

How Rail Can Enable the Circular Economy

A White Paper



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Executive Summary

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This white paper represents an extension of the original Institute of Asset Management (IAM) circular economy white paper set within a UK rail sector context. In November 2022, the IAM published its White Paper *How Asset Management Can Enable the Circular Economy*¹. The paper was published to eliminate the notion that an asset has an end of life. The paper discusses how asset management can be used, both now and in the future, to support the future circular economy. Generally, anything that grows an economy or that incentivises regenerative and/or restorative outcomes, reduces consumption compared to alternatives, and, therefore, could be considered as having some form of circular economy value. The value that can be realised from the future circular economy will be dependent upon holistic systems thinking, enabling greater value from the sum of the system's parts. For example, extending the lives of assets, adapting business models to move towards service models, designing assets for maintainability, supported by the need for more refurbishment and remanufacturing opportunities.

Rail is a low-carbon transport mode, and accounts for only 1.4 percent of overall transport emissions when compared with alternatives². For example, when considering freight alone, freight moved by rail results in 76 percent less carbon generation than freight transferred by road. However, only 9 percent of freight is moved by rail in the UK³. With the UK now having a legally binding net zero target by 2050, and new interim targets to reduce emissions by 78 percent by 2035⁴, enabling transport policies, industry strategies and incentives to maximise the switch of transport to rail now is one of the most effective measures the UK government and industry could take in meeting those targets.

We should recognise, however, that the negative impact of climate change is directly related to the outcome of how our current economies and policy frameworks have evolved. If the outcome of policies and our current economy can be described as a competition based upon the short-term value of profit, then at the other end of the spectrum, there would be an economy that can be described as a competition based upon the short, medium, and long-term value of profit from enabling social capital, regeneration, and restoration towards sustainability.

In the future, this means that organisations compete, and, by definition, the economy depends on how regenerative and restorative services and products are in wider and longer-term contexts. Competition between rail and alternative modes of transport, for example, can no longer be based upon price alone, but rather new conditions that support and commit to longer-term investment in rail transport are required. Our current economy does not incentivise profits gained from restorative and regenerative transport modes, but in the context of rail, (or for any other sector, for that matter), this is what a move towards a more circular economy would mean.

The development of this white paper relied upon the outcome of three workshops with a sample of key rail industry actors and stakeholders. This included the Government regulator, railway industry bodies, and supply chain partners. The feedback concludes that a systems thinking approach or 'whole systems approach' is needed to exploit the greater potential value that our railways can offer. Incentivising the adoption of circular economy principles and concepts within a whole systems context would accelerate the growth in our economy at local, regional, and national levels, as well as grow exports, improve wider society, and improve the quality of life across our communities.

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1. The Institute of Asset Management: How Asset Management Can Enable the Circular Economy. <https://theiam.org/media/4103/iam-how-asset-management-can-enable-the-circular-economy.pdf>
 2. Office of Rail and Road - Rail emissions 2020-21 <https://dataportal.orr.gov.uk/media/1993/rail-emissions-2020-21.pdf>
 3. Department of Transport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/552492/rail-freight-strategy.pdf
 4. UK Government Global Net Zero Commitments <https://commonslibrary.parliament.uk/global-net-zero-commitments/#:~:text=The%20UK%20has%20a%20legally,focus%20on%20long%2Dterm%20goals.>

This white paper aims to take a broader whole systems approach in a railway context and show how the impact of adopting circular economy practices can enable positive outcomes for our economy and have positive impacts on our society and our environment.

This white paper makes the following main recommendations:

- 1.** Government should promote behaviour that is conducive towards achieving a circular economy and establish a rolling short, medium, and long term level playing field, based upon a whole systems approach, for transport systems. For example:
 - a.** Adapt and develop policies to purposefully exploit the latency and projected life of railway systems to offset the negative impact alternative transport systems have on our environment, business, and health.
 - b.** Move towards a whole-life value policy decisionmaking framework for investments, which is an extension of the existing whole-life cost approach. Whole-life cost is the total expense of owning an asset over its entire life, from purchase to disposal. Whole-life value is situation and context-specific. It considers the maximum impact in the short, medium, and long-term, while considering the value of the asset in terms of what it enables in the bigger picture, not just what it costs. The value (capability) of the externalities of what the asset enables needs to be brought into the picture. Enabling this clarity provides visibility of regulatory harmony across sectors. If we don't have this visibility, we don't understand the social, economic, and environmental impact of the benefits and trade-offs that have to be made across sectors when we make investment decisions.
- 2.** Simplify and modularise the technical landscape of the railway infrastructure assets as well as interfaces between systems. This opens up opportunities for a broader and more diverse supply chain to supply into the rail industry.
- 3.** Focus towards railway asset life cycle performance. For example, in terms of the life cycle length that assets are designed for, whether they are upgradeable, can be remanufactured, and so on. Performance should be based upon measures of exceeding compliance, rather than simply meeting minimum thresholds of acceptance. Procurement strategies should incentivise asset performance in this context.
- 4.** Move towards 'assets as a service', which switches the onus of ownership and issues around asset reliability and asset performance back to the manufacturer. For example, it would be in the interests of the manufacturer to have an asset back if it is going to be refurbished/ upgraded and put back into service.
- 5.** Establish the means by which data can be made open and accessible within and across systems boundaries. This forms the foundation for communications and feedback loops that push and pull data enabling opportunities to understand, develop and adapt measures of effectiveness. Data insights will inform performance and settle governance or management arguments. Communication channels and communication protocols need to be readily understood and purposeful. Having access to this level of data creates opportunities for existing and new business types across the supply chain that would rely upon datacentric intelligence around improving asset performance. The ability to gather evidence attracts strong management attention.

6. Link this broader capability to railway industry resilience at a local, regional, and national level and grow and establish new types of businesses across the railway network. Develop and deploy new technologies that specialise in improving railway asset performance. Exploit this capability across the UK's industrial landscape and use this as a platform for exports. The development of the Global Centre for Railway Excellence⁵ (GCRE) must contribute significantly towards these goals, as well as the need to take a systematic approach to exploit and integrate academic research⁶ to those ends.
7. Simplify the route for engagement in railway exploitation. This means how to engage, who to talk to, and the turnaround in decision making to exploit the railway at a local, regional, and national level, as well as at an industry level. The route to railway exploitation should be simple, timely, and effective, and the railway systems should be flexible enough to adapt to changing demands. For example, simplifying access for local, regional, and national freight services.
8. Create the convenience of end-to-end journeys with multi-modal solutions where rail forms the existing and expanding land backbone of a fully integrated, broader transport system that exploits the optimisation of resources and economies of scale. This includes the concept of creating sharing platforms supported by open data that supports rail actors and stakeholders that share a common rail transport purpose.

5. The Global Centre of Rail Excellence will be a purpose-built site for world class research, testing and certification of rolling stock, infrastructure and innovative new rail technologies that will fill a gap, not just in UK rail, but across Europe.

6. The UK Rail Research and Innovation Network (UKRRIN) is designed to create powerful collaboration between academia and industry, aiming to provide a step-change in innovation in the sector and accelerate new technologies and products from research into market applications globally.

The concepts and ideas described in this paper are drawn from a range of sources and research. We have hypothesised the benefits of these concepts and ideas, relying upon a simple whole systems approach that exploits the wider value of the railway. The circular economy relies upon systems thinking to create economic value.

Societies in future will be moving towards economies that are more circular, whether that is planned for or made compulsory through legislation. Current legislation is lagging, as, for example, it is designed to prevent climate change from getting worse. For organisations to remain viable, they need to plan to exceed compliance and show how much they will exceed compliance by promoting the concept of circular economy competition year on year.



1. Introduction

The circular economy is an economic and societal shift towards sustainability and regeneration through the maintenance and rebuilding of natural and social capital stocks. The maintenance and rebuilding of these stocks can be greatly accelerated through the deployment of systems thinking, where sustainability and regeneration are the product of the interaction of the circular economy parts.

This white paper describes how the application of thinking in systems is lacking in general, and the rail regulatory framework that's currently in place does not encourage or incentivise circular economy-like behaviour, but it needs to appropriately value assets from all perspectives and maximise benefits for future generations. This paper could inform or become the basis for a wider circular economy strategy for the UK rail sector. That would touch upon and exploit existing initiatives but put a boundary around them to show how the value of existing initiatives can be extended in a joined-up-thinking approach. Organisations that plan to be more viable and sustainable must plan to work in the future circular economy, which continually strives to address and improve upon the social, economic, and environmental challenges we face now and will be facing in the future.

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Within the context of asset management, the discipline that manages physical infrastructure, the focus for investment should be evidenced in delivering and leveraging value over the long term. This is particularly relevant for major investments such as rail transport, where value is multifaceted, and that value changes and grows over multiple generations. The value of a railway investment made today will only represent a fraction of the expenditure and the value the railway will create in the future. The adage 'one generation plants a tree; the next sits in its shade' works well in this context, hence decisions for long-term investments should go beyond terms of government.

This value is founded on long-term shared goals and must be regularly planned for and adapted. This is why investment outcomes will always matter⁷. By way of example, within a circular economy and asset management context, organisations can make existing assets last longer, i.e., design products that can be refurbished over multiple life cycles, shift operations to service models, create syndicates, networks, or value chains that offer greater sustainability and regenerative outcomes.

In contrast, and in the broadest context, economic growth and business performance over many generations have been intrinsically linked to consumption. Yet as a society, we are only responding to the outcome of those consequences in the last few generations. Most of the responses to climate change are lagging, for example, applied through legislation in an attempt to prevent our present situation from getting any worse. The challenge for organisations and hence for the economy to adapt and break out of the profit/consumption-driven model shouldn't be underestimated.

There are many routes to break out of this model, and most of the ways will be contextual. Pathways (means, not ends) have been developed as a way to encourage changes in behaviour in industry, such as carbon accounting and the adoption of the 'Net Zero' mantra. Many organisations are responding by making marginal gains on reducing their existing carbon footprint, but many still operate the same business model of increasing revenues based on encouraging consumer consumption. This is not viable in the long term.

The route to longer-term economic viability—and viability of businesses—will not solely be linked to what profit they make, but profits from regenerative and restorative outcomes organisations choose to be identified with (their purpose) and what they create. This can be represented in many forms, for example, a resilient, advanced, and diverse manufacturing base and a resilient supply chain employing a steady throughput of developing staff in advanced skills, apprenticeships, and lifelong learning.

7. The Institute of Asset Management. Designing with outcomes in mind means asking, right from the concept stage, what is the overall value of this project? Available at: <https://theiam.org/knowledge/why-outcomes-matter/>

This white paper identifies what can be done to support the enabling of a circular economy approach in the railway industry, through three themes:

1. The deployment of systems theory and systems thinking to create wider value.

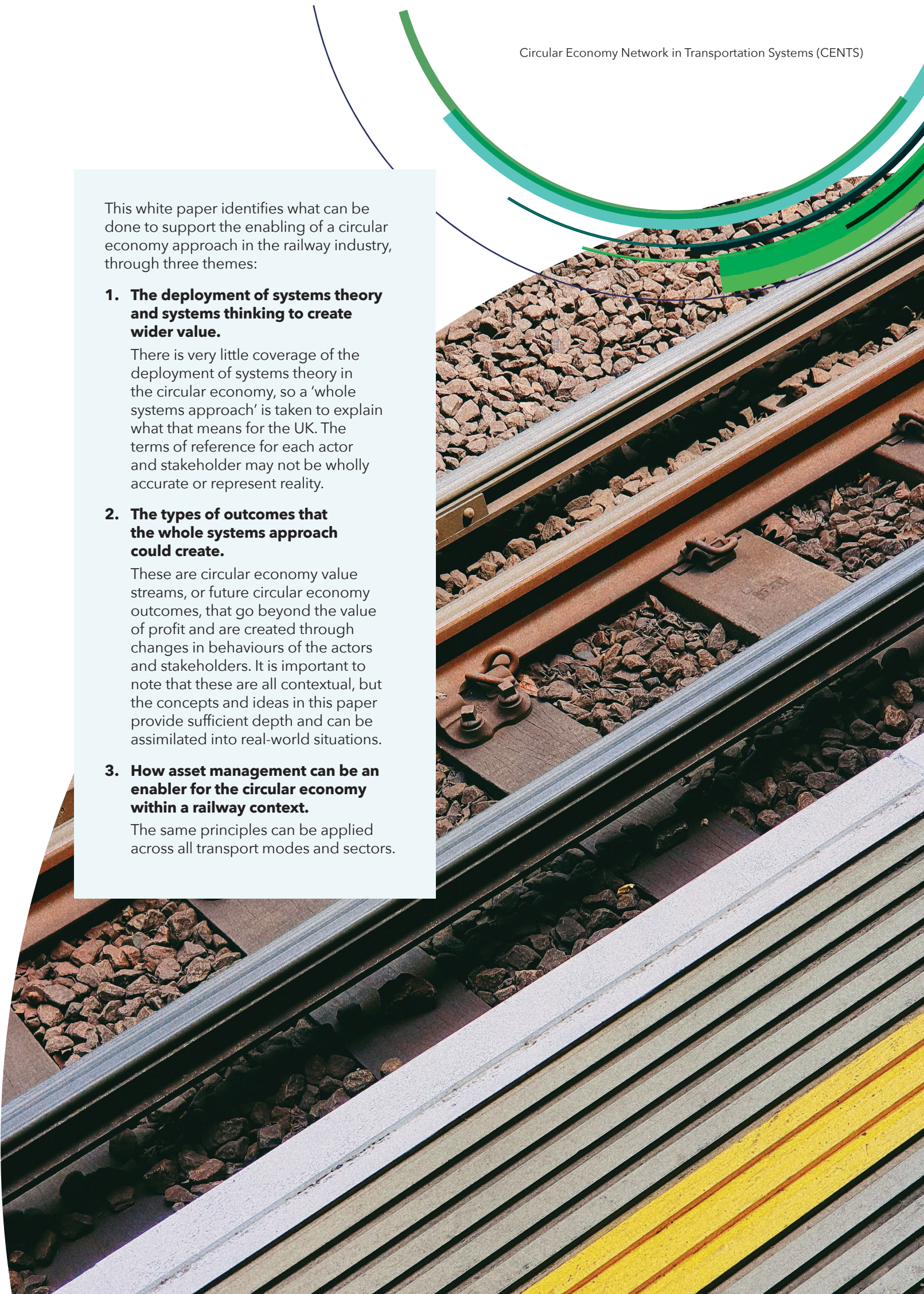
There is very little coverage of the deployment of systems theory in the circular economy, so a 'whole systems approach' is taken to explain what that means for the UK. The terms of reference for each actor and stakeholder may not be wholly accurate or represent reality.

2. The types of outcomes that the whole systems approach could create.

These are circular economy value streams, or future circular economy outcomes, that go beyond the value of profit and are created through changes in behaviours of the actors and stakeholders. It is important to note that these are all contextual, but the concepts and ideas in this paper provide sufficient depth and can be assimilated into real-world situations.

3. How asset management can be an enabler for the circular economy within a railway context.

The same principles can be applied across all transport modes and sectors.



2. Layout of this paper

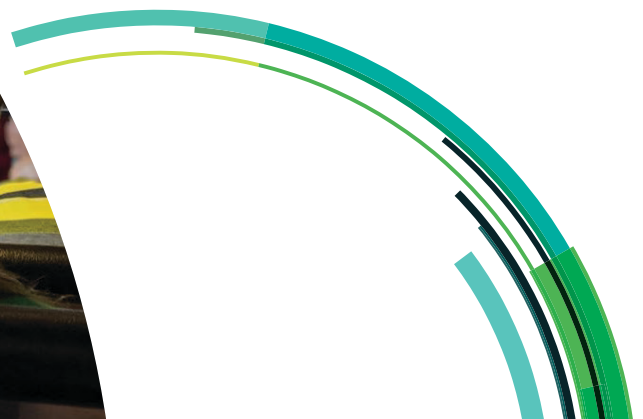
In Section 3, Systems Theory is applied as a basic setting to describe a viable railway system within the UK—a whole systems approach. This shows the actors and stakeholders of the railway and how governance works to make a railway system viable. The application is at a very high level and, thus, does not necessarily represent reality, and in some instances, some of the governance might already exist. However, the purpose is that the value of the railway can be interpreted as a regenerative platform, one that serves a common and shared purpose for a myriad of stakeholders. *Readers should familiarise themselves with the makeup of the whole systems approach, as it is used as the backdrop to visualise where actors and stakeholders sit, understanding policy impact, where circular economy value can be created at different scales in and around railway systems, and then how that value is converted into creating greater values that support the benefits that the railway enables.*

Section 4 describes how the discipline of Asset Management can be used as an enabler for the circular economy. This uses the whole systems approach as a backdrop, and we show how the discipline of asset management covers a broad spectrum around the governance and deployment of engineering practices across asset life cycles. Focusing on the recently published Institute of Asset Management white paper *How Asset Management Can be an Enabler for the Circular Economy*, placed within an applied rail context.

Section 5 explains some circular economy perspectives and challenges that were presented during rail industry consultation workshops. Three workshops were held with rail sector actors and stakeholders where several circular economy challenges were fielded, and the feedback captured—blockers and enablers—to use in this white paper. The appendix captures the feedback from the workshops as a record of our research. The content of this paper can provide a platform for several routes to additional research. The blockers and enablers captured in the workshop fall into eight key themes that are outlined in the Executive Summary and explained in more detail in Section 6.

Section 6 explains our conclusions and recommendations by assimilating the workshop feedback and mapping these across the whole systems approach to assess where blockers occur and what the enablers might be to unblock them within a circular economy context. This is intended to provide insights into the types of interventions that can be made, the value those changes enable at multiple scales, and what the benefits of the impact of these changes could be and why.

Section 7 acknowledges the support, contributions, and time given by the people and organisations who engaged in this project.



3. A 'Whole Systems Approach' for the UK Railway

The commitment of the government to invest in railway transport systems represents a desired and permanent commitment to build upon and improve the fabric of communities and create the means of shared transport systems at a societal level.

The positive outcomes of what the railway system does are at scale. Effective railway systems create the fabric of the society we want to live in; it deals with the challenges of society getting to work, becoming educated, seeing friends and relatives, travelling long distances, delivering goods, and preventing city congestion and pollution. The mobility of our society is directly proportionate to the health and well-being of that society and its economy. The well-being of our society and the environment is directly proportionate to which transport mode is exploited. The balance of transport modes needs to be continually managed.

The purpose of adopting a whole systems approach for the overarching railway is to provide a backdrop for governance and the deployment of systems thinking within the context of railway systems and the circular economy. This also supports the context of deploying asset management practices to enable an economy that is more circular. The whole systems approach diagram is shown in Figure 1, and an explanation of each area of the diagram is detailed below.

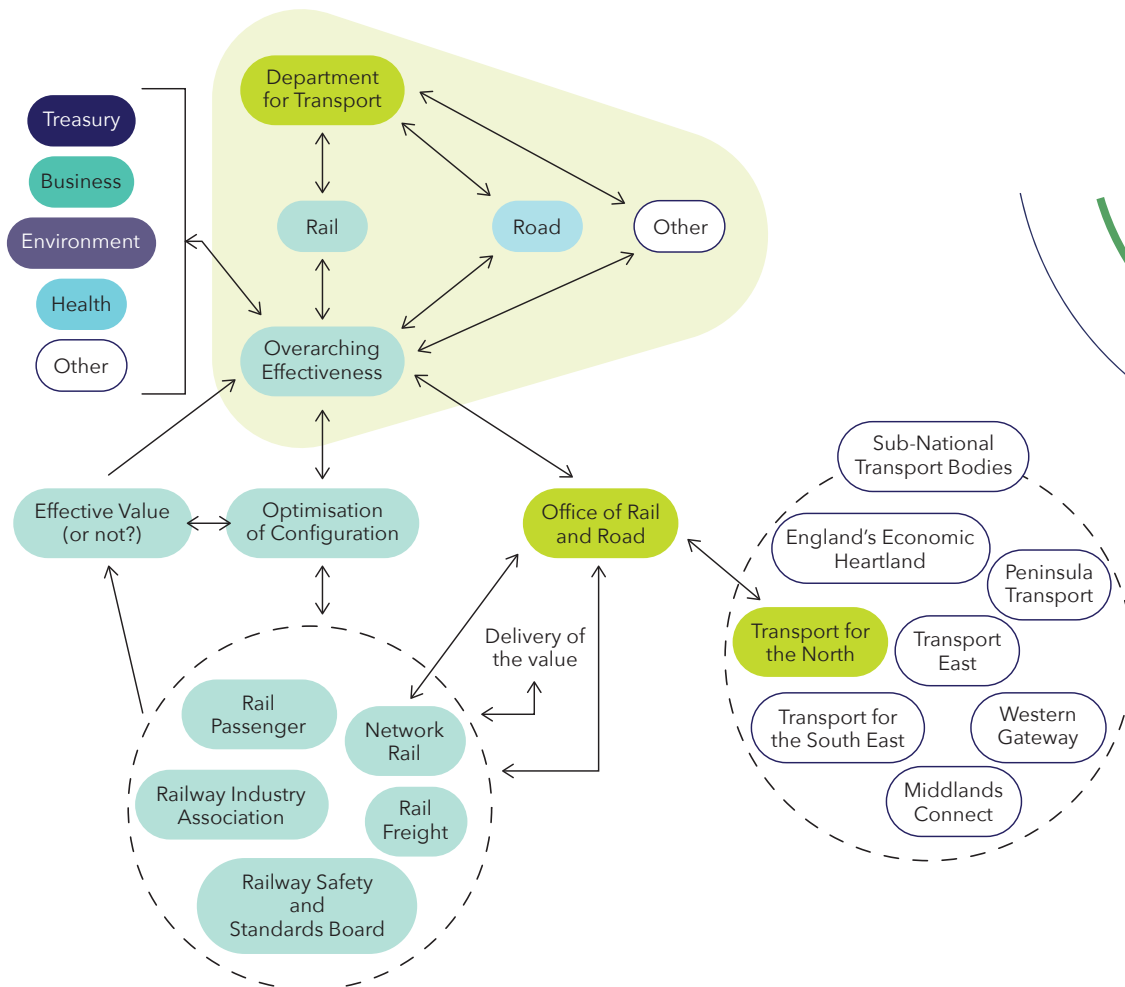


Fig.1. Whole systems approach diagram

The whole systems approach has been produced 'without constraints', meaning the design of the function of the whole system has been based upon the objective of the railway remaining a viable transport system that integrates with other transport modes, such as buses, cycling, or road transport in general. In producing the approach, we have been loosely cognisant of terms of reference of existing actors and stakeholders that make up the railway system, but we have not carried out any detailed analysis as to whether their terms of reference align with the whole systems approach.

In addition, we recognise that the governance and structure of the UK railway are in a state of transition⁸ through the establishment of the Great British Railways Transition Team (GBRTT). We have not carried out an analysis as to whether the whole systems approach is in line with any outputs from the GBRTT. We anticipate that the function of the whole system would encourage future discussion and validate existing practices, as well as provide the opportunity to adapt existing policies. This may shape and create the intended outcomes of the whole railway system and encourage changes in actors' and stakeholders' circular economy behaviour within and around the railway system.

10 The whole systems approach adopted a loose interpretation of several problem structuring methodologies (PSMs)⁹ for actors and stakeholders that exist in the UK. This white paper is not intended to identify limitations with the existing UK railway structures, but to describe a possible railway structure where the wider value of the railway system can be interpreted and exploited, and in so doing, create visibility of the whole life value of railway assets as an extension of whole life cost and the deployment of circular economy principles in context.

The Department for Transport (DfT) is responsible for the highest policy decisions and to balance the demands from different transport modes, as well as the demands from different parts of the transport systems across the UK. It is responsible for determining the governance and identity of transport and the overarching effectiveness (value creation) of each transport mode. This basic relationship is shown in Figure 2. Figure 2 also shows the feedback loops and interdependencies that are needed between the 'Overarching Railway Effectiveness' and the link to other transport modes, as well as the monitoring of the external horizon on how the railway needs to adapt to address future demands to remain viable.

The external horizon is anything that the effectiveness of the railway has an impact on, or the horizon has an impact on the railway. In this context, we've included other government departments that are stakeholders that benefit from, or can have a positive or negative impact on, the effectiveness of the railway. A good example would be the railway enabling people to get to work, thus realising revenues for the Inland Revenue or legislation established under environmental law to prevent pollution. Similarly, the horizon can be exploited where there is a lack of legislation, or a lack of strong policy. The feedback loops are not intended to be comprehensive or at scale and are shown purely to indicate a significant channel of communication.

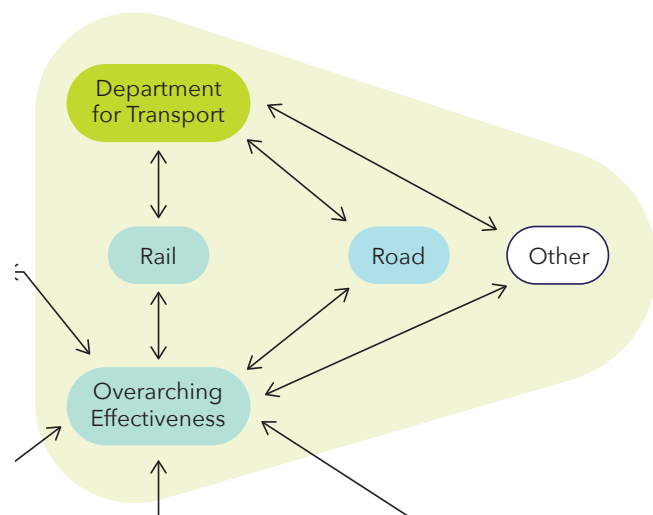


Fig.2. Transport modes and effectiveness of rail

8. The UK Government has established the Great British Railways Transition Team that is targeted to create a simpler, better railway for everyone in Great Britain. Available at: <https://gbrrt.co.uk>

9. For example, see the deployment of Viable Systems Theory and Soft Systems Methodology.

There should be comparable 'overarching effectiveness' impact measures for each transport mode in context. This includes the impact on wider society and the environment. For example, the overarching effectiveness of road freight with other transport modes for freight.

Policies established by the Department for Transport influence what transport effectiveness means. Effectiveness should be viable, considering wider contexts, and the DfT should set boundaries that encourage actor and stakeholder behaviour within and across transport modes. For example, policy changes should happen before it becomes apparent that changes in one transport mode are having a negative impact on the benefits of another, and thus lowering the overarching effectiveness of all of the transport systems combined. An example may be incentives to encourage more people to travel by rail, which would mitigate the demand for road congestion charges, and in so doing, reduce air pollution, reduce demand on our health services, and reduce the potential for lost time.

Figure 3 shows the externalities that the railway enables. For example, at the highest level, these are the regenerative and restorative outcomes that actors and stakeholders related to the railway system can be identified with, in terms of creating value. It is this value that the DfT influences, and the railway is just one of several modes of transport that the DfT affects. This is the combined purpose of the railway. In this context, the purpose of the railway is but not limited to:

- Enabling social, economic, and environmental uplift enabled through travel, including generating income for the Treasury through tax revenues from the direct and indirect actors and stakeholders that enable the railway, including the supply chain. Reducing the negative environmental impact from alternative modes of transport and generally facilitating society to connect. This needs to be interpreted at local, regional, and national levels.

- Enabling the optimum tax income per capita and positive social and environmental impact per route mile. This draws on the need for understanding and developing the governance and content (data) within and across communication channels that actors create and is understood by stakeholders. The value of data under a broad range of contexts needs to be linked with externalities¹⁰. For example, just understanding why and where people travel to and from would provide a step change in justifying investment as well as increase the value of the asset base because it's linked to enabling those externalities.
- Enabling local, regional, and national economies to grow in general through providing an effective platform for mass transit for employment and education purposes, as well as developing and continually growing home-grown capabilities and know-how for export purposes. This includes expertise in designing and building railways.

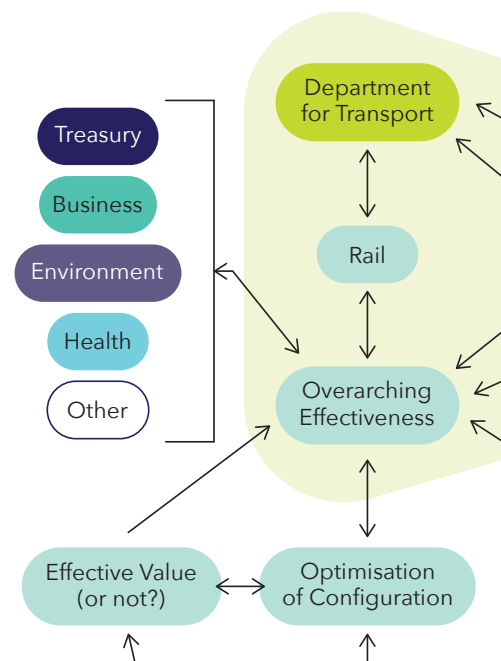


Fig.3. Externalities that the railway enables

10. Understanding the social and economic value of sharing data. The Open Data Institute. Available at: <https://www.theodi.org/article/understanding-the-social-and-economic-valueof-sharing-data-report/>

- Optimising the exploitation of transport resources. For example, certain transport modes are more effective than others when supporting densely populated areas. External impacts of transport modes, such as pollution or general negative impacts on the environment, need to be considered when making policy decisions.
- The reduction of any negative impact on the environment compared with alternative transport modes. The positive impact on the health and well-being of the population, as well as a reduced demand upon the National Health Services. This can be improved again with the potential saving of £17 billion off the NHS budget over 17 years, with the accelerated introduction of Active Travel¹¹.

Within a viable railways systems context, there is the need to continually monitor the overarching effectiveness of the railway all of the time to determine if the external environment changes. For example, the need for new, more, or fewer levels of effectiveness. The Department for Transport makes policy decisions as to what that level of effectiveness should be on a continuous basis. This level of effectiveness is also influenced at a regional, city, town, and local level. The integration of these transport systems should be at scale.

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It is also possible that demands and priorities will change. For example, the significant reduction of road investment projects made by the Welsh Government with the UK Committee on Climate Change makes it clear that a shift to electric vehicles is not enough to achieve UK targets, and there is a need to reduce other harms associated with road traffic. In particular, ‘increasing capacity for cars on our road network has been seen as a solution to transport problems. This has contributed to increasing reliance on the private car, resulting in urban sprawl, and in many instances, exacerbation of congestion, which has an economic impact and causes access issues as well as social and environmental problems.

The Welsh Government has stipulated the need for an approach that delivers social and economic benefits, is consistent with the Welsh Government’s land use, decarbonisation, and transport policies and helps address the nature and climate emergencies together¹².’ The emphasis is that there has been an imbalance between road and rail transport investment and private and public transport for decades. However, this decision to reduce highways investment should be supported by alternative public transport investment to make up the shortfall in transport capability in the longer term.

Within a viable systems context, the communication channels and feedback loops would predict this situation happening, and interventions could take place to prevent future possible negative outcomes. *The optimisation of configuration* (see Figure 4) is responsible for determining how value is delivered. This is different and needs to be kept separate to the delivery of the value (see below) because optimisation of configuration is responsible for establishing (and updating) the rules, types of resources, rights, and responsibilities of the parties that deliver value.

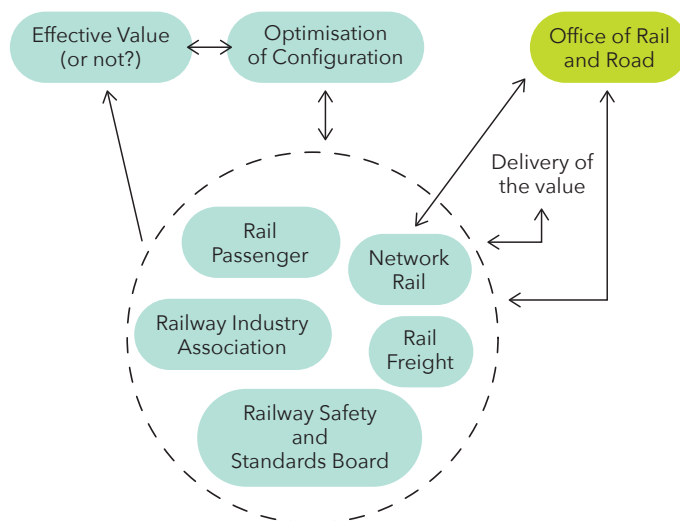


Fig.4. Parties that deliver value and the regulation of the value

11. Working Together to Promote Active Travel. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/523460/Working_Together_to_Promote_Active_Travel_A_briefing_for_local_authorities.pdf

12. Welsh Government Response to the Road Review. Available at: <https://www.gov.wales/welsh-government-response-roads-review.html>

An example of how value is delivered is the specification for the need of a railway infrastructure operator and its license. In this case, the operator being Network Rail, and how the performance of the infrastructure operator is monitored through its license by the Regulator.

The 'delivery of the value' of the railway that enables the positive impact on the externalities is bounded within the circle shown (see Figure 4). These are the industry actors and stakeholders that provide assets and operate the assets of the operational railway. For example, this includes Network Rail, which is held to account by license and regulated by the Office of Rail and Road. Other actors and stakeholders that support the delivery of value include The Railway Freight Group, which represents railway freight operators and the supporting supply chain, the Railway Safety and Standards Board, which manages standards as well as research on behalf of the railway sector as well as several other organisations. The combined group delivers the effectiveness of value.

The interaction of the stakeholders and actors within this boundary can be influenced by the major actor Network Rail, and it is assumed that their scope of influence (and, with that, their responsibilities) are embedded within their license agreement.

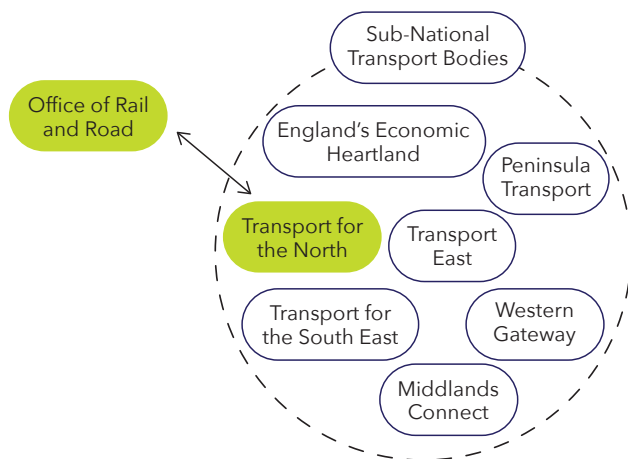


Fig.5. Sub-national transport bodies

The measure of effectiveness needs to be considered from at least two perspectives:

- Whether the railway is delivering the value it is supposed to be enabling. This is the planned impact on business, tax revenues, the environment and
- Whether that value is still effective considering changes in circumstances, for example, one transport mode becoming more dominant and, as a result, having a detrimental impact on the environment and people's health. This also includes wider strategic perspectives around industrial and scientific capabilities, as to whether that capability should be 'home-grown' and thus enabling exports or utilising those relied upon from others.

The need for these types of changes should primarily be recognised and understood by the *optimisation of configuration*, which would have gathered feedback as to whether the value of the railway is effective or not, as well as to what the existing and/or new *overarching effectiveness* is. Action should be taken to adjust or intervene on how value is delivered. Not having the foresight that sits outside the delivery part of the system would render the delivery of value far more challenging to control if it was done another way. Measures of effectiveness rely upon a continuous horizon-scanning activity. These broader impacts should be managed through policy and alignment across Government departments; for example, each Government department being cognisant of the positive and negative impacts of each of their decisions for the wider benefit of the economy, society, and the environment. In addition, the benefits of the impact of the mode of transport should be scalable and proportionate at a UK, regional, city, and local level. The same approach is applied across each transport mode and at scale.

13. Sub-national transport body. Wikipedia. Available at: https://en.wikipedia.org/wiki/Subnational_transport_body

14. England's first sub-national transport body. Available at: <https://transportforthenorth.com/about-transport-for-the-north/sub-national-transport-body/>

Within England, there are currently seven sub-national (or regional) transport bodies. A sub-national transport body is a type of ad hoc statutory transport governance organisation in the United Kingdom. They are intended to provide strategic transport governance at a much larger scale than existing local transport authorities by grouping councils together¹³. Outside London, their membership is formed from a mix of local highways authorities, Local Enterprise Partnerships (LEPs), local airports, National Highways, Network Rail, and the Department for Transport. They also work closely with Chambers of Commerce and other business interests. Only one sub-national transport body has statutory status (Transport for the North¹⁴), meaning it operates under the devolution of power from Central Government.

City transport systems operate under local government authority. Most operate concessions where transport systems, for example, tram operations, are subcontracted to operators or separate frameworks are established to open competition to the private sector, for example, with the operation of buses. Transport for London (TfL) operates under a more integrated approach compared with other cities and is responsible for managing the asset infrastructure for multiple transport networks, including London Underground, trams, etc., but it does not cover all National Rail services in London. In 2019-20, TfL had a budget of £10.3 billion, 47% of which came from fares. The rest came from grants, mainly from the Greater London Authority (33%), borrowing (8%), congestion charging, and other income (12%). Direct central government funding for operations ceased in 2018. City transport authorities are now moving towards a more integrated approach like that of TfL.

For simplicity, only the sub-national transport bodies have been shown, but clearly, the relationships between cities, rail transport systems (of any form), local enterprise partnerships, businesses, opportunities for employment and education, the Department for Transport, and the impact transport has on the environment, and our health is situation specific. The whole system approach is intended to be scalable, meaning it can be applied at multiple levels from a national perspective through to regions, cities, and towns, providing continuity of transport. Making decisions about what the overarching effectiveness of the railway should be is key. This should be done from a 'guiding mind' principle ending the fragmentation of the UK railway systems¹⁵, offering rail for passengers and freight operators as being a preferred option, and shifting the balance towards rail, offsetting the negative impact of alternative transport systems.



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15. Rail Review Chair Calls for Guiding Mind to oversee Sector. New Civil Engineer. Available at: <https://www.newcivilengineer.com/latest/rail-review-chair-calls-for-guiding-mind-to-oversee-sector-30-10-2019/#:~:text=The%20E2%80%9Cguiding%20mind%E2%80%9D%20can%20be,responsibility%20for%20track%20and%20trains.>

4. Asset Management as an enabler for the circular economy

Asset management is the discipline that manages physical infrastructure. The focus for investment should be evidenced in delivering and leveraging value over the long term.

This is particularly relevant for major investments, such as railways, where value is multifaceted and value changes and grows over multiple generations. The value of a railway investment after it is built will only represent a fraction of the intended value over the longer term. That value has to be continually planned and grown over decades. The adage 'one generation plants a tree; the next sits in its shade' works well in this context, hence, decisions for long-term investments should go way beyond terms of government.

This longer-term value must be regularly adapted. This is *why investment outcomes will always matter*¹⁶. By way of example, and within a circular economy and asset management context, within the rail sector, organisations can make existing assets last longer, design products that can be refurbished over multiple life cycles, shift operations to service models, create syndicates, networks, or value chains that offer greater sustainability and regenerative outcomes compared with what was achieved previously, and compared to their competition. That competition works at multiple levels.

Effectiveness of the transport system itself on a social, economic, and environmental perspective, and competition on a social, economic, and environmental perspective across the supply chain that enables the transport system.

The railway already does this to some extent, but it is not accredited for doing so. The sustainability brand of our railways needs to be rejuvenated and promoted. For example, when assets are cascaded and life extended way beyond their design life¹⁷, this is an achievement. For example, the current rolling stock franchise investment model does not take into account the value of the residual life of rolling stock. This, directly and indirectly, encourages a take-make-waste mindset within the rolling stock industry. This needs to be turned on its head to drive the need for increasing asset performance, and accounting rules need to be adapted to accommodate this extra value because that extra value is already being taken advantage of. The railway is uniquely positioned to work towards the circular economy because of its 'shared platform' status. Multiple stakeholders have a vested interest in the railway working, and more stakeholders would benefit from the railway if its latency was exploited further. For example, policy and regulatory frameworks can be adapted to grow new rail demand and change industry behaviour.

In general, traditional asset management practices follow a linear 'take-make-waste' philosophy, where resources are 'taken' as raw materials and 'made' into new assets. Those assets are then utilised to maximise their performance and then disposed of, making them 'waste'. This cycle is then repeated to fulfil the business need, using new assets.

Historically, this has been a convenience for linear global economies, where the negative impact on externalities is almost invariably not counted (e.g., such as the negative impact of climate change, our societies, and the environment). This has called into question the suitability and effectiveness of linear economies and the businesses that operate within them that have supported the asset life cycle as we know it.

Moreover, asset managers will now be only too familiar with the existing and looming crisis associated with interruptions on global supply chains, the increased degradation of assets due to climate change, and the increased demand on limited resources. The concept of a future where there is an uninterrupted or abundant supply of new and replacement assets within a take-make-waste way of working will become unsustainable for some and/or most industries.

16. The Institute of Asset Management. Designing with outcomes in mind means asking, right from the concept stage, what is the overall value of this project? Available at: <https://theiam.org/knowledge/why-outcomes-matter/>

17. Chiltern Railways puts refurbished MkIII coaches into service. These classes of coaches are in excess of 50 years old. Available at: <https://www.railwaygazette.com/passenger/chiltern-railways-puts-refurbished-mk-iii-coaches-into-service/36974.article?adredir=1>

In an effort to reduce the impacts of climate change, organisations (and subsequently, asset managers) are focused on understanding the carbon emissions (and, increasingly, the environmental impact) of their assets. By looking to the future, they aim to measure and reduce these overall limits, with the goal of meeting net-zero targets and commitments. However, when applied to the traditional take-make-waste business model, these objectives can often contradict, prioritising the generation and consumption of new assets when practiced alongside relatively novel sustainability goals. Importantly, meeting net-zero targets should not be constrained by a purely sustainability or environmental view but must also include economic opportunities driven by innovation and behavioural change. This view should then also be enacted beyond the operational life of the asset to consider its prospective impact across factors such as the asset's production, supply chain, and disposal.



The emerging circular economy should recognise rail as one of the most sustainable forms of transport and should call upon the discipline of asset management to design and deploy asset systems that are regenerative by design, to innovate to increase asset resilience, and reduce reliance on global supply chains, create the need to grow strategic, local, and regional capabilities across the railway network, whilst also meeting or exceeding organisational and global sustainability targets. The circular economy is a strategy that engages systems-thinking enabling organisations to link together important drivers and networks of actors, stakeholders, and value chains that when combined create greater value than the sum of its parts. And in so doing, delivers regeneration, seeking to accelerate the reduction of carbon (and is sustainable by definition).

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The future challenge for railway asset managers will be, given the organisation's transition towards a circular economy, what can we already capture that we are doing now in our asset management systems that is going to add value and how can we exploit asset management further given the organisation's revised strategy and purpose?

If we initially view a traditional take-make-waste model (Figure 6), the asset life cycle is very much a linear process. For example, during the system or asset design stage, a cost reduction or value engineering review may be carried out to identify where savings can be made, enabling the same function at a lesser cost. In many respects, whole-life cost considers the cost of replacement only, not the wider impact that that replacement has on externalities. This may support the reduction of cost in the short-term, but if the organisation is transforming towards a circular economy, those externalities become important, and those previous design decisions may have been made to the detriment of the asset life within a circular economy context, limiting the ability for the life of the asset to be extended through repair or remanufacture. That said, it is likely that asset managers utilising this type of model already include some form of activities related to the circular economy. For example, life extension activities look at expanding the asset system utilisation boundary. Asset management already covers the ways and means of extending the design life of assets, and where this occurs, organisations are, in effect carrying out circular economy interventions within their operating model.

So why don't we design railway assets with that expectation in mind? The question then becomes:

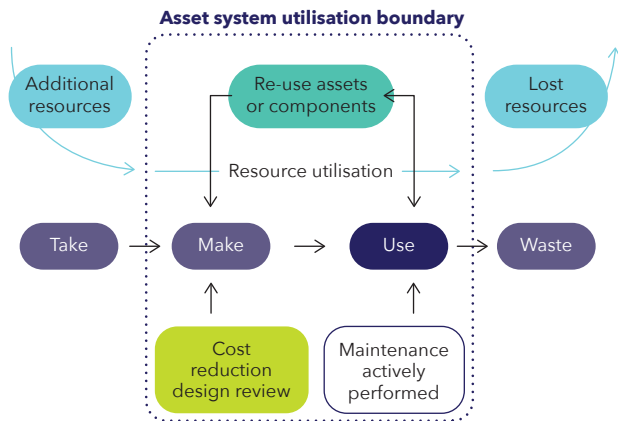


Fig.6. Asset resource utilisation boundary within a traditional take-make-waste management model

How do you expand your boundary to further increase asset and resource utilisation (and performance), and what tools and processes do you subsequently develop to enable this?

Caterpillar already offers a discount on replacement engines if the damaged engine is returned in reasonable condition (Caterpillar, 2022). Primary benefits of this include Caterpillar's opportunity to reuse its own parts with minor refurbishment at a reduced cost (compared with procuring/manufacturing new assets). Secondary benefits also include ownership of any data generated during operation, and increased understanding of asset performance which allows for more effective design iterations. Moreover, if conditions are built into the asset's as-a-service contract which ensures it must be returned to a certain standard for returned payment, this may shape user behaviour to promote better asset stewardship.

Not only are railways the most sustainable form of transport, but the vision should also be that the railways adopt asset management systems that are restorative and regenerative by design and aims to keep products, components, and materials near their highest utility and value always. The asset life cycle is a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimizes system risks by managing finite stocks and renewable flows (Ellen MacArthur Foundation, 2013), such as in a 'closed loop asset management system' (Figure 7). This also addresses the protection of the demand for future rare earth materials. A framework based around the circular economy promotes the exploration of different services or business models. It can potentially bring groups of organisations together to support each other in symbiosis. This enables the concept of 'circular economy syndicates', a strategic network of organisations or value chains that collaborate in the interests of optimising value from the circular economy. However, this reflects the challenge of defining where the asset system resource boundary is and who has responsibility for it.

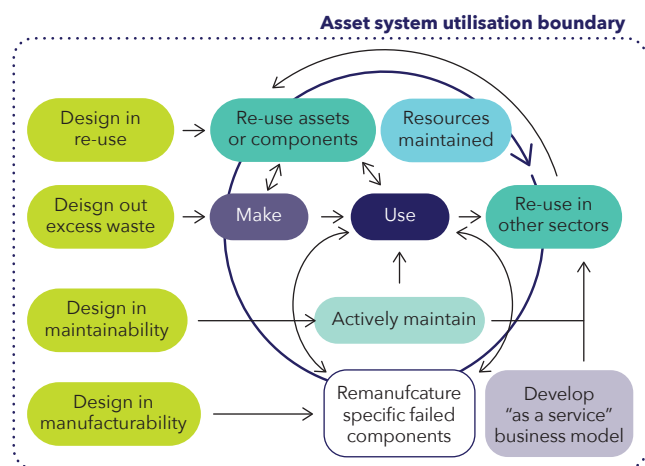


Fig.7. Asset resource utilisation boundary within a closed loop circular economic model.

Hence, what are the different entry points to developing an asset management system based on a circular economy, and what respective tools and processes can help feed into each of these points of the system?

4.1 Where to create circular economy value from

Figure 8 illustrates three entry points for railway asset managers to understand where to start creating value for the circular economy within their asset management systems. Beginning with the assets at the centre, the first viewpoint is the 'here and now,' where we can positively affect assets that already exist and are in everyday operation. In general, an effective way of minimising the environmental impact of assets may be to extend the life of the asset. Asset managers are already good at this.

Next, considering the asset life cycle boundary more widely, we have the 'before and after,' where we can intervene in how the assets are initially designed or renewed.

Finally, the widest boundary to consider is the 'overarching practices' which influence how assets are used and the value (e.g., the externalities, the impacts on businesses, the environment, tax revenues, and our social well-being) that the assets enable.

Value management needs to be applied, but its application should extend beyond the asset and the asset creation project. It's what externalities the asset enables that matter. Those externalities that the assets enable must be tied back to the organisation's purpose and the value that organisations create. Asset managers need to work continuously in all the three entry points.

Creating value from circular economy can start at one, or all, of the entry points at the same time. Each entry point creates its own opportunities and is interdependent of the others. The objective, therefore, should be to identify interventions that combine into an interlinked system which gives value greater than the sum of its parts.

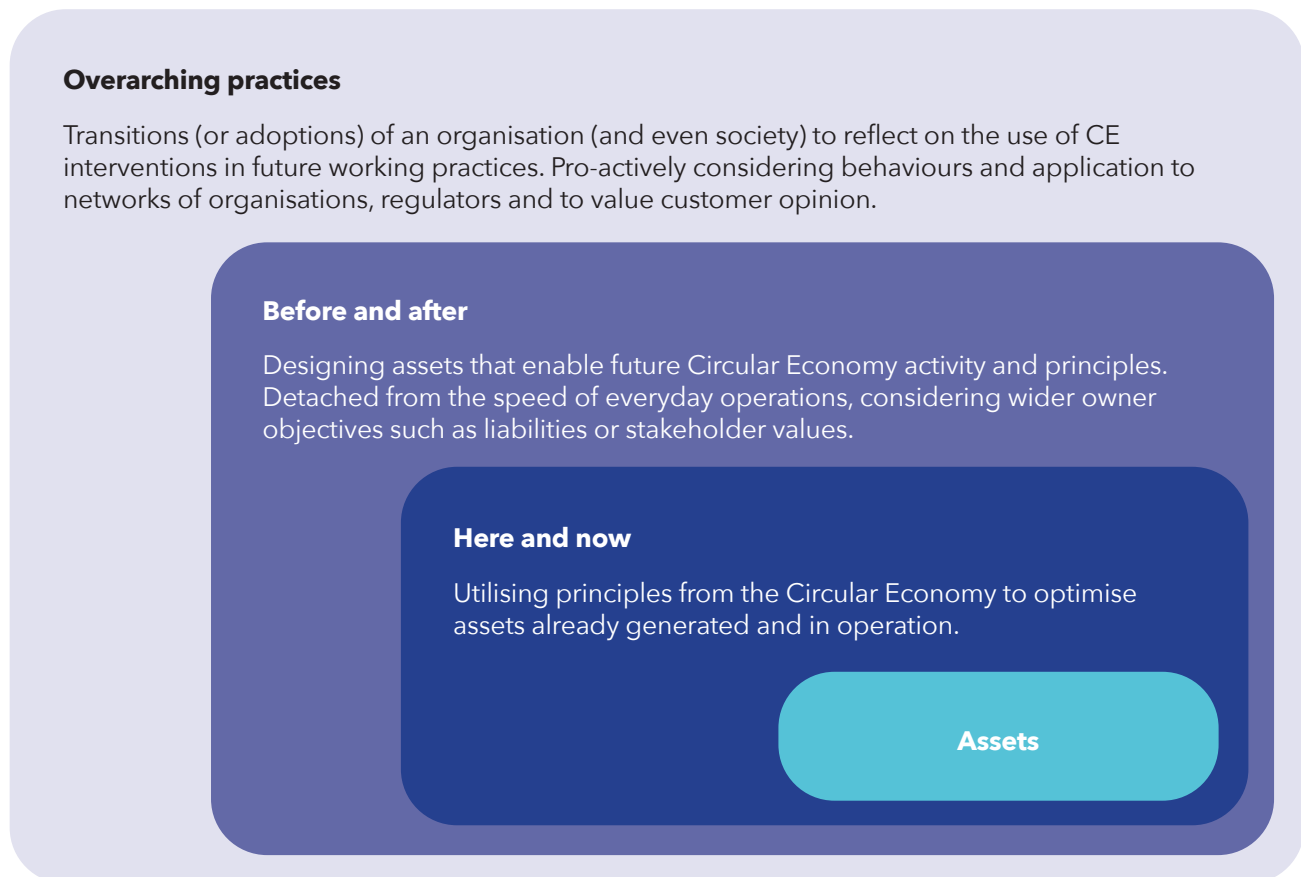


Fig.8. The three entry points to creating value through circular economy utilising a systems-based approach

4.1.1 Here and now

For organisations wanting to start their circular economy transformation and for asset managers looking to start adopting circular economy practices, one of the most effective interventions is either to extend the life of current assets or develop alternative practices which make the need for new assets redundant. Within an asset management context, the asset management system is no longer running the asset down towards the end of its life but rather determining in more detail using a circular economy lens how asset life could be extended - considering options beyond those that are already counted. Good asset management already does this, but you are now considering, for example:

- Different areas (beyond those already being considered) of asset criticality (i.e., how much additional risk are you willing to accept on your asset's condition) to prolong the asset's useful operation
- New asset breakdown structures (i.e., components and sub-components) to enable the retention of parts that have a longer life than the whole of the asset system or sub-system. Activities asset managers can undertake in this area can include:
 - Developing tools and processes that extend the life of assets you already own (e.g., component replacements that ensure longer life and less maintenance)
 - Developing tools and processes that enable you to have a greater understanding of your asset's condition (such as through utilising the Internet of Things (IoT) or digital twins to enable condition-based monitoring (CBM))
 - Evaluating the risks and opportunities of the status quo against any interventions applied, including the potential added value that can be created (such as multiple life-cycle costs).

4.1.2 Before and after

The circular economy provides an opportunity to fundamentally challenge traditional business models through a drive to design assets that can extend their useful life, develop components that can be reused and remanufactured, and utilise new materials that can then later be reclaimed, all while facilitating new business models that promote continued development of the circular economy.

For example, the 'assets-as-a-service' business model, where organisations lease their assets to operators, which are then returned at their end of life. In this case, the asset is worth more to the manufacturer because the manufacturer will have already planned its remanufacture or will upgrade to the next generation of asset. This can place the problem of obsolescence back with the original manufacturer or, indeed, open new markets with the supply chain that exploit obsolescence as an opportunity.

Although technically, most things can be shared, repaired, reused, or recycled; there are constraints on how the circular economy can create value from asset management systems (for example, due to intellectual property protection blocking the reuse of designs from becoming widely adopted, or legislative barriers preventing the life extension of certain assets, due to increased risk). This is where and how the value of deploying systems thinking counts (which is central to good asset management practice) - by allowing asset managers to adopt and develop a circular economy which enables the design and management of closedloop asset management systems for their specific assets, taking into consideration the different barriers to widespread deployment.

Activities that could be considered in this area include:

- The adaptation of business models that work towards assets as-a-service. If systems interfaces are standardised, the assets-as-a-service model can work without being locked into a single supplier.
- The development and strengthening of strategic partnerships and links with relevant markets and sectors that enable secondary re-use, or other circular economy activities
- Modelling multiple life cycle costs of an asset that utilises circular economy activities (e.g., remanufactured parts vs. new)
- New commercial frameworks that establish multiple 'circular economy syndicates' involving the client and a network of circular economy actors and stakeholders working within the supply chain
- Redesign of assets so that they are:
 - Designed for life extension interventions (i.e., designed for repair)
 - Designed for remanufacture
 - Designed for reuse
 - Considering innovative materials which enable all of the above.

4.1.3 Overarching practices

As organisations move away from the take-make-waste way of working and move towards being part of (and supporting) closed-loop asset management systems, the emergence of demands for new types of business, and opportunities that specifically enable the circular economy, will increase. These changes will be used to transition an organisation (or network of organisations) from current working practices to necessary future working practices, adopting potentially new business models. Some of these may be temporary, replaced, or phased out by new ways of working as part of the organisation's future position on the circular economy. This is where systems thinking is beneficial.

For example, in the manufacturing sector, there is the opportunity for asset managers to develop in-house refurbishment and reconditioning centres, support the growth of local small to medium-sized enterprises (SMEs), or new technologies and industries that specialise in assured asset systems upgrades. This can have the knock-on effect of creating employment by re-developing the skills and capabilities that were previously lost - therefore supporting wider societal benefits. It is also worth reflecting that changing climate, and regional instabilities due to conflict, may affect future global supply chain security, including materials and resource availability. Hence, by returning the production and manufacture of goods back to companies' in-house manufacturing sites, or perhaps delivered through local trusted suppliers, supply chain volatility can be mitigated.

There may also be drivers to increase value from the circular economy by external stakeholders. For example, in the future, there may be demands for evidence of circular economy credentials. In some sectors, there is already a move towards this, with evidence in emerging policy, strategy, and future demands. Furthermore, 'the circularity' of an organisation's value proposition may be considered and compared against others. Contracts may no longer be awarded on upfront price alone. New, non-monetised values will have to be identified that address the changing priorities of individuals, communities, industries, and regional and local governments that want to be part of the circular economy future. Hence, it may soon become important to measure how developed your 'circular economy system' is compared to your competitor.

Overarching practices - Network Rail's sustainability strategy is committed to reuse, repurpose, or redeploy all surplus resources and embed circular economy thinking into the rail industry by 2035 (Network Rail, 2022). In the future, Network Rail's procurement decisions will consider factors other than price alone. Circular economic value will play a part in that decision making process.



4.2 Where to initiate and position circular economy interventions

Within an asset management context, ‘outcomes matter,’ and those outcomes should be embedded within the corporate identity, strategy, and goals of an organisation. If the organisation is working towards the circular economy and being more sustainable, it should continually show increasing evidence of circular economy behaviour.

From an asset management perspective, this identity would be reflected through the Asset Management Strategy (AMS) and Strategic Asset Management Plan (SAMP). When we think about where changes need to happen, we can think of the three levels of intervention. This includes strategic, tactical, and operational levels. These levels of intervention directly align with the previous section, 4.1. We can assimilate the impact on these in the following contexts, for example:

1. Strategic

1.1 The organisation preparing for, and the need to be, competitive in the future circular economy

From a strategic perspective, the organisation has decided to move away from a take-make-waste way of working and is looking to understand where the opportunities sit to remain competitive in the future circular economy. This would call upon the discipline of asset management to be used from a strategic perspective, i.e., linked to beyond whole-life cost. Any future change in business strategy, for example, moving towards a service model, would have to be reflected in the AMS and SAMP. This, in turn, would open up requirements for new capabilities and new types of businesses. For example:

- The business model can no longer be solely dependent upon price, where the burden of responsibility for disposing of products is passed onto clients. The organisation, products, and services we sell need to be identified not by volume/ profit sales alone but linked to other regenerative value streams. These value streams will have to be developed and linked to the corporate identity

- Our products and services are identified by how well they perform and by how much they exceed compliance by.

For example, our train systems last longer, are easily upgradeable, are interchangeable across different railway networks, some of the assets are used in other sectors, we aim to keep assets in service for as long as possible, we employ and educate local resources and support communities, we work with partners to ensure we diversify our service offering, and so on.

1.2 Changes in Government and Industry Policy

This is already happening in the UK. The UK is committed to moving towards a more circular economy, which will see us keeping resources in use as long as possible, extracting maximum value from them, minimising waste, and promoting resource efficiency¹⁸.

Sovereign states are also implementing circular economy policies. Some policies focus on the exploitation of waste (see section 5.3 Figure 12 (R8, R9)), have narrower scopes, and relate to the lowest form of value, whereas other states interpret circular economy more broadly, incorporating pollution and other issues alongside waste and resource concerns, and it is framed as a response to the environmental challenges created by rapid growth and industrialisation¹⁹. From an industrial and viable systems perspective, this needs to be on everyone’s horizon.

Network Rail is already reviewing the dependencies of materials and products they currently use and is looking to identify alternatives to support circular economy objectives²⁰. The rail sector has also collaborated to produce the first version of the Railway and Safety Standards Board (RSSB) Sustainable Rail Strategy, which now includes early steps to accommodate the circular economy²¹. In addition, Network Rail’s ambition is to reuse, repurpose, or redeploy all surplus resources, design out waste and plastic pollution, and embed circular economy thinking into the rail industry by 2035²².

18. The UK Circular Economy Package policy statement. Available at: <https://www.gov.uk/government/publications/circular-economy-package-policy-statement/circular-economypackage-policy-statement>

19. Circular Economy Policies in China and Europe. Will McDowall, Yong Geng, Beijia Huang, Eva Barteková, Raimund Bleischwitz, Serdar Türkeli, René Kemp, Teresa Doménech

20. Network Rail Environmental Sustainability Strategy 2020 - 2050. Available at: <https://www.networkrail.co.uk/wp-content/uploads/2020/09/NR-Environmental-Strategy-FINALweb.pdf>

21. Railway Safety and Standards Board. Sustainable Rail Strategy. Available at:

22. Department for Transport. Rail Environment Policy Statement On Track for a Cleaner, Greener Railway. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002166/rail-environment-policystatement.pdf

2. Tactical

The tactical state represents the transitions (short, medium, and longer-term) to implement the strategy until the strategy gets adjusted. For example, work should be carried out that:

- Makes decisions about platforms that enable the common shared purpose for the supply chain. This would include an adaptation of standards to focus on the function of the asset, enabling the supply chain to exceed compliance, standard systems interfaces, communication platforms, and protocols that enable access to asset performance data to accelerate competition and improve asset performance.
- Adapts existing and develops new procurement strategies that encourage and incentivise circular economy-type products and services.
- Designs assessments and feasibility studies to determine where the opportunities exist to operate, for example, 'product as a service' operating models or other alternative operating models.
- Redesigns supply chains to become more resilient and diverse. Establishing trusted remanufacturing capabilities across the railway regions.

3. Operational

Given the tactical outlook in the short, medium, and longer-term, re-evaluating the asset base, for example:

- Critically evaluate the current performance of existing railway assets and assets in service, and determine an intervention strategy that would extend the life of the asset, including the asset sub-systems. This would drive the need for additional and more frequent data about the performance of the railway asset.
- Critically evaluate the wider supply chain and existing commercial frameworks that lend themselves to transition towards working in the future circular economy.



5. Rail industry consultation, workshop perspectives, and challenges

While developing this paper, we ran three workshops; two covered rail in general, and a third was dedicated specifically to rail freight. We described a number of asset management and circular economy perspectives in each of the three workshops. The outcome of the exercise was captured, and the details are provided in the Appendix.

5.1 Perspective 1 Rail circular economy impact

We presented this way of understanding the intended outcomes of rail-related circular economy impacts. Figure 9 was used to elicit an understanding of the value of rail in a circular economy context from the widest perspective. For example, considering rail and its supply chain in enabling the overarching effectiveness that the Department of Transport would promote.

Impact: The impact that organisation/s have on the local, regional, and national economy across the economy, sustainability, whole-life cost (value), and carbon spectrum²³. This is associated with financial flows (not value extraction) incoming, going within and across the local, regional, and national economy (which can also include exports), and provides visibility of economic fluidity, which is an indicator of economic growth of the local, regional and national economy. Evidence of diversity is an important characteristic for a viable circular economy. This means capability can be distributed across the rail network and operated by multiple actors and stakeholders.

Carbon: The status of the reduction of, or increase in, carbon impact that each organisation reduces their carbon footprint by or contributes towards. Organisations should be committed to the reduction of carbon (Scope 1-3). In some cases, that may be a difficult challenge due to wanting to take advantage of new markets. However, the organisation should have plans to mitigate carbon impact. These carbon impacts may be offset by other members of, for example, a syndicate when it is considered as a whole system. In addition, the need to create a reduction in the impact of carbon can be accommodated by alternative means. For example, by changing business strategy, changing the business operating model, or changes to products and services.

Whole-life cost (value) of the asset infrastructure. This is one of the areas where key drivers for circular economy value can come from. Conventional asset investment is based on whole-life cost conditional upon a take-make-waste linear economy approach. This needs to change so that members of the sector can move towards whole-life value where that value is tied into externalities. For example, it's not what the assets are; it's what the assets enable in terms of the benefits customers gain from the product and services that the sector produces.

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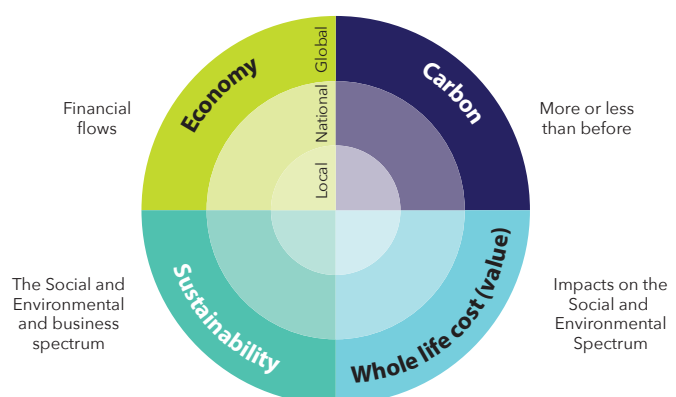


Fig.9. Circular economy value impact

23. Similar to the concept of 'Doughnut Economics' (see Raworth, K. (2017). Doughnut economics: seven ways to think like a 21st century economist. White River Junction, Vermont, Chelsea Green Publishing) but it is considered here at an industry sector and Local National and Global level.

If the capability to create those benefits didn't exist locally or at a national level, then those benefits would be relied upon to be created by someone else overseas. Therefore, the impacts or dependency on those assets (externalities that the assets enable) to create that value needs to be captured at a high level and interpreted on a social and environmental spectrum. An example of that could comprise:

- a) A continuous stream and a broad range of sustainable employment opportunities, working from apprenticeships upwards across a wide range of professions, particularly around the manufacturing sector. This would support the upgrading and remanufacturing of assets, extending asset life and immediately reducing the carbon footprint of the rail sector.
- b) Establishing ways and means of re-purposing existing assets, for example, systematically collecting end-of-life assets across the railway network and redesigning new assets. This presents new problems to be solved and will need a continuous demand for advanced research, new skills and technologies, new types of businesses and services, new partnerships, and changes in business operating models.
- c) Achieving the transition to beyond carbon emissions where the rail sector has established a resilient and diverse network of actors and stakeholders where competencies and capabilities continually evolve to support the transition from carbon-dependent industries to non-carbon-dependent industries, including exports of the technologies and capabilities to make that happen overseas.

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Some of these value streams already exist, but their value is not being articulated effectively.

Sustainability and resilience: refer to the sustainability and resilience of the organisation (and/or network of organisations) in providing value to those externalities. The railway sector and its members should never get into a state of fragility such that it is no longer able to provide the social, economic, and environmental outcomes on a sustainable basis. The continuity and growth of the rail sector set a precedent, and the route to achieving that will be based upon the evolving diversity of businesses, policies, standard practices and communication protocols, behaviours, and transparency.

5.2 Perspective 2 Products as a service and whole-life cost/value

We introduced the concept of organisations moving from generating revenues from a single point of sale to providing products that have multiple life cycles and the impact that can have on business operating models. The rail industry is accustomed to this, to some extent, but there are opportunities where platforms and incentives can be created to change industry behaviour.

Changes in business operating models were discussed. For example, the differences between costs incurred by the customer and provider as shown in Figure 10²⁴. In addition, the impact of reduced life cycle costs over four life cycles is shown in Figure 11.

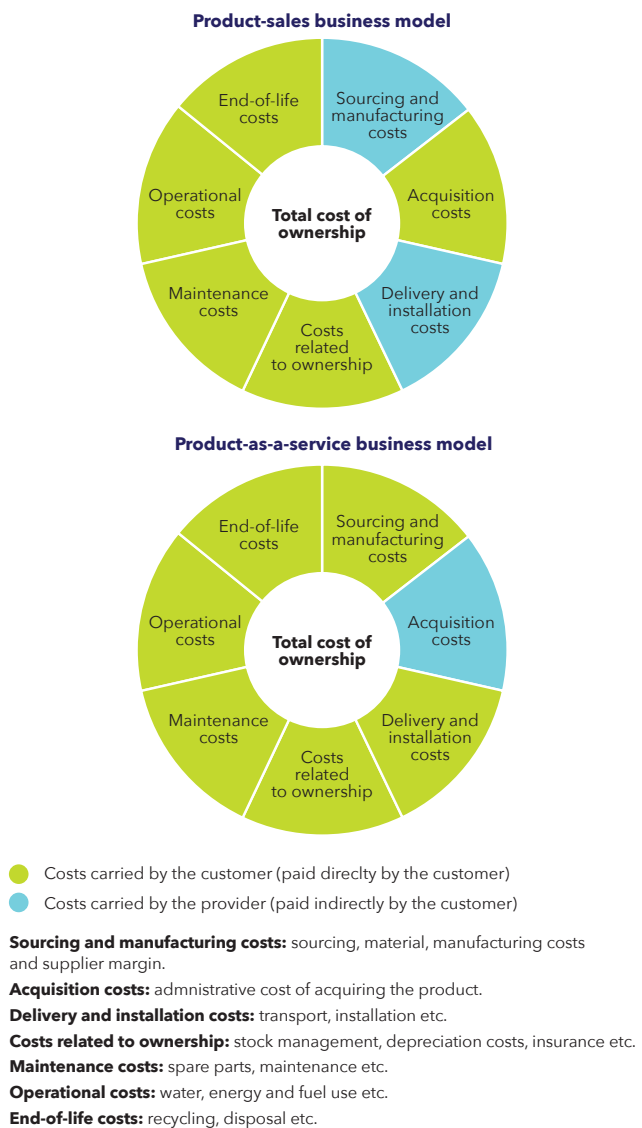


Fig.10. Costs incurred by the customer compared with costs incurred by the provider

24. From 'Products as a service in the circular economy' - an EU Regional Development Funded paper presented at The Nordic Circular Summit November 2022. Available at: <https://www.stenarecycling.se/en/circular-consulting/inspiration--insights/product-as-a-service/>

Total life cycle cost over four use cycles

Explanation of cost changes



Fig.11. Reduction in life cycle costs over four life cycles

This is particularly relevant in the field of asset management, for example:

- Knowledge of the performance of the asset becomes critical because the supply chain would be generating revenue on the outcome of what the asset does and how well it does it (e.g., price per use)
- The issues associated with the reliability of the asset become the supplier's problem, not the operator's problem, but the operator would be prepared to pay for high-performance assets.
- Manufacturers would want the assets back at the end of their respective life cycles to refurbish, upgrade, and send them back out into service.
- There would be a growth in the reliance upon advanced technologies to make assets last longer.
- There would be a growth in new types of businesses that work within the remanufacturing/refurbishing sectors.
- Standard communication platforms and standard systems interfaces could be developed that the supply chain could 'plug into' to access data and communications between systems interfaces.
- The interpretation of standards could be reshaped, so instead of the supply chain complying with minimum acceptance thresholds, performance is interpreted by how much the supply chain exceeds standards compliance by. This accelerates innovation and opens up opportunities for performance-based procurement.

5.3 Perspective 3

Increasing circularity

In relation to a physical asset context, we introduced the concept of 'increasing circularity,' suggesting some degree of circularity value from one state to another. We can think of this within the context of the organisation putting effort into changing and adapting its products and services from one level of circularity to the next and being incentivised to do so. The railway already does this to some extent; for example, the cascading of railway tracks to less used or less critical routes would certainly align against 'R3 Reuse' (see Figure 12). The deployment of asset management would be relied upon to move from one level of circularity to the next.

The 'Railway Asset Utilisation Scale' was constructed as a concept for discussion purposes so that stakeholders could appreciate the dependency on a number of factors and capabilities. For example, many of the interventions required to move a railway asset from one level to the next can focus on the problems that need to be solved and the value if the problem is solved.

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- **R0** - Eliminating the dependency for certain types of railway assets could represent a design challenge pipeline.
 - **R1** - Sharing railway asset resources, such as the design of platforms, would open up new opportunities, new types of business, assets can remain less idle, and create the need to apply asset management techniques at a higher level of integrity.
 - **R2** - Relates to new designs, new materials, and new manufacturing techniques that improve railway asset performance.
 - **R3** - Can relate to cascading assets. This gets the maximum life out of assets and can be extended further if assets have multiple life cycles, so they can be cascaded after every time they are remanufactured.
 - **R4** - Repair and maintenance are well understood within the context of railway asset management. However, as is often the case, this is only related to one asset life cycle. An emphasis should be placed on novel methods of repairing assets instead of replacing them, as well as continually enhancing maintenance practices to extend asset life.
 - **R5** - While railway assets have a prescribed design life, that design life may not represent the actual remaining life of the asset. A good example of this is the redeployment of the ex-London Underground stock that was originally introduced in the 1980s being re-engineered as low-speed units²⁵ or the large number of freight vehicles that were originally designed for coal to now take aggregates²⁶.
 - **R6** - While it may be inevitable that assets need replacing sooner or later, the asset could be redesigned to be more modular so that only key parts of the asset are replaced. This opens up opportunities for re-design, the need for new types of materials, and the need for local/regional resources to carry out the work.
 - **R7** - In many respects, the structural integrity of the material that assets are manufactured from can mean that the asset, in part or in whole, can be used for alternative purposes. There are many examples where this concept has been deployed across the railway, but this needs to be captured and accredited. In addition, opportunities and incentives should be sought to redeploy the repurposed assets where possibilities arise.
 - **R8** - Recycling represents the lowest form of asset value. The asset is no longer performing the function it was intended for, and the only value remaining is the material value that the asset is made up of. In many respects, the act of recycling is enforced through legislation and can be considered a burden to those organisations that work within a take-make waste way of working. Recycling involves the processing of materials, often at a high energy cost. Recovered materials may be reused within the rail sector as part of a 'closed-loop' system or shared across other sectors.
 - **R9** - Incinerating materials represents the irrecoverable transformation of the asset. i.e., this is a one-time-only transaction, and there's no going back. This is seen as an absolute last resort.

25. 'Why not do some re-engineering?' Adrian Shooter on the Vivarail D Train. Available at: <https://www.railtechnologymagazine.com/Inbox/why-not-do-some-re-engineering-adrianshooter-on-the-vivarail-d-train>

26. UK partners convert coal hoppers for aggregates. Available at: <https://www.railfreight.com/business/2017/11/07/uk-partners-convert-coal-hoppers-foraggregates/?gdpr=accept>

After considering the railway asset life in this context, it is clear that incentives can be established that change behaviour and encourage the supply chain to respond accordingly. This, of course, creates the demand for the deployment of more advanced asset management practices.

Introducing the means by which data can be made open and accessible within and across systems boundaries plays a critical role here. Gathering evidence of asset performance creates opportunities for strategic decision making and investment. This can inform decisions around risk and opportunities, moving the asset up the circularity scale and enabling the manufacturer or operator to create that value based on asset performance facts.

If such data can be made readily available new types of businesses can be set up that run under hybrid business models, such as investing in servitization, radically reducing the demand for materials in the supply chain, setting up refurbishment centres involved in remanufacturing or raising the need for better performance which crystallises the problems to be solved and the rewards that can be returned if solutions are found.

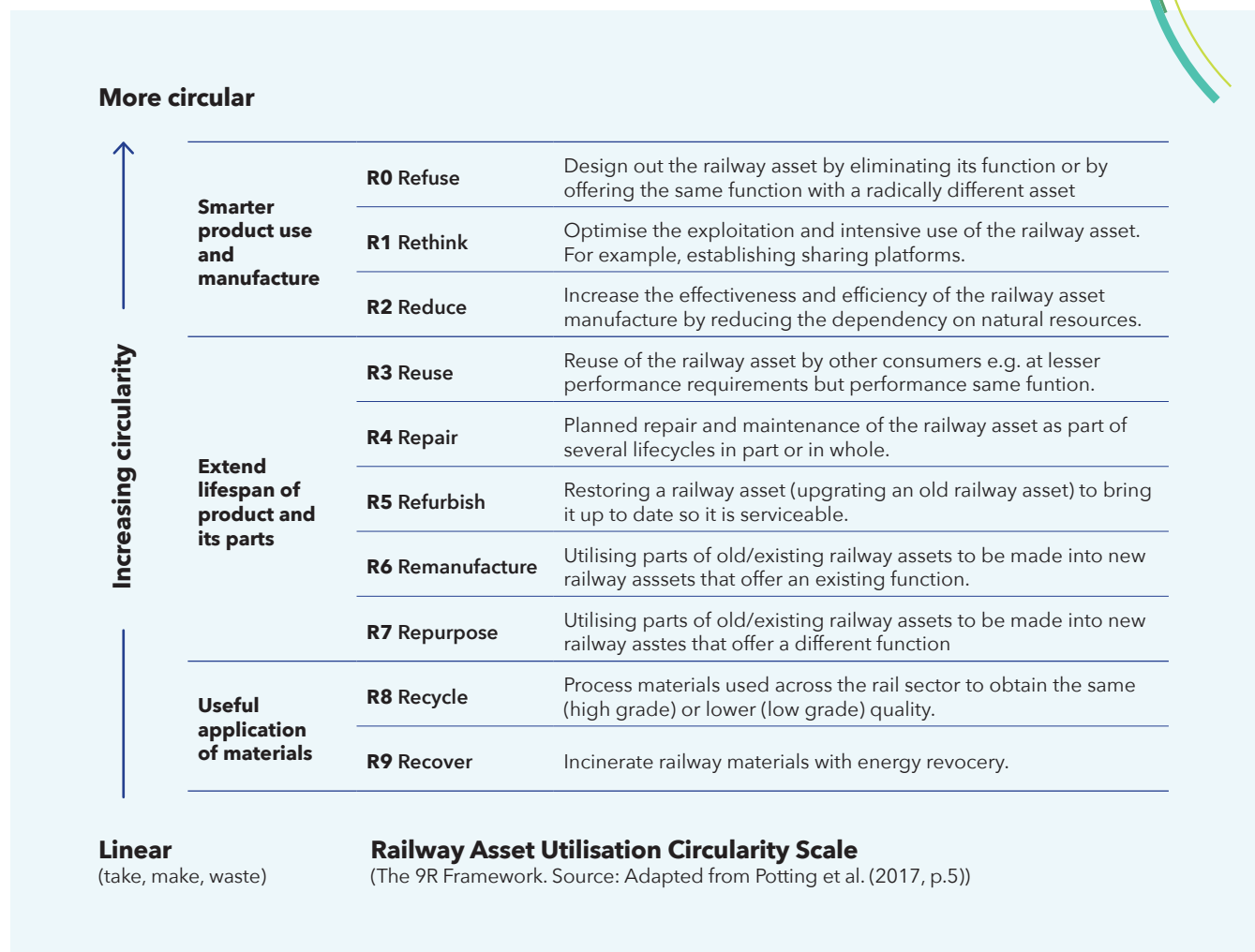


Fig.12. Increasing circularity

5.4 Workshop challenge

The workshop challenge was set using the Institute of Asset Management white paper as the backdrop and relating it to the rail sector. The challenge included: Using the products as a service as a circular economy example enabler:

1. What would need to change in the rail sector (or be developed)?
2. How could these changes in the rail sector be incentivised?

The stakeholders in the workshops were asked to consider 'the here and now', 'the before and after', and 'the overarching practices' points of entry. The outcome of the workshop was to produce a high-level dependency map with the enablers that need to be in place to support circular economy behaviour in the rail sector. The outcome of the workshops was captured and included in the Appendix.





6. Conclusions and recommendations

We provide our conclusions and recommendations within the context of the whole systems approach, so we can see where an intervention in one area can have an impact on another. This is presented in a systems thinking context. It is clear that several interventions are required from multiple perspectives to achieve the overall greatest impact.

A good example is that we identified that Network Rail should look to incentivise circular economy behaviour across the railway supply chain, and the Railway Regulator should review Network Rail's 'Circular Economy Strategy' to determine Network Rail's effectiveness in doing this. A Circular Economy strategy can reside in many forms and across several disciplines. For example, it can be accommodated within an asset management strategy and plan, as well as other strategies and plans.

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If we present the railway sector in this way, we can see how the rail sector can behave towards the circular economy and what types of interventions are needed to do that. In addition, when we implement asset management within this context, we can see asset management also being a key enabler for the circular economy. In simple terms, extending the life of assets demands more rigorous asset management systems.

Adopting a whole systems approach helps us understand where we are entering the system from and from whose perspective. This means we appreciate value in different contexts and can begin to understand what the value of interventions are. An intervention by Network Rail would impact the railway supply chain, but it is important to acknowledge the wider perspective and appreciation of the impact of the intended outcome of Network Rail's intervention. This may be outside of Network Rail's purview, which means other influences need to be in play, and should sit within the part of the system that monitors the overarching effectiveness of the value that Network Rail provides. While Network Rail is a key actor and stakeholder, not every initiative would come from Network Rail.

For example, the rail industry can capture the overall impact and present itself as a more sustainable transport system supporting the local economy and businesses because of the need for new remanufacturing and service businesses. It is not necessarily within Network Rail's remit to do this, as Network Rail is only seen as a key enabler at a tactical level. Identifying this wider value needs to be appreciated and recognised by other parties. For example, some form of joint recognition by the Department of Business, Energy and Industrial Strategy, The Treasury, and the Department for Transport would appear more appropriate, with the Department of Transport being seen as a key enabler that can influence the railway supply chain.

Considering this part of a wider strategy, it makes sense for the Department for Transport to lead the initiative to promote circular economy behaviour across transport systems. In this sense, we can develop a top-down and bottom-up approach, knowing that if we enter the system at a particular point of entry, we can work 'upwards' to explore who should own strategy and business drivers and what they should be, as well as work 'downwards' to see what behavioural changes need to take place to get the result we need in context and at scale. Importantly, the whole systems approach adopted in this paper helps people understand the value and meaning of governance and technology interventions on the system, where they sit, and the impact they can have within context.

We replicate parts of the whole system as described in Section 3 and map the key conclusions and recommendations to each area of the whole system so we can see how value is created across the system.

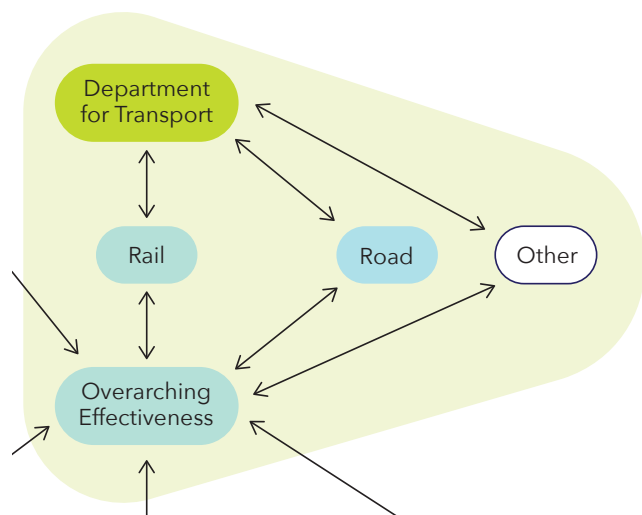


Fig.12. Reduction in life cycle costs over four life cycles

The Institute of Asset Management We were not aware of any Department for Transport led directives for transport systems to work towards the circular economy. Having this directive or policy/strategy would focus the transport sector to adopt circular economy practices and focus transport modes to be considered on a level playing field within a circular economy context. i.e., some transport modes are more circular economy effective than others. This directive needs to be set at a top level and represent a business driver across the transport systems supply chain.

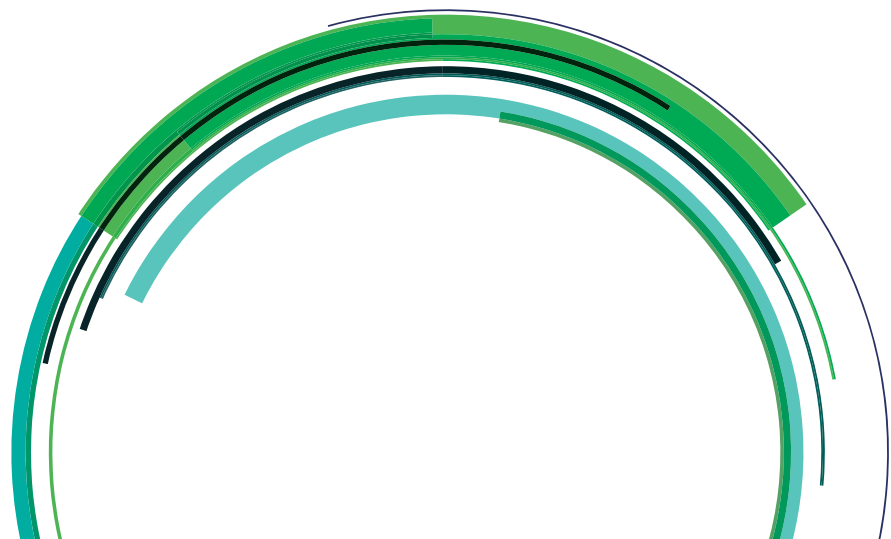
We considered that the longer-term positive impacts on externalities (value) that the railway enables are not sufficiently represented in terms of investment business cases. For example, the wider and future benefits that can be exploited by relying upon the railway as a foundation for long-term growth and social and environmental benefits. If this wider and longer-term perspective was taken, the value of circular economy interventions, such as making assets last longer and realising whole-life value, would become more meaningful and important.

1. Government should promote behaviour that is conducive towards achieving a circular economy and establish a rolling short, medium, and longterm level playing field, based upon a whole systems approach, for transport systems.

1.b Move towards a whole-life value policy decision-making framework for investments, which is an extension of the existing whole-life cost approach. Whole-life cost is the total expense of owning an asset over its entire life, from purchase to disposal. Whole-life value is situation and context-specific. It considers the maximum impact in the short, medium, and long-term, while considering the value of the asset in terms of what it enables in the bigger picture, not just what it costs. The value (capability) of the externalities of what the asset enables needs to be brought into the picture. Enabling this clarity provides visibility of regulatory harmony across sectors. If we don't have this visibility, we don't understand the social, economic, and environmental impact of the benefits and trade-offs that have to be made across sectors when we make investment decisions.

The whole systems approach should consider the impact the railway has on externalities, and these impacts should be appreciated by those departments gaining the benefits. Trade-offs need to be made.

1.a Adapt and develop policies to purposefully exploit the latency and projected life of railway systems to offset the negative impact alternative transport systems have on our environment, business, and health.



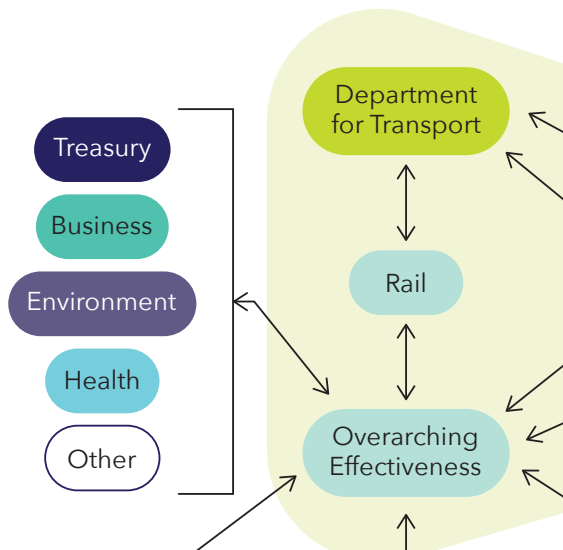


Fig.13. Externalities that the railway enables

2. Simplify and modularise the technical landscape of the railway infrastructure assets as well as interfaces between systems. This opens up opportunities for a broader and more diverse supply chain to supply into the rail industry.

3. Focus towards railway asset life cycle performance. For example, in terms of the life cycle length that assets are designed for, whether they are upgradeable, can be remanufactured, and so on. Performance should be based upon measures of exceeding compliance, rather than simply meeting minimum thresholds of acceptance. Procurement strategies should incentivise asset performance in this context.

The railway supply chain is not incentivised to work towards the circular economy. There are many 'entry points' as to where these incentives could happen, but the workshops came back with a number of possibilities.



The route to enter the railway sector and railway supply chain is complex and expensive. In addition, railway systems are proprietary. This constrains innovation and slows the pace of change, adaptation, and routes to markets. The circular economy works more effectively in a diverse environment based on sharing platforms. This means the basic principles and parameters of the functions of systems are well understood so that the focus is on asset (or system performance). If platforms are well-defined and interfaces to systems are simple and well-described, this opens up the opportunity for greater flexibility and diversity. This way of thinking and working also supports business resilience and continuity and derisks the supply chain. This type of requirement would come from the optimisation of configuration if, for example, it became apparent that the supply chain was becoming dominated by only a few factors that controlled technology.

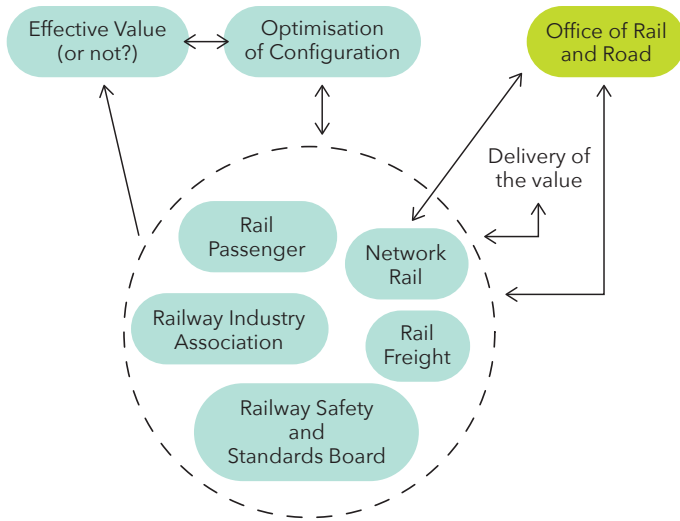


Fig.14. Parties that deliver value and the regulation of the value

Given Network Rail's role, the Office of Rail and Road could request evidence of Network Rail balancing short and longer-term needs, for example, circular economy changes and progress being made. It would then follow that the ORR would monitor Network Rail's circular economy commitments and progress. Evidence of this may be Network Rail's engagement towards the concept of 'assets as a service'. Just looking at this alone would influence the need for, and value of platforms, as discussed earlier.

4. Move towards 'assets as a service', which switches the onus of ownership and issues around asset reliability and asset performance back to the manufacturer. For example, it would be in the interests of the manufacturer to have an asset back if it is going to be refurbished/ upgraded and put back into service.

5. Establish the means by which data can be made open and accessible within and across systems boundaries. This forms the foundation for communications and feedback loops that push and pull data enabling opportunities to understand, develop and adapt measures of effectiveness. Data insights will inform performance and settle governance or management arguments. Communication channels and communication protocols need to be readily understood and purposeful. Having access to this level of data creates opportunities for existing and new business types across the supply chain that would rely upon data-centric intelligence around improving asset performance. The ability to gather evidence attracts strong management attention.

These interventions specifically create the demand for local businesses to exist, new types of businesses, the demand for new types of research, new technologies, and products and services, as well as a pipeline for technical problems to be solved. However, as shown previously in this section, the demand to create this is primarily influenced from outside the supply chain.

6. Link this broader capability to railway industry resilience at a local, regional, and national level and grow and establish new types of businesses across the railway network. Develop and deploy new technologies that specialise in improving railway asset performance. Exploit this capability across the UK's industrial landscape and use this as a platform for exports. The development of the Global Centre for Railway Excellence (GCRE) must contribute significantly towards these goals, as well as the need to take a systematic approach to exploit and integrate academic research to those ends.

The route to access and exploit the railway at a local and regional level is complex, and the existence of rail freight is predominantly driven by price. This has resulted in a limited market for railway freight, and is generally confined to carrying large bulk traffic. We have already identified that the value of rail freight should not be driven by price alone. Wider contexts and value streams need to be developed and brought to the fore. These may well be in context at a local and regional level. If these wider value streams were identified, then there is the need to simplify how businesses could engage with the railway at multiple levels of engagement so that the railway could be exploited further. For example, one could envisage engagement frameworks being developed that simplify multiple forms of freight being transported within and across regions.

7. Simplify the route for engagement in railway exploitation. This means how to engage, who to talk to, and the turnaround in decision making to exploit the railway at a local, regional, and national level, as well as at an industry level. The route to railway exploitation should be simple, timely, and effective, and the railway systems should be flexible enough to adapt to changing demands. For example, simplifying access for local, regional, and national freight services.

Given the future access to rail services being simplified and the potential for an expanding rail transport market, there will be the need to exploit and integrate rail services with other transport modes. Some of the concepts are dependent upon reoccurring themes, such as the need for platforms that can be shared by actors and stakeholders that have a common purpose, as well as technology platforms that can share and distribute data.

8. Create the convenience of end-to-end journeys with multi-modal solutions where rail forms the existing and expanding land backbone of a fully integrated, broader transport system that exploits the optimisation of resources and economies of scale. This includes the concept of creating sharing platforms supported by open data that supports rail actors and stakeholders that share a common rail transport purpose.



6.1 Summary conclusion

We have presented this paper by adopting a whole systems approach for the UK Railways. The concepts and ideas discussed in this paper are based on the premise that we should move towards an economy that is more circular.

We also mentioned that future competition in the circular economy should be based around competition that exceeds compliance, and competition should be based on how regenerative products and services are within a circular economy context. We have provided a backdrop as to what that competition may comprise within a railway/asset management/circular economy context.

If the future circular economy is to be viable, then businesses that work within it need to plan how to be viable. This will require a shift from organisations being identified, for example, based only on how much profit they make, to additionally how regenerative and restorative their products and services are. In some cases, this may require an identity shift.

The whole systems approach is a representation of a viable system; a system that strives to be viable, whether that is a business sector or a business that works within that sector. In any event, the concept of viability is scalable - supported by various feedback loops. Within the context of the rail sector and it being an enabler for the future circular economy, we would envisage actors and stakeholders would be identified with the following characteristics:

1. The organisation's identity (e.g., members of the railway supply chain) is formally engaged with and adopts the concept of the circular economy - and is therefore committed to developing its circular economic policy, strategy, and strategic circular economic plan and implementing the plan through its circular economic management system or similar. This is an ongoing commitment. The boundaries of the policy, strategy, and plan are continually emerging and will continually improve over time.

- a. Within the context of the rail sector, the sector identifies itself as the most sustainable form of transport compared with alternative means and is promoted as the highest level from government/local government sponsorship, and in so doing, promotes the sector and its supply chain to engage with circular economic practices under a coordinated and integrated approach, promoting circular economic good practice.
 - b. Within the context of asset management, the drive for circular economic value will be defined through the organisation's rail sector-related business goals and enabled through its asset management strategy and strategic asset management plan, which responds to and enacts the requirements of the circular economic strategy and strategic circular economic plan.
2. In so doing, the organisation will continually move away from a take-make-waste operating model towards more sustainable and regenerative modes of operation.
 - a. Within the context of the rail sector, the sector will promote viable operating models and commercial frameworks, circular economic syndicates (networks of actors and stakeholders that provide circular economic solutions as opposed to those that don't), and enablers that facilitate the adoption of more sustainable operations.
 - b. Within the context of asset management, this will be deployed at advanced levels of practice that uphold the strategic circular economic plan, the design, integrity, and configuration of the asset and asset systems through its multiple life cycles, upholding asset service delivery in a drive, for example, for closed-loop circular economic management systems involving a strategic network of actors and stakeholders that are part of that circular economic syndicate.

7. Acknowledgements

We thank the following organisations for their time and contribution to the workshops. We hope the attendees found the workshop insightful and could take away some ideas and concepts discussed during our work and apply them within their own context. The following organisations contributed to the workshops:

We want to thank the generous contribution that Frazer-Nash Consultancy made in providing resources that facilitated the workshops and sponsored the efforts of a number of their staff.

- Office of Rail and Road
- Rail Freight Group
- Freightliner
- Transport for London
- GB Railfreight
- East West Rail
- Railway Safety and Standards Board
- HS1
- VTG Rail UK
- University of Birmingham
- Institute of Asset Management
- Frazer-Nash Consultancy
- Professor Brian Collins University College London



Appendix - Feedback from the workshops

During the workshops, we explained the perceived roles of actors and stakeholders that work across the rail sector. A simple relationship model was developed to capture the feedback that gravitated towards actors and stakeholders. The relationship model is shown in Figure 15. The linking between the actors and stakeholders is intended to represent general feedback loops and is not supposed to provide any level of detail.

Using the workshop challenge, the workshop attendees worked through a number of circular economy challenges and perspectives and produced a range of blockers and enablers that sit in and around the current railway governance and operating environment. The assumption is that if actors and stakeholders changed their behaviour, it would have a positive impact on the circular economy, thus suggesting that the rail sector could enable circular economy outcomes.

The following sections are the blockers and enablers captured during the workshops. These blockers and enablers have been assimilated and placed into the 'whole systems' relationship diagram loosely arranged around viable systems theory. The principle is that if the railway is to be a viable concern, it should have viable systems characteristics. To simplify the blockers and enablers, we summarised them into eight major themes.

As part of that viable system, we have assimilated what the value of asset management is within a rail context so that the practice of asset management within the rail sector also becomes an enabler for the circular economy.

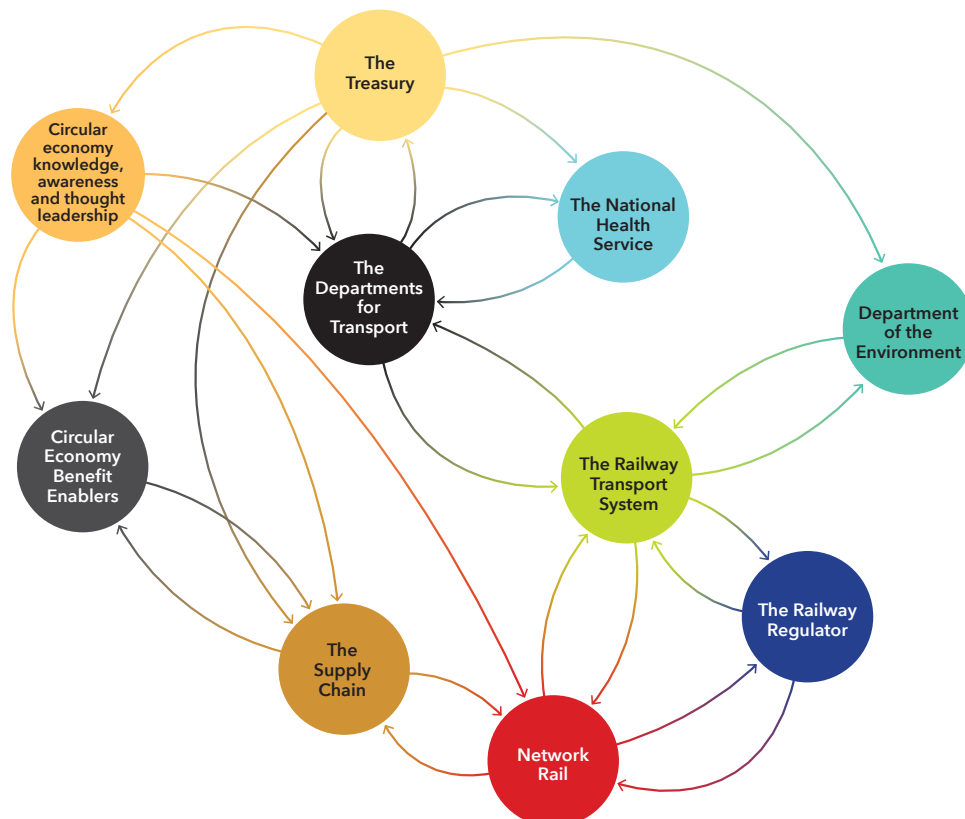
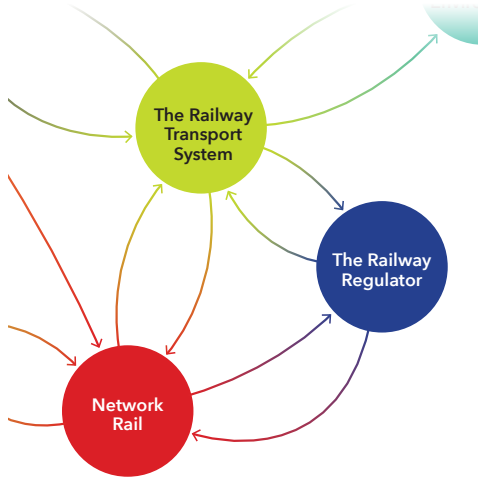


Fig.15. Actors and stakeholders identified in the workshops

The Railway Regulator

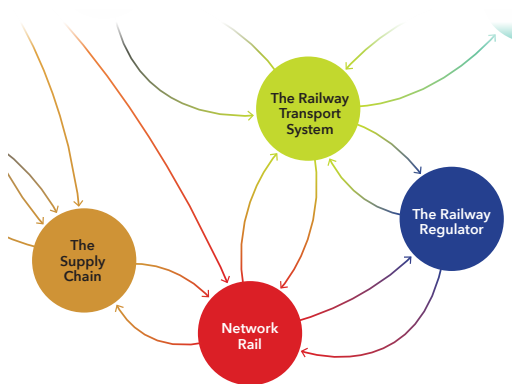


Workshop feedback

- Balancing short and longer-term needs, e.g., circular economy changes and progress being made
- Monitoring Network Rail’s circular economy commitments and progress

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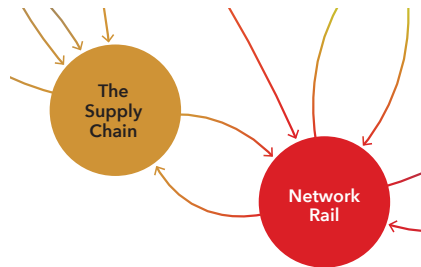
Network Rail



Workshop feedback

- Procurement incentives for circular economy behaviour, e.g., considering the 9Rs
- Reconfiguration - outcome-based standards
- Incorporate circularity into design standards
- Simulation of design standards to reduce risk/cost
- Standard systems interfaces to promote asset systems performance
- Shift from price to price and value in relation to outcomes
- Communications backbone to allow access to asset performance monitoring
- Guarantees to the supplier
- Infrastructure capacity growth for freight
- Standardisation of systems interfaces
- Open data sharing and sharing of good practice
- Opportunities for Network Rail to sell operational and performance data to support the acceleration of innovation
- Collation of asset life cycle data, provision of life cycle data in tenders

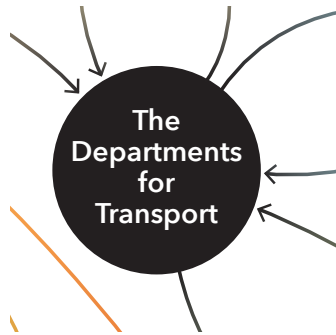
The Supply Chain



Workshop feedback

- Extending the life of existing products
 - Manufacturer diversification to support resilience
 - Accredited remanufactures
 - Reuse incorporated into warranties
 - Knowledge and awareness of the organisation's circular economy roadmap
 - Life cycles - understanding the full life cycles and potential opportunities of products and alternatives
 - Life cycles - carbon to be 'priced' into manufacturing
 - What are the fundamental assets that we can reuse and remanufacture now? And which ones can't and why?
 - Life cycles - residual value to affect flexibility of use, e.g., post-use utility
 - PAAS vs. service-based ownership
 - PAAS products to be leased rather than owned
 - Accredited CE repair and overhaul services
 - Ownership defining the moral imperative, e.g., the organisation's identity
- Wheelset procurement - ownership sits with the manufacturer/maintainer
- Opportunity for a market for asset distribution
- Incentives - taxation, owner vs. lease
- Additive manufacturing
 - Alternative fuels
 - Material flows - new materials - reclaimed materials - mapping
 - Better product knowledge, e.g., 'carbon/life cycle classification'
 - Outcome-driven capabilities - ownership of external values

The Department for Transport



Workshop feedback

- A level playing field within the context of the circular economy for transport systems, e.g., rail freight offsetting road freight, passenger rail offsetting the car, active travel offsetting NHS budget, including positive impact on wellbeing
- Investment in end-to-end multimodal transport
- Re-balancing whole life value of longer life rail freight assets to encourage future investment, e.g., investment of circular economy life cycle/value
- Clarity on priorities, e.g., cost vs. carbon vs. circular economy value
- Regulate the supply chain and incentivise the move towards, e.g., product as a service pass
- Describe railway (and other transport mode) circular economy outcomes
- Make data available or platforms to communicate it, e.g., open
- Promotion of rail freight/rail freight part of multimodal solutions
- Simplify the regulatory framework (e.g., reduce cost)
- Shared collaborative contractual frameworks, e.g., across the supply chain
- 'Revolution' to switch to ownership of products to be kept within the supply chain
- Regulation for circular economy interventions sits across multiple government departments, e.g., impact of one department is the benefit of another, and vice versa
- Regulation is set by the respective government agency and acts of law
- Rail sector-based recycling facilities and technologies
- Regulation is set in codes of practice which are set by government

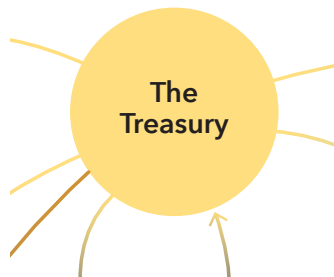
The Department for Environment



Workshop feedback

- Links between circular economy value and environmental impact across transport modes
- Considers environmental factors, risks, and opportunities to influence circular economy behaviour and regulation
- Performance frameworks that place more emphasis on the circular economy

The Treasury



Workshop feedback

- Statement of circular economy intent and industrial financial incentive
- Grants for circular economy innovation
- Incentivise enhancements vs. renewals
- Long-term investment incentives that encourage circular economy behaviour linked to long-term economic growth
- Single transport budgeting (better value for money)
- Longer duration of funding periods - de-politicise railway funding settlements
- Need for a baseline of funding, and set competition better
- Clarity on priorities, e.g., cost vs. carbon vs. circular economy value

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The National Health Service



Workshop feedback

- Health outcomes to be considered in transport policy

Circular economy knowledge, awareness, and thought leadership

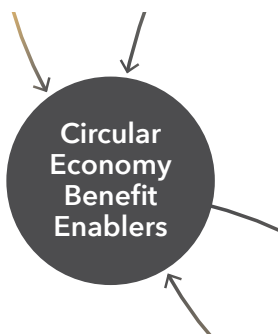


Workshop feedback

- Accelerate research funding around rail and the circular economy
- Make the key challenges and problems to be solved known
- Incentivise training and education
- Innovation about the circular economy
- Moving away from fast manufacturing consumer goods behaviour

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The circular economy benefit enablers



Workshop feedback

- Research and academic pipelines for the circular economy (the technology challenges) the industry needs to fix
- Seed/investment funding for new actors and stakeholders that work in the new or adapted circular economy market
- Opportunity and risk management around technology change and adaptation
- Policy around technology dependencies and technology diversity
- Department for business engagement/sponsorship and support



How Rail Can Enable the Circular Economy

A White Paper

