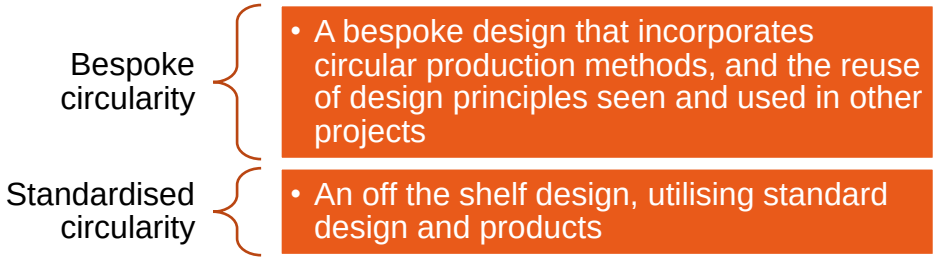
Case Study

The London 2012 Olympic shooting venue comprised of three huge PVC tents. Multi coloured 'spots' provide natural ventilation. Mott MacDonald provided full design services for the combined 50/10m range, the 25m range, the finals range and the shotgun and Paralympic archery ranges. The buildings were fully relocatable and were being considered for use at the 2014 Commonwealth Games in Glasgow. It was this foresight within the planning stage of the project that demonstrates teleocircularity; by having infrastructure, that's very purpose is to be re-used, or all of its assets re-used one is able to influence the greatest level of circularity. It is at this stage that the greatest benefits can be articulated and fed into subsequent stages of the infrastructure delivery chain.

Mott MacDonald provided technical review and site supervisory services for the acoustic, civil, MEP and structural engineering for the velodrome, handball arena and Eton Manor. Mott MacDonald worked with the Olympic Park Legacy Company advising them on the legacy options and design of the main Olympic Stadium. Circular economy principles were considered during the teleocircularity stage meaning that when it came to the end of life the principles of re-use, extending life of the assets and by being designed for disassembly it was truly circular.

3.2 Design stage and concept circularity

Once into the design stage, or what we are calling concept circularity, we can set the parameters of design that ensures the circularity of the asset is enshrined going through to construction, operation, and end of the current life, making sure that we allow the asset (or part of it) to be reused as much as possible following the teleocircularity stage. Concept circularity can also be split further by the way in which the design phases in conceptualised.



Concept circularity necessitates two different kinds of products; bespoke products and standard products. Starting from these last ones, standard products are designed for infrastructure to be used in design and much easier to be reused at the end of their life. They are by their nature easier to be included in circular infrastructure.

Bespoke products on the other hand have the advantage of being high value items that standard products would tend to be. They may result in being only at the beginning of the circularity loop and include innovative ideas that if successful will be used in future projects too. This also requires a system level understanding and a true embrace of the circular economy and data management, creating a market place for reusable products and assets and enabling bespoke products to gain a second life.

The design phase also provides many opportunities to integrate different aspects of the circular economy into a project. During concept circularity, it is possible to influence the supply chain and design in construction techniques that utilise the circular economy. By ensuring that techniques such as DFMA and modularity are included during this phase of a project, a greater level of influence over the circularity of the project can be achieved when compared to only later considerations.

Case Study

Mott MacDonald together with our client, Anglian Water, have developed an online catalogue of standard products, streamlining design, procurement, and project delivery, contributing to cost savings of up to 45% and time savings of up to 90%. Through creating a digital product library the design phases of a project can open opportunities for circularity to be embedded into the project lifecycle.

Under an initiative termed 'product-based delivery', Anglian Water is achieving whole-life performance improvements by creating standardised designs for common items of equipment. 181 products have been developed and further have been identified for development. They are manufactured and can be combined in different ways "like Lego" to meet different project requirements.

Products have been developed by pooling the technical, operational, construction and manufacturing knowledge of engineers and operating staff from Anglian Water, consultant and contractor partners, and specialist suppliers. BIM plays a key role in co-ordinating their input. Designs are value engineered and optimised for whole-life performance. With significantly greater investment in product development, waste can be reduced and energy efficiency can be optimised, delivering cost and carbon benefits.

By integrating circularity into the design phases, through digital technology you can ensure a greater level of influence over the circularity in subsequent phases. By having standard products, including DFMA products build in at the design phases you can ensure a project, assets, and parts of assets can retain a higher degree of circularity throughout delivery of the infrastructure.

3.3 Construction stage and capital circularity

Circular concepts previously considered and espoused across the planning and design phases take place during the construction stage. Once these are implemented, it becomes a much easier process to ensure circularity across the asset lifecycle. By using DFMA, modular design, and integrated data we can construct in a way that stays true to the purpose of the asset and retain the levels of circularity. Capital circularity is identified at the construction stage, hence closely linked to capital aspects of the project.

The way in which a site is managed and run also has a direct impact on the circularity of a project. We can be circular through the minimisation of use of natural resources, minimising waste production on site, maximising the reuse and recycling of materials, and through choice of energy use on site. These decisions make greater the circularity of an asset. It is at this stage that there is a danger that circular principles are forgotten but we can see that there is much that the industry can do to deliver the circular economy in this context.

Case Study

Mott MacDonald have been pioneering the use of standardised design through a project with the Department for Education in the UK. Mott MacDonald are leading the procurement for a £95m framework to deliver around 25 new primary schools by 2020 for the former Education Funding Agency (EFA) – now Education and Skills Funding Agency.

The framework is the first by the EFA to be based on off-site solutions and aims to deliver repeatable high-quality schools, with a greater degree of cost certainty and the minimum of disruption for the school.

Since April, Mott MacDonald has been working with Bryden Wood Architects to develop four primary school templates for the EFA. These are designed to work with all common off-site construction techniques and will be developed by the D&B Contractors to suit their own off-site methods.

Ultimately it is hoped to dramatically reduce both the time it takes to get a project to site and the construction time itself, enabling outdated and inadequate schools to replaced more rapidly with modern and comfortable spaces.

3.4 Operation stage and operational circularity

The operational phase of an asset life is often overlooked during traditional understandings of the circular economy. As it has been understood the circular economy deals largely with waste and product design but ignores the two major opportunities that operational circularity can unleash.

The first is around the operational inputs of an infrastructure asset. Namely, the energy source that is powering a building, stations, etc. Circular supplies ensure that we are drawing from a non-linear energy source and have further circularity within a circular project. As briefly discussed in the introduction to this piece, the construction industry will embed renewable technologies as the source of power for the infrastructure of the future.

The second opportunity that operational circularly throws up is through extending the life assets. This is an opportunity to influence infrastructure that has not been designed with circularity in mind during the phase of a project discussed above. Nevertheless, by working to extend the life of assets, utilising data and innovative technologies as enablers, we can introduce circularity and ensure we don't miss the opportunities just because they have been missed earlier. It is for this reason that the levels of influence over the circularity of a project spikes during this phase. By extending the life of assets we can ensure that we delay the need for new assets or indeed to bring in additional or replacement modular elements. Through keeping the asset living we enhance its circularity by delaying the shift towards a second life or the end life.

Figure 2 clearly demonstrates the extent to which circularity in assets diminishes over time. Again, through the extension of the life of assets we improve the circularity of a project as we extend the period of an assets usefulness before shifting towards a 2nd life.

Case Study

Anglian Water's Biosolids programme exemplifies a water utility successfully integrating the expertise of its contracting and consulting partners to deliver benefits at the strategic level. Cotton Valley and King's Lynn, two of the programme's schemes, exemplify how using a successful integrated design and construction capability can deliver significant benefits at the project level.

As a result of the work undertaken by Mott MacDonald capital expenditure (capex) increased by 10% but was offset by an operational expenditure (opex) saving of £3M per annum. These opex savings pay back the increase in capex within three years. The substantial opex savings were achieved as a result of opting for hydrolysis processes to treat the sludge, a valuable consequence of this approach being a substantially increased biogas yield. Combined heat and power (CHP) units are able to convert sufficient quantities of the biogas to meet the heat requirements of the hydrolysis process and generate enough electricity to run the new and retained existing works. As a result, the four treatment centres will be energy self-sufficient. A

further element of the opex reduction resulted from the cut in bulk lime purchases. In sustainability terms, this approach greatly reduces the treatment centres' reliance on fossil fuels for power and road fuel.

By utilising the power of biosolids one can create a more circular energy supply. These circular inputs feed into the infrastructure lifecycle and ensure more circularity.

3.5 End of current life stage and asset, component and material circularity

The end of life of an infrastructure asset will bear the fruits of the circularity incorporated into the preceding project phases. Crucially, if the planning and design phases are conducted with the end of life in mind then we will be able to see a truly circular asset. For example, components within in a building designed for disassembly and reuse in mind can be repurposed and circularity will be achieved. Nonetheless, if previous stages of the asset life did not consider circularity principles, only reuse and recycle of materials will be possible giving new life to portions of assets that otherwise would be completely landfilled.

Case Study

The use of design expertise and materials from the London Olympics, incorporated into the Glasgow Commonwealth games two years later, is how the loop can be closed in the infrastructure sector. By designed for re-use, both in materials and design, companies can ensure circularity from one life of an infrastructure, into its second life. Not only that but assets and parts of assets that aren't needed in that second life, gain a second life of their own. By incorporating circularity across the value chain, the end of life become not an end of life but a re-birth of assets, components, ideas, and infrastructures.

No venue has ever been reused from one major games to another – this was possible due to the intelligent use of rental components in the original London 2012 design by Mott MacDonald. In addition there was a political will to make it happen on all sides, but only for a very low budget. To deliver this project was not only a challenge of technical redeployment and strengthening of components originally designed for a different configuration and wind loads, but also a significant logistical, planning and project management challenge against an immovable deadline of the summer games.

Using the blue print from the Olympic games, Mott MacDonald re-engineered the solution – providing savings where possible and removed all non-essentials such as stainless-steel fixings, flashings and a reduced paint specification. In addition, we worked closely with the fabricator of the firing line canopies to develop our design and details to optimise material length for delivery and splice location reducing work at height and erection time. Developing this approach, we undertook the design and documentation in a once through process without a single RFI from the fabricator.

Across the Mott MacDonald design team, technology and processes associated with BIM was used to streamline delivery, optimise range locations, and produce once through design processes. To ensure a fair competition during the event, all shooting lanes are required to be considered equal. Therefore, at the time of the shooting rounds, the targets must either be fully in shadow or not. Using the architectural centreline model, we undertook environmental analysis to assess sun path and shadow lines. Then – within the competition

A further consideration is the re-use of materials from assets to aid circularity in infrastructure. At Mott MacDonald the use of concrete gabion, allows previously disposed of materials to be reduced, recycled, or reused.

For highway widening there is usually limited space within the existing boundary to accommodate conventional earthworks and thus a retention system of some form is required. These traditionally include: sheet pilling, concrete retaining walls, reinforced soil slopes among others.

These systems are either expensive or impact upon the existing vegetated slopes. By utilising the solution developed for NRTS on the M11 Upgrade we have further developed a more versatile and cost effective retaining solution by utilising rectangular manhole units.

The key benefits of this are:

The concrete gabion concept offers significant benefits over traditional slope support and protection measures as summarised below:

- Excavated material re-used
- Imported materials minimised concrete gabion
- Vehicle movements for ‘muck-away’ operations reduced
- Construction cost reduced (estimated to be £200/m2 as opposed to £400/m2 for Ecocrib and sheet pile wall and £250/m2 for stone gabions.)

This solution allowed us to make considerable material savings on several projects, ensuring a further level of circularity that can be expanded to any infrastructure project.

4 Enablers

What will drive society and the infrastructure sector towards the circular economy?

We may say that leadership from individuals and organisations within the asset value chain is the first and foremost pre-requisite needed to deliver a model of circular economy in the construction sector as described in this paper.

Nevertheless, the following enablers and drivers will not only make the transition towards a circular economy easier but they will create and demand an environment in which the circular economy will be required.

- Data and new technologies (digital)
- Systems of production and consumption
- Demographic

Several key enablers sit behind the ability to move towards a circular economy in the infrastructure sector. Perhaps the most influential enabler is that of the growth of big data. Data, both the collection of it, and the use of it, can be used across the lifecycle of an infrastructure project. It can, among other things, inform kind of project that will be delivered in the first place, it can monitor asset health, and provide an understanding and market place for assets at the end of life. New technologies, in particular the digital technology will enable circularity.

The systems of production and consumption will also influence the ability of a project to be deemed circular. The rise of DFMA forms of construction will drastically impact the traditional project lifecycle and enable a shift towards a closed looped style of project. Furthermore, the habits of consumers will also have a big impact on the way in which the infrastructure sector embraces the circular economy.

Demographic change also provides a significant enabler to the circular economy. As urbanisation sees the rise of cities around the world the demography of urban spaces will inform the how infrastructure can response to and enable lifestyle choices which are demanded by the body politic, less materialistic and material but more focused on services and outcomes.

These three key enablers are intertwined and provide the catalyst for a circular economy, and crucially, a circular economy in infrastructure. Modern society and the behaviours of that society can be captured through data, this can inform decision makers and in our context, can provide our sector with an understanding of how people imagine a future society. Data also enables assets to be designed and manufactured in a new way. It provides the entire lifecycle of a project with the opportunity to extent asset life and fed into a truly circular approach to infrastructure.

5 Conclusion

The circular economy, as traditionally known, is a useful framework for addressing issues around waste management and unlocking opportunities in product design. However, far too much pressure and too high expectations have been deferred to the waste management industry to close the circularity loop in the infrastructure sector.

What this article has done is break down the notion and applied it across the lifecycle of the infrastructure asset. In doing so we have identified several circular economies that are both dependent on each other and enabling to the extent to which true circularity can be achieved.

The first question that lingers though is the extent which our common and accepted understanding of infrastructure will be challenged by embracing a multi dimension circular infrastructure narrative that combines elements of traditional infrastructure with new and innovative alliancing and production methods. In other words, is the wishful and monopolistic current approach to circularity in the infrastructure sector, that aims to distort the intrinsic and traditional linearity of asset life, in opposition to the teleological circularity that we are proposing in this paper? The answer is yes.

But perhaps the question is not whether the two concepts are opposed but whether it matters at all if they are. A circular economy, comprising of the circular systems described in this article, presents a new image for infrastructure, one that paints an exciting and innovative future for the sector.

As discussed throughout the desire for, and ability to achieve, circularity is dependent on both the enablers and the ingenuity of the people that put these concepts into practice; but to achieve a truly circular infrastructure sector many different things will need to happen within the industry. These include:

- Creating a market place for assets to be utilised for a following life – at present only a fraction of materials and whole assets are being repurposed.
- Ensure that alliancing happens on project level throughout the lifecycle. This article has shown that the planning stage has a direct impact on the end of life of assets, these different phases, and the actors within them, need to be speaking from the outset.
- Enablers such as data and production methods are not only enablers but can inform and influence many of the project phases. Using these to our advantage the infrastructure sector can embed and maintain circularity throughout the project lifecycle.